Frontiers of Plant Science

A REPORT FROM THE CONNECTICUT AGRICULTURAL EXPERIMENT STATION, NEW HAVEN

Water chestnut, *Trapa natan* (Photo credit: Leslie J. Mehrhoff, University of Connecticut)

Nursery inspectors examining plants at a Connecticut nursery for the 2005 Ramorum Blight National Survey

Eurasian green pug, *Pasiphila rectangulata*

THE CONNECTICUT AGRICULTURAL EXPERIMENT STATION, founded in 1875, is the first experiment station in America. It is chartered by the General Assembly as an independent State agency governed by a Board of Control. Station scientists make inquiries and experiments regarding plants and their pests, insects, soil and water quality, food safety, and perform analyses for State agencies. Factual information relating to the environment and agriculture is provided freely and objectively to all. The laboratories of the Station are in New Haven and Windsor; its Lockwood Farm is in Hamden. Copies of this and other publications are available upon request to Publications; Box 1106; New Haven, Connecticut 06504
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Phytophthora ramorum: *a new threat to Connecticut's forests and landscapes*

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"Sudden Oak Death" – now officially renamed "Ramorum Blight" – is a disease that has been ravaging coastal forests of central California and southern Oregon for at least ten years. It has recently piqued interest and concern in the eastern United States, including Connecticut, as a result of nationwide shipments of potentially infected plants. This emergent and potentially destructive disease could have enormous consequences if established in Connecticut, with its vigorous nursery industry and heavily wooded landscapes and forests.

History and background

Beginning in 1993, twig and foliar blights turning up on rhododendrons and viburnums in nurseries and gardens in Germany and the Netherlands appeared to be associated with an unidentified species of *Phytophthora*. The cause of these blights was identified as *Phytophthora ramorum*, a new species. Somewhat concurrent with the European observations, in the mid-1990's, coastal areas of California were experiencing unexplainably high rates of mortality in tanoak (*Lithocarpus densiflora*) and several species of oak, including coast live oak, *Quercus agrifolia*. The rapid browning of foliage and subsequent tree death led to the name, popularized in the press, of "Sudden Oak Death." California researchers determined early on that the bleeding cankers associated with these tree deaths were typical of *Phytopthora* infections, although the identity of the causal agent was not known. Confirmation that the Sudden Oak Death pathogen was *P. ramorum*, the same species as that causing foliar and twig blight in Europe, would not come until 2002. *P. ramorum* is most likely an introduced invasive pathogen in both North America and Europe; however, its origin has so far eluded scientists.

Connecticut, along with many other states, participated in United States Department of Agriculture – Animal and Plant Health Inspection Service, Plant Protection and Quarantine (USDA-APHIS-PPQ) "National Surveys" in 2003 and 2004, and United States Forest Service "Perimeter Surveys" in 2004, in an effort to determine the extent of *P. ramorum*'s distribution in the United States. Neither of these surveys detected *P. ramorum* in Connecticut. Connecticut was also involved in nationwide "Trace Forward" surveys in 2004. One survey was initiated when a large Oregon nursery was found infested with *P. ramorum* only after it had shipped plants from February through September of 2004 to 27 of the 29 states constituting the eastern APHIS-PPQ region. In Connecticut, which was one of the affected states, all 56 outlets that had received shipments from the Oregon nursery, totaling over 10,000 plants, were included in the "Trace Forward" survey. As a result of the survey, three outlets were confirmed to have plants infected with *P. ramorum*. Since this is a pest of national regulatory concern, protocols established by USDA-APHIS-PPQ for handling the *P. ramorum*-positive outlets were followed, with the cooperation of The Connecticut Agricultural Experiment Station (CAES). Infected inventory, as well as all plants on the "associated hosts" list, were incinerated under supervision of USDA-APHIS-PPQ agents and CAES inspectors. Unfortunately, many if not most of the plants from the Oregon shipment had already been sold by the time the "Trace Forward" survey was initiated, raising valid concerns about the possibility that *P. ramorum* had already been released into the Connecticut environment.

In an attempt to avoid any further accidental shipments of infected material, USDA-APHIS-PPQ initiated a new Emergency Order in January 2005, which covers all of California, Oregon, and Washington. All nurseries in these states must be inspected and determined free of *P. ramorum* before shipments to other states can occur.

Biology of *Phytophthora ramorum*

Often mistakenly called a fungus, and certainly fungus-like in some respects, *P. ramorum* is actually not a fungus at all. Rather, *P. ramorum* is a member of a group called the Water Molds, or Oömycetes. As the name suggests, Water Molds typically require a wet, or at least moist, environment in order to grow and reproduce, although many, including *P. ramorum*, can survive long dry periods. Many other *Phytophthora* species are found in Connecticut, and most are soil-borne, invading and infecting plants through their roots. However, *P. ramorum* is principally, though not exclusively, an above-ground pathogen, causing foliar and bark symptoms, depending on the host.

Figure 1. Photomicrograph of *Phytophthora ramorum* isolated from infected plants shipped to Connecticut. Note the thin-walled sporangium and the thick-walled chlamydospore.

The body of *P. ramorum* consists of long branching filaments, collectively called the "mycelium." This is the part of the organism that invades and grows through the host tissue. *P. ramorum* also produces reproductive structures (Figure 1), which are found in soil, water, plants, and plant debris. In addition to having a reproductive function, they also function in survival and dissemination.

Chlamydospores are asexually produced thick-walled spores that survive drought and temperature extremes; *P. ramorum* produces unusually large and abundant chlamydospores. **Sporangia** are also produced asexually, and contain large numbers of very small motile spores called **zoöspores**, which can be transported by water – even a thin film of water – to infect new host tissue. Sporangia are most important for reproduction and spread; in addition to producing zoöspores, sporangia can themselves be disseminated, followed by germination directly on new host tissue. **Oöspores**, the result of the *P. ramorum* sexual cycle, have not been observed in natural or nursery infections, and there are no other indications that sexual reproduction plays a role in the epidemiology of the pathogen.

Hosts

Broad host range and symptoms that vary by host are two features that distinguish *P. ramorum*, and which contributed to making *P. ramorum* so difficult to identify when the disease initially caught researchers' attention in Europe and California. Since the initial reports of hosts from Europe, California, and Oregon, over 70 plant species, both herbaceous and woody, from numerous families, have been added to the list of plants that are susceptible to *P. ramorum*. This list continues to grow as more plants are identified (USDA-APHIS-PPQ maintains and updates a list of hosts at http://www.aphis.usda.gov/ppq/ispm/pramorum/pdf_files/usdaprlist.pdf). Currently, 31 are "officially proven" or regulated hosts, and 37 are "officially associated" hosts. Proven or regulated hosts are those for which scientific tests have been completed to confirm that they are *P. ramorum* host plants. Associated hosts are those that have been found to be naturally infected with *P. ramorum* and for which testing has not yet been completed. Examples of proven hosts include rhododendron, azalea, lilac, viburnum, Japanese pieris, several species of oak, Douglas fir, and heather. Table 1 lists regulated and associated hosts that are found in Connecticut.

Proven Hosts:
Calluna vulgaris, Scotch heather
Camellia, all species
Hamamelis virginiana, Witch hazel
Pieris, some species
Rhododendron spp, including azaleas, all species and cultivars
Viburnum, some species
Associated Hosts:
Aesculus hippocastanum, horsechestnut
Castanea sativa, European chestnut
Fagus sylvatica, European beech
Kalmia latifolia, mountain laurel
Leucothoe fontanesiana, Mountain laurel
Pyracantha koidzumii, Formosa firethorn
Quercus rubra, Northern red oak
Salix caprea, goat willow
Syringa vulgaris, lilac
Taxus baccata, English yew
Hosts Tested in Greenhouse:
Acer saccharum, sugar maple
Castanea dentata, American chestnut
Quercus alba, white oak
Quercus prinus, chestnut oak
Juglans nigra, black walnut

Table 1: *Phytophthora ramorum* hosts of concern in Connecticut

Interest in determining the potential susceptibility of plant species currently not on the host lists has been generated largely by concern that escape of *P. ramorum* into new regions, such as the northeastern United States, might create new epidemics of scales equivalent to that seen in California and Oregon. Greenhouse studies on seedlings of several important east coast tree species were conducted at the USDA-ARS Foreign Disease – Weed Science Laboratory at Fort Detrick, Maryland. These studies demonstrated the ability of *P. ramorum* to infect and produce cankers on many of the species tested, including northern red oak, chestnut oak, and white oak, all of which are important components of our Connecticut forests and landscapes. The susceptibility of northern red oak, *Q. rubra* in particular, has been substantiated by natural infections of landscape plantings of this tree in Europe.

Symptoms

Disease symptoms associated with *P. ramorum* infections are diverse, largely determined by host species. In general, symptoms fall into two classes: "bleeding" bark cankers and foliar lesions. Bleeding bark cankers, as the name suggests, are characterized by black or reddish ooze seeping from the main trunk (Figure 2).

Figure 2. Bleeding bark canker on coast live oak, resulting from infection by *P. ramorum*. The seepage does not contain spores or other parts of *P. ramorum*; rather, it is the plant's response to the pathogen. (Reprinted with permission, Joseph O'Brien, USDA Forest Service, www.forestryimages.org)

These lethal cankers invade the bark, cambium, and outer xylem, eventually girdling and killing the tree. Tanoaks and certain oaks in the red oak group, which includes northern red oak, exhibit these symptoms. Foliar lesions, often accompanied by shoot dieback, are found on all other, non-oak, hosts, and are characterized by irregular browning of the leaf, with symptoms observable on both sides (Figure 3). Foliar lesions are less severe than cankers, and usually not lethal. However, foliar infections are the primary cause of disease spread, as the lesions produce sporangia and chlamydospores, which function in dissemination.

Figure 3. Symptoms on rhododendron plants shipped to Connecticut from Oregon that tested positive for *P. ramorum* from "Trace Forward" surveys. a. Note blotchy, dead areas on leaves; b. Note dieback of twigs. (Photos courtesy of Eric Chamberlain, USDA-APHIS-PPQ)

Interestingly, tanoaks are the only species known to manifest both bark and foliar symptoms.

Methods of detection

Diagnosing Ramorum Blight can be difficult and confusing, as the disease symptoms characteristic of *P. ramorum* infections are often indistinguishable from other diseases or insect problems that are frequently encountered in Connecticut woodlands and landscapes. For this reason, identifying *P. ramorum* as the causal agent of symptomatic material can only be made by trained scientists using special techniques.

Like most plant diseases, the first methods used for identifying the causal agent of Ramorum Blight involved efforts to grow, or culture, the organism out of the infected host tissue, then confirming its identity as *P. ramorum* by microscopic examination. However, while this is widely recognized as the "gold standard" of plant disease diagnostics, isolating a pure culture of *P. ramorum* from its host is not always successful, and can take weeks when it is. Therefore, although diagnosticians make every effort to isolate and identify *P. ramorum* from suspect material, other methods of pathogen detection have been developed and are critical for accurate diagnosis of this disease.

The first test performed on the plant sample is the simplest but also the least specific. This type of test is called Enzyme-Linked Immunosorbent Assay (ELISA), and will identify all species in the genus *Phytophthora*. If a plant sample returns a positive *Phytophthora* ELISA result, DNA is extracted from the symptomatic plant tissue, and then tested for the presence of DNA sequences that are unique to *P. ramorum*.

Evaluating the risk of *Phytophthora ramorum* to Connecticut forests and landscapes

During 2004, there was confirmation of *P. ramorum* in 22 states, including Connecticut, that had received infected nursery stock from California and Oregon. In an effort to make additional accidental shipments less likely, stricter rules were implemented in 2005. Nevertheless, there is justifiable concern that *P. ramorum* may pose a serious threat to the northeastern United States if it continues to be introduced into the area. Risk maps produced by researchers at USDA-APHIS-PPQ show that the northeastern United States has the forest composition and climate that are highly conducive to survival and spread of *P. ramorum* (Figure 4). Connecticut's forests and landscapes comprise a number of species that are proven or associated hosts for *P. ramorum*. While the northern red oak has been the focus of much concern, rhododendron, lilac (*Syringa vulgaris*), and mountain laurel (*Kalmia latifolia*) may pose the greater threat in spreading the disease through sporulating foliar symptoms that can sustain the pathogen.

Connecticut's cool, wet spring and fall are nearly ideal for sporulation and spread of Ramorum Blight. Research from California and Oregon has shown that even small amounts of rain or fog can initiate new rounds of sporulation and infection. Although we do not yet have good data on the ability of the pathogen to survive the low temperatures typical of Connecticut winters, circumstantial evidence from our laboratory at The Connecticut Agricultural Experiment Station suggests that *P. ramorum* may be able to overwinter here. A more accurate appraisal of the risk that *P. ramorum* poses to Connecticut will require additional research on the ability of *P. ramorum* to survive low temperatures.

Notwithstanding the uncertainty regarding the ability of *P. ramorum* to survive and spread in Connecticut, there is no doubt that this is a serious pathogen with significant potential to threaten our state and region both economically and ecologically. Therefore, we at The Connecticut Agricultural Experiment Station remain committed to a strategy of early detection and containment. Critical to this commitment is the molecular diagnostics laboratory that is nearing completion in the Department of Plant Pathology and Ecology. This laboratory will provide us with state-of-the-art molecular technologies in our efforts to identify *P. ramorum* quickly, efficiently, and accurately.

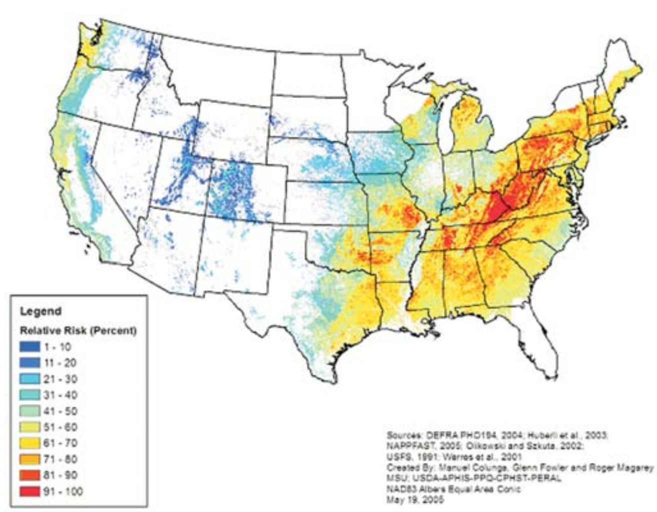

Figure 4: *P. ramorum* risk map, based on climate and host distribution, from USDA-APHIS. Note that much of the eastern U.S., including Connecticut, is at elevated risk. (courtesy Drs. Glenn Fowler and Roger Magarey, USDA-APHIS,PPQ, Raleigh, NC).

Invasion of alien insects

By Chris T. Maier
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Since the beginning, people inadvertently have carried insects from place to place. At first, humans probably transported insects on their bodies (parasites), on their clothing, or in their food. The distances traveled were short. But, in the twenty-first century, the distance and the speed of travel have changed. In a matter of hours, or at most days, insects can be moved from continent to continent. Rapid transport increases the chances of survival of insects from abroad. The number of alien insects reaching North America has escalated with increased international travel and imports. David Pimentel and co-workers at Cornell University recently have estimated that foreign organisms cost us about 140 billion dollars annually. A real crisis is at hand!

Farmers, businessmen, and others in Connecticut have long coped with the impact of exotic insects. During the last few centuries, unwanted arrivals have included such notorious insect pests as the codling moth, the gypsy moth (Fig. 1), the Japanese beetle (Fig. 2), and the hemlock woolly adelgid (Fig. 3). Much to our regret, these and other alien insects have found Connecticut to their liking. And, not far away, lurk more foreign pests that may soon find a home here.

Fig. 1. Caterpillar of gypsy moth, *Lymantria dispar* (photo by Jeff Fengler, Connecticut Agricultural Experiment Station [CAES])

Fig. 2. Japanese beetle, *Popillia japonica* (photo by E. Bradford Walker, Vermont Department of Forests, Parks, and Recreation)

Fig. 3. Hemlock woolly adelgid, *Adelges tsugae* (photo from CAES Archives)

Of course, not all foreign insects are highly destructive; they run the gamut from good to bad. The honey bee is considered a valuable intentional introduction that produces honey and pollinates crops. Parasitic wasps and flies have been imported and released to combat foreign insect invaders. Classical biological control involves the importation and release of a parasite or predator from the homeland of a pest. This biocontrol practice often helps to reduce populations of harmful pests, but occasionally even projects with the best intentions go awry. For example, the multicolored Asian ladybird beetle (Fig. 4) was brought into this country to suppress aphids on plants. The beetle has done so well that it now is a nuisance pest, sometimes entering dwellings by the thousands to seek overwintering quarters. Some fear that this beetle may drive some of our native ladybird species to extinction.

Fig. 4. Multicolored Asian ladybird beetle, *Harmonia axyridis* (photo by Scott Bauer, USDA, ARS)

Personnel at The Connecticut Agricultural Experiment Station work closely with the USDA (Animal and Plant Health Inspection Service and the Forest Service) and with several state organizations to detect new pests and to eliminate them or devise strategies to cope with them. Early detection is critical for mitigating the impact of destructive foreign insects.

During the past 10 years, regulatory agencies have focused their attention on exotic wood-boring insects, and for good reason—some of the beetles can kill or severely injure trees. The wave of new wood-boring insects, especially beetles, arriving at our shores has reached epidemic proportions. Immature wood-borers often are unnoticed hitchhikers in imported wood, especially solid wood packing material. They easily can be overlooked during spot inspections of wood. In Connecticut, we have much to fear from these invaders because forest covers about 60% of our land, valuable shade trees line our urban streets, and trees increase the beauty and value of our yards. Importation of plants, cut flowers, souvenirs, and food also bring unwanted insects to North America.

Fig. 5. Small Japanese cedar longhorned beetle, *Callidiellum rufipenne* (photo by Chris Maier, CAES)

In 1998, the small Japanese cedar longhorned beetle (Fig. 5) was detected in live arborvitae in garden centers and landscaped areas of two coastal counties of Connecticut. Boring by the larvae of this eastern Asian insect can disfigure or kill branches of arborvitae, junipers, cedars, false cedars, and related plants. In the eastern United States, the small Japanese cedar longhorn beetle resides mainly in coastal counties from the greater Boston area to North Carolina. It commonly infests cedar trees or juniper bushes in the wild. In Connecticut, the beetle is restricted to the southern half of the state. My research at the Experiment Station has shown that this pestiferous beetle limits its attack to stressed plants; thus, good planting practices and follow-up care can reduce the likelihood of an infestation.

Two nasty wood-borers that may soon threaten Connecticut trees are the Asian longhorned beetle (Fig. 6) and the emerald ash borer (Fig. 7). Both of these eastern Asian beetles are true tree killers. Their larvae bore into the outer wood of trees, disrupting the flow of water and

Fig. 6. Asian longhorned beetle, *Anoplophora glabripennis* (photo by Michael Bohne, USDA Forest Service);
Fig. 7. Emerald ash borer, *Agrilus planipennis* (photo by David Cappaert, Michigan State University)

nutrients. In North America, breeding populations of the Asian longhorned beetle were discovered first in the Greenpoint area of Brooklyn, New York, in 1996. Later, beetles turned up in several other areas on Long Island, in Chicago (Illinois), in Jersey City and Carteret (New Jersey), and in Toronto (Ontario). The Asian longhorned beetle apparently prefers maples, although it will eat many other shade trees. As you might imagine, the discovery of this beetle has sent chills up the spines of the people in the maple syrup and wood products industries. To date, many millions of dollars have been spent to eradicate populations of this beetle, but the job is not yet completed. Based on surveys conducted by staff at the Experiment Station, this beetle has not yet reached Connecticut.

The emerald ash borer, first detected in 2002, occurs mainly in southern Michigan, northern Indiana and Ohio, and Windsor, Ontario, where it kills exclusively ash trees. Based on my examination of over 6,200 ash trees in 167 of 169 Connecticut towns in 2004, this noxious insect does not yet occur in our state. In the Midwest, eradication programs and extensive research on biology and control are underway.

Fig. 8. Giant resin bee, *Megachile sculpturalis* (photo by Michael Thomas, CAES)

The giant resin bee (Fig. 8) is yet another eastern Asian insect that probably snuck into this country concealed in wood. This bee is impressively large (about 1” in length), but it is not a stinger. The adult female forms her nest in a cavity, more often than not in wood, and visits flowers. At first glance, this and several other alien bees seem relatively benign; however, these foreigners may be able to displace native bees that are effective pollinators of crops.

9. Viburnum leaf beetle, *Pyrrhalta viburni* (photo by Paul Weston, Cornell University)

In the summer of 2004, nursery inspectors at the Experiment Station detected an exotic beetle new to the state, the viburnum leaf beetle (Fig. 9). Both the larvae and the adults of this European beetle eat the foliage of viburnum. If this leaf beetle were to become established, as it has in New York and a few other northern states, it will become another costly problem for the nursery industry and homeowners.

Fruit growers also suffer losses from insect invaders. Nearly one-third of the insects that normally feed on apple trees are alien species (apples also are not native). Two moths—the apple tortrix and the green pug—are recent arrivals that soon may threaten the health of fruit trees. The caterpillar of the apple tortrix (Fig. 10), an important pest in Japan, eats the blossoms, leaves, or both of over 90 plant species, including all types of tree fruits that are commercially grown in Connecticut. The caterpillar of the European green pug (Fig. 11) has a taste for the blossoms of apples and pears. Feeding by caterpillars of both of these exotic moths could substantially reduce the size of fruit crops. The good news is that, although both occasionally damage wild trees, they are not established in sprayed commercial orchards. Apparently, neither has developed resistance to insecticides commonly used in orchards.

Fig. 10. Caterpillar of the apple tortrix, *Archips fuscocupreanus* (photo by Chris Maier);
Fig. 11. Caterpillar of the green pug, *Pasiphila rectangulata* (photo by Jeff Fengler)

Fig. 12. Brown marmorated stink bug, *Halyomorpha halys* (photo by David R. Lance, USDA, APHIS, PPQ)

Another eastern Asian insect that is waiting in the wings is the brown marmorated stink bug (Fig. 12). The adult and immature of this foreign stink bug use their piercing mouthparts to suck juices from over 60 hosts, including shade trees, fruit trees, and vegetable crops. In 2001, the stink bug was found in eastern Pennsylvania where numerous adults had entered houses to overwinter. Subsequently, it has been discovered in several other eastern states and in Oregon. In 2005, a survey will be conducted to determine if this foe has arrived in Connecticut.

A list of new alien insects could go on and on. The bottom line is many foreign insects are already here, and more will arrive in the near future. Much is being done at the federal and state level to stem the flow of unwanted pests into this country and our state, but a failsafe system of exclusion would be prohibitively costly and virtually impossible to implement. Nonetheless, we, at the Experiment Station, are ready and willing to tackle each new pest to help to safeguard your plants, your products, and your health. [For detailed information on exotic insects visit the following websites: http://www.bugwood.org (many color images of alien insects) and http://ceris.purdue.edu/napis/index.html (distribution maps and other information)].

Suggested Reading:

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Aquatic plants among most destructive invasives

By Robert S. Capers, Roslyn Selsky, Gregory J. Bugbee and Jason C. White

Department of Soil and Water

In the past 150 years, aquatic plants have provided some of the most potent demonstrations of the power of invasive species to alter natural ecosystems and to interfere with human activities, both economic and recreational. From *Elodea canadensis* (waterweed) in Europe to *Eichhornia crassipes* (water-hyacinth) in Florida, aquatic invasive species have frustrated natural resource managers and amazed botanists with their ability to grow rapidly, producing enormous numbers of plants, often vegetatively, crowding out native plants, covering the surface of lakes and rivers, and clogging navigation channels, flood-control canals, water intake pipes and drainage ditches.

As one example, Lake Kariba was created in 1958 by damming the Zambezi River on the Zimbabwe-Zambia border to generate hydroelectric power. One year later, *Salvinia molesta*, an aquatic fern native to Brazil, was first observed in the lake. After three years, the plant covered 1,000 square kilometers, more than 20% of the lake's surface area, threatening the hydroelectric dam's operation as well as commercial fisheries and recreational use of the lake. Calculations showed that what came to be known as Kariba weed had a doubling time of 4.6 days and that dry weight of the species was increasing at a rate of 4% per day. Herbicide treatments and mechanical removal were unable to control the plant, but biological control efforts with invertebrates (a grasshopper and a weevil) now have greatly reduced the species' abundance.

Kariba weed is probably not a threat to Connecticut, but *Hydrilla verticillata* (hydrilla) is. *Hydrilla* was intentionally introduced to drainage canals in Florida by the aquarium trade around 1950, and it had spread to all drainage basins in Florida by the early 1970s. It reached 13,340-acre Orange Lake in 1972 and covered 90% of the lake's surface four years later. An economic impact study determined that the economy of the Orange Lake region incurred losses of about $10 million a year through lost tourism, reduced real estate values and declines in recreational activities due to the effect of *Hydrilla*. Meanwhile, *Hydrilla* continued to spread through Florida and was found in 41% of the state's water bodies by 1991. The state spent $14.5 million on *Hydrilla* control in 2003-04.

Other states' experience with *Hydrilla* has been similar. Connecticut, so far, has been lucky. *Hydrilla* arrived in 1995 and has been confined since then to a few small ponds. Biologists take little comfort in this. Even when invasive aquatic plants do not grow explosively, they represent a threat for the future.

Fig. 1.

Invasive aquatic plants are not new to Connecticut, but they are receiving increased attention, in part because the public is becoming more aware of their serious effects, economic and ecological. Annual losses and control costs related to invasive aquatic plants total $110 million in the United States, and among the causes of species' extinctions globally, invasive species rank second only to habitat destruction.

The Connecticut Agricultural Experiment Station has engaged in research on invasive aquatic plants for a number of years, focusing primarily on management. In the past year, support from U.S. Department of Agriculture has permitted expansion of the program to include aquatic plant surveys of state lakes and ponds.

The surveys have several goals. First, Experiment Station scientists hope to find invasive plants more quickly, which may make it possible to eradicate them. Second, the surveys will allow scientists to track the spread of invasive species already present in the state, and this will lead to testable hypotheses about the species' environmental affinities and about what factors place lakes at risk of invasion. Third, surveys over time will reveal how aquatic plant communities are changing. Finally, the surveys provide baseline information on lakes that have no invasive species, and this, too, is valuable in quantifying the effects of invasions on native communities. This kind of basic information is currently lacking for most Connecticut lakes and ponds.

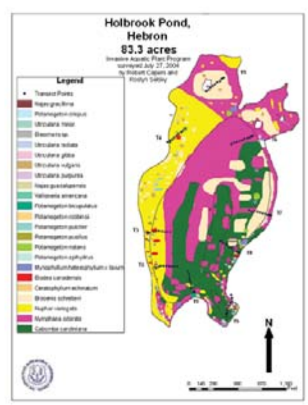

Fig. 2.

The surveys are conducted in a boat by two people, one to sample vegetation and one to record observations and sampling locations (Fig. 1), using Global Positioning

System equipment that records satellite-generated signals. Vegetative beds are mapped in each lake (Fig. 2), and specimens of all submerged and floating-leaved species are collected, dried and archived. The mapping is done by surface observation of plants and sampling in deep water with a long-handled rake. Water is tested in the lake for clarity, and temperature and dissolved oxygen profiles are recorded. Water samples are collected and returned to the laboratory for pH, alkalinity, conductivity and phosphorus analysis. Correlations are being sought between water chemistry and aquatic vegetation.

Experiment Station investigators also obtain quantitative information on species abundance in permanent, 80 m georeferenced transects established perpendicular to the shoreline in each lake, recording the abundance of all aquatic plants at 5–10 m intervals.

In addition to conducting the surveys, Experiment Station scientists are working with the Connecticut Department of Environmental Protection, the Invasive Plant Atlas of New England and other agencies to coordinate activities and consolidate information on invasive aquatic plants in the northeast United States.

A database is being developed in which information on aquatic plant occurrence and abundance will be compiled and made available for research. In addition, a web site has been developed that will provide access to the database and other information, including information on management of aquatic plants.

Experiment Station scientists and the Connecticut Federation of Lakes launched a program in the spring to recruit volunteers to monitor state lakes, perform surveys of aquatic plants, analyze water for chemical changes or distribute literature on aquatic plants at boat ramps. This program will put more people to work, looking for new invasive species and tracking those already here, and thus, will generate more information than would be available otherwise.

Table 1. The frequency of aquatic plants recorded during surveys of 32 Connecticut lakes and ponds is reported. Shown are the names of aquatic plants and the percentage of the surveyed lakes in which each was observed in 2004. Invasive species are in boldface.

SUBMERGED SPECIES			
Potamogeton pusillus	59.4	*Potamogeton spirillus*	12.5
Ceratophyllum demersum	46.9	*Elodea canadensis*	12.5
Elodea nuttallii	46.9	*Najas gracillima*	12.5
Najas flexilis	43.8	*Gratiola aurea*	12.5
Potamogeton bicupulatus	40.6	***Myriophyllum heterophyllum* X *laxum***	**12.5**
Potamogeton epihydrus	40.6	*Potamogeton illinoensis*	9.4
Potamogeton crispus	**40.6**	*Utricularia intermedia*	9.4
Utricularia gibba	37.5	*Isoëtes* sp.	9.4
Myriophyllum spicatum	**34.4**	*Potamogeton vaseyi*	6.3
Vallisneria americana	34.4	*Potamogeton oakesianus*	6.3
Najas minor	**31.3**	*Myriophyllum tenellum*	6.3
Potamogeton amplifolius	28.1	*Myriophyllum humile*	6.3
Potamogeton gramineus	28.1	*Zosterella dubia*	6.3
Potamogeton robbinsii	28.1	*Zannichellia palustris*	6.3
Potamogeton natans	25.0	*Isoëtes tuckermanii*	6.3
Utricularia purpurea	25.0	*Isoëtes echinospora*	6.3
Najas guadalupensis	21.9	*Elatine triandra*	6.3
Myriophyllum heterophyllum	**18.8**	*Callitriche sp.*	6.3
Potamogeton perfoliatus	18.8	*Myriophyllum sibiricum*	6.3
Potamogeton pulcher	18.8	*Potamogeton friesii*	3.1
Potamogeton zosteriformis	18.8	*Utricularia minor*	3.1
Utricularia geminiscapa	18.8	*Utricularia subulata*	3.1
Utricularia vulgaris	15.6	*Ranunculus longirostris*	3.1
Utricularia radiata	15.6	*Isoëtes lacustris*	3.1
Ceratophyllum echinatum	15.6	*Elatine minima*	3.1
Polygonum amphibium	15.6	*Elatine americana*	3.1
Cabomba caroliniana	**15.6**	*Callitriche heterophylla*	3.1
FLOATING LEAVED SPECIES		EMERGENTS	
Nymphaea odorata	56.3	*Eleocharis acicularis*	40.6
Nuphar variegata	53.1	*Eriocaulon aquaticum*	21.9
Brasenia schreberi	43.8	*Sparganium* sp.	6.25
Nymphoides cordata	15.6	*Eleocharis parvula*	3.1
Nymphaea odorata ssp. *tuberosa*	3.1	Unidentified sedges	21.9
Marsilea quadrifolia	**3.1**	*Sagittaria* sp.	*
Lemnaceae	*		

*** Several species in the family Lemnaceae and the genus *Sagittaria* also were observed, but their presence was not recorded.**

During the first summer of surveillance in 2004, 32 lakes were surveyed, ranging in size from 18 to 445 acres. A total of 59 species were recorded, including five floating-leaved species. Of the total, seven were invasive taxa (Table 1). The most frequently found invasive species was curly leaf pondweed (*Potamogeton crispus*), found in 41% of surveyed lakes, followed by Eurasian water-milfoil (*Myriophyllum spicatum*) found in 34%.

Fig. 3.

One of the survey program's first substantive contributions was the discovery that an annual species native to Europe, *Najas minor*, is more common and is spreading more quickly than had been appreciated (Figs. 3, 4). The species, which probably arrived in Connecticut during the 1980s, was found in 10 of the 32 lakes surveyed in 2004 (31%).

Of the 32 lakes examined, 24 had at least one invasive species, and not surprisingly, the number of invasive species in the surveyed lakes increased with lake area. The lakes with the fewest aquatic species also were the smallest – Maltby Lake No. 1 in West Haven, which had four aquatic plant species, and Dooley Pond in Middletown, with five. Three bodies of water had high plant diversity: Lake Quonnipaug in Guilford, 25 species, Manitook Lake in Granby, 23, and Holbrook Pond in Hebron, 23. Lake Quonnipaug also had more invasive plant species than any other surveyed lake, a total of four, while Manitook Lake and Holbrook Pond had two and three invasive plant species, respectively. Several of the plant species recorded in 2004 represented first-time reports in the surveyed towns, and the collection of European water-clover

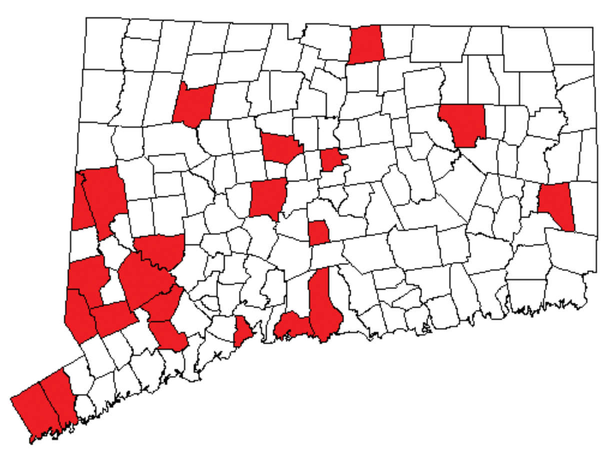

Fig. 4.

(*Marsilea quadrifolia*, Fig 5) in Batterson Park Pond was the first record of the species in Hartford County.

Compared with all Connecticut lakes and ponds, those surveyed in 2004 were disproportionately large, in part because large lakes tend to have boat ramps, so access is easier. Station scientists plan to survey more small ponds and lakes in 2005 to obtain a more representative sample of the state's water bodies.

Fig. 5.

NOTES

NOTES

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