Biological Immigrants Under Fire

Ecologists address an age-old problem with new urgency, warning that "the homogenization of the world" is becoming a threat

IN THE 1870S, SPENCER FULLERTON BAIRD of the U.S. Fish Commission, relying on the cutting-edge scientific thinking of his day, had a bold idea: He'd improve the fish fauna of the growing United States by bringing in a delectable species of Eurasian carp. The idea was a complete success—then. His import, bred in ponds in Baltimore and Washington, became the culinary craze of the nation. Eager congressmen clamored to have the new delicacy brought into their own states, and Baird set his staff to shipping fish by railroad car to congressional districts around the country. Ever since, carp have been reproducing with a vengeance in American waters—much to the dismay of modern limnologists, who find the bottom feeders destructive to natural habitats and no longer the public's favorite filet.

Since Baird's time, countless other biological aliens have thrived in U.S. territory, as our ancestors deliberately or inadvertently ferried plants, animals, and insects with them across geographical barriers, often with disastrous results. Take, for example, a new strain of the sweet-potato whitefly, possibly a Middle East native that is currently wreaking havoc in California's Imperial Valley (see p. 1445).

Ecologists have chronicled such introductions for decades, seeking to understand how ecosystems work by watching exotic species perturb them. But in recent years, they have approached the exotic species issue with a new urgency, increasingly alarmed at what invasion experts such as Ted Case of the University of California, San Diego, call "the homogenization of the world."

Not only do invaders often exact a heavy price in terms of lost crops and expensive control programs, they can cause less visible ecological damage on a grand scale. When ecosystems are already under stress, as they now are in most parts of the world, a biological invader can deliver the coup de grace to native species by predation, competition, or by transforming landscapes.

"Most of what we read about in conservation biology has to do with habitat loss. But it becomes increasingly obvious that species introduction can also be devastating," says ecologist and biological invasion specialist Stuart L. Pimm of the University of Tennessee. Adds George Rabb, chair of the species survival commission of the World Conservation Union: "There is nothing more insidious as an agent of extinction than exotic species." And as the pace of human commerce quickens, more and more stowaways are expected to arrive uninvited.

FLORIDA DEPT. OF NATURAL RESOURCES

A lovely nuisance. *Blue water hyacinths, imported from South America because of their beauty, now clog Florida's waterways.*

Thus, a small band of ecologists has been broadcasting an urgent message: Stricter controls should be placed on the movement of species around the world.

But they face an uphill task. In the United States, the legacy of intentional introductions, such as those promoted by Baird, still lingers in regulations that rigorously screen potential agricultural pests but pay much less attention to nonagricultural species. Individual states can, for example, import exotic fish species from other countries or regions without even consulting their neighbors.

"With fishes, states keep repeating the mistakes made by other states," sighs Walter Courtenay of Florida Atlantic University in Boca Raton, who says there are 69 species of exotic fish in U.S. waters and 158 more that have been transplanted beyond their native ranges within the country. He points to Clear Lake in California, which originally had 12 native fish species, according to biologist Peter Moyle of the University of California, Davis. Thanks to a series of introductions, including carp, there are now 20 species of fish in the lake—but only five native ones remain in any numbers.

Courtenay is crusading for a required national peer review for introduced fish. But even the most distinguished review panel would have a tough job predicting the fate of an introduced species. In many cases, the current state of knowledge doesn't provide an answer to the billion-dollar question of which species will make trouble in a new environment. Thus ecologists are likely to find themselves pitting their uncertainty against strong economic incentives to bring in new commercial species.

But the battle isn't hopeless. Oddly enough, ecologists' strongest ally in the anti-exotic campaign is the zebra mussel, an approximately inch-long mollusk that apparently hitched a ride from Europe in a ship's ballast tank in the late 1980s and has been growing out of control in U.S. waterways ever since (also see p. 1446, and *Science*, 21 September 1990, p. 1370). The mussel sparked rules on ballast water, commanded a flurry of federal attention and some money, and prompted cooperation within a previously fragmented research community.

The "field" of exotic species includes everyone from academic ecologists to park managers and aquaculturalists, and communication among them has been spotty at best. "There's a number of interest and research groups involved, and not a whole lot of conversation across the lines between them," says Phyllis Windle, director of an Office of Technology Assessment study on nonindigenous species. "Now, people are beginning to look at the broad problem for the first time."

In one of the first concrete examples of the more cooperative approach, conservation types and academic ecologists got together in October for a meeting on "Biological Pollution: The control and impact of invasive exotic species."* The gathering's chief purpose was cross-fertilization, to inform bee specialists about problems in fisheries, for example, and let managers of nature preserves think about invasion theory.

*Sponsored by the Indiana Academy of Sciences, the meeting was held in Indianapolis on 25 to 26 October.

To be sure, presenters were preaching to the converted, since everyone there was already convinced that invading species can be dangerous, but attendees seemed to appreciate having a place to rally around their common cause. "It was the best meeting I've ever been to," Thomas Crisman, limnologist at the University of Florida, said enthusiastically. "There's never been a place to sit down and look at everything to do with exotics."

One task shared by meeting attendees: how to reshape public attitudes toward exotics. Although the zebra mussel and a few other problem species have recently gotten plenty of negative attention, the average citizen *likes* exotic species. Pets, crops, prized ornamental plants, game birds, and fish—most of these are imports. The idea that native species are better is relatively new to the public consciousness. "In the subconscious of our country lies the approach of those 19th-century scientists," said ecologist Richard Mack of Washington State

"Superbug" Attacks California Crops

In California's Imperial Valley, farmers are losing their crops to a speck-sized invader they call "Superbug." Expected to eat its way through $200 million worth of produce this year in the valley alone, this new version of an old pest spells sudden disaster for agriculture in infested areas, as clouds of insects descend on melons, lettuce, cauliflower, and other winter crops. California Governor Pete Wilson has declared a state of emergency in the two counties encompassing the Imperial Valley—with good reason. Entomologists agree that the Superbug is among the worst infestations in U.S. agriculture. "I've never seen devastation like this before in entomology," says Ray Gill, senior research entomologist at the California Department of Food and Agriculture. "In one season it's gone to total chaos in that valley. This is a primary example of what happens when you move genetic stock around the world."

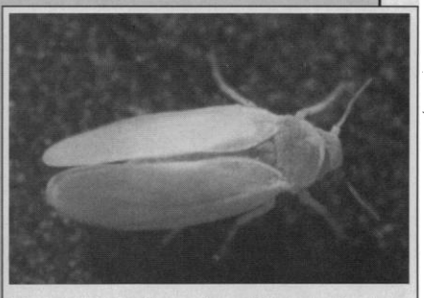
Entomologists suspect Superbug is a new version of an old pest, a strain of sweet-potato whitefly (*Bemisia tabaci*) that was imported to the United States sometime before 1986, when it was first spotted on Florida poinsettias. No one knows exactly when or how the "poinsettia strain," as it's called, got into Florida, although it may have come from somewhere in the Middle East, the sweet-potato whitefly's native habitat.

Varieties of the pest have plagued global agriculture for decades. One strain, called the cotton strain, had already invaded North America by the late 1800s, according to Smithsonian records. But that pest is nothing compared to Superbug, although physically the two are twins. For one thing, while the cotton strain primarily lives off cotton and a few of its weedy relatives, the poinsettia strain feeds on a legion of hosts, up to 500 plants in all, including alfalfa, broccoli, cabbage, citrus, corn, cotton, melons, peanuts, sesame, sugar beets, tomatoes, and of course, poinsettias. "I haven't found a plant the whitefly won't feed on, at least in its immature stages," says Nick Toscano, entomologist and associate dean at the University of California, Riverside.

Although Superbug has been in Florida for about 5 years, it has inflicted relatively moderate damage on fruit and vegetable crops there. But when it arrived in the Imperial Valley a few years ago—possibly on those Florida poinsettias, which were shipped around the country for the Christmas trade—it apparently took a liking to the hot, dry climate. And it thrived on the uninterrupted food supply offered by the Imperial Valley, where its host crops are grown year round.

Unlike the Medfly, which dines only on vegetables or fruit, the aphid-like whitefly attacks leaf tissue, sucking up the leaf juices and often stunting plants before they even have a chance to bear fruit. One melon field Toscano visited usually yields 750,000 melons per acre, he says; this year, there were 50 melons per acre. "There are clouds of these things—billions of them," he said of the white flies in the infested field. "It's difficult to walk among them because they get into your hair, eyes, mouth, nose. I've never seen anything like this in my 20 years in entomology. Whatever plants they don't kill, they completely stunt."

And whatever they don't stunt, they spoil. All white flies deposit a sticky secretion known as "honeydew" on fruit and leaves, but the poinsettia strain, true to its noxious character, produces more than most. On vegetables and fruits, the honeydew encourages the growth of an unsightly black mold that turns off consumers.



MAX E. BADGLEY/BIOLOGICAL PHOTOGRAPHY

Voracious. *Superbug likes to feed on collard greens, melons, and just about everything else.*

What's more, Superbug's catholic tastes and crop-hopping habits make it an excellent candidate for transmitting diseases. In Florida, for example, cabbages and tomatoes grew for years with no virus problems. "Now suddenly there's a virus infecting cabbage," says Jane Polsten, plant virologist at the University of Florida. "Tomatoes are the same way. We grew tomatoes in Florida for years without any problem. But this whitefly likes tomato and the other one didn't."

And to top it all off, insecticides haven't worked very well on Superbug. The tiny insects tend to congregate on the undersides of leaves, beyond the reach of most sprays, and appear to have evolved resistance to many pesticides, although entomologists are still testing their responses.

Greenhouse growers have now learned how to keep poinsettias relatively whitefly-free, by individually inspecting and treating all new plants, says Michael Parrella, chair of entomology at the University of California, Davis. But controlling Superbug in open fields is much harder. Entomologists and crop scientists are mobilizing to investigate the bug's biology and find a way to put the brakes on its voracious appetite. "Everybody's submitting grant proposals," says Parrella. A key first step is systematics: verifying that Superbug is indeed the same strain from Florida to California and is genetically different from the cotton strain. For short-term management, solutions may include pesticides, crop rotations, and keeping fields fallow for a season—a sobering thought for growers accustomed to year-round cultivation.

For the longer term, entomologists have already begun to search India and Pakistan for natural enemies to use in biological control. But in the Imperial Valley, growers use pesticides to keep a host of other bugs at bay, and biological controls may require reducing or rescheduling spraying. Superbug can be beat, entomologists say, but Imperial Valley agriculture may never be the same. ■ E.C.

University, referring to biologists like Baird.

Agreed Don Schmitz of the Florida Department of Natural Resources, "It's a tough sell. The whole concept of biological pollution is not well understood by the public because they don't understand the concept of an ecosystem." Schmitz' agency quietly spends $11 million each year to control just two exotic aquatic plants, waterhyacinth, a South American import, and hydrilla, which came in from Southeast Asia, that are clogging Florida's waterways.

Despite the fledgling attempts at unity in evidence at the Indiana meeting, however, even the scientific community remains split over exotic species. While some biologists try to blacken the image of introduced species, others try to introduce a few more. One of the best ways to control an exotic species is by importing a predator from home, for example, and introductions for biological control or for sound economic reasons are hard to turn down. "Introduced species have proved their worth," says Roger Mann of the Virginia Institute of Marine Sciences. Mann wants to test the Japanese oyster, which may resist disease better than the declining American version, in Chesapeake Bay, in hopes of revitalizing the East Coast oyster industry. "The total of North American agriculture is based on introduced species. If we want to go back to trying to farm buffalo, that's one thing," he says.

Once here, exotic species may quickly worm their way into human culture. Take Kentucky bluegrass, ***Poa pratensis***, a Eurasian native that's given its name to a distinctive style of American music. "If people grew up with it, they figure it belongs there," grumbled Bruce Coblentz of Oregon State University. One public education tactic is therefore to remind people of the origins of such familiar pest species as crabgrass (Eurasia) and starlings (Europe). "Never, never let exotics be legitimized!" Coblentz admonished at the meeting. He himself takes a no-holds-barred approach to controlling exotic species: He shoots on sight the introduced feral goats that have been destroying native landscapes on the Pacific islands where he works.

When it comes to wild goats and other exotic species on islands, history has repeated itself often enough so that ecologists can offer unequivocal advice: Never introduce goats—or any other large herbivore—onto islands. Unfortunately, however, biologists can't make such predictions for all environments and all species. If they could, they'd have a much easier time convincing policy makers to keep exotics out or control them.

But such predictions require sophisticated knowledge of both invader and environment. The vast majority of invading species vanish shortly after reaching a new community, and only about 10% of established immigrants have major effects, says Pimm, referring to results obtained in the late 1980s by the Scientific Committee on Problems of the Environment (SCOPE), which was established by the International Council of Scientific Unions. As a result, few ecologists dare to identify what marine scientist James Carlton of Williams College calls "the ghosts of Christmas future"—next year's problem invaders. And even fewer are ready to guarantee that a new introduction will be benign. "Nothing is more difficult than to predict what will happen to an exotic," says botanist Warren Herbert Wagner Jr. of the University of Michigan.

Still, ecologists can paint a rough portrait of a typical invader. Successful exotic species tend to eat like whiteflies, breed like rabbits, and colonize like crabgrass. They also tend to have high growth rates and good dispersal abilities. For example, a single

A Rogue's Gallery of Pests

Despite the best efforts of quarantine officers, exotic species keep pushing into new territory. Here's an update on a few of the more troublesome biological immigrants to the United States:

■ **Africanized honey bee.** An aggressive stinger and moderate honey producer, *Apis mellifera scutellata* was brought from Africa to Brazil to improve honey production in 1959. Now ranging from central Argentina to southern Texas, the bee is heading north at an estimated 150 miles per year, to be stopped eventually by cold winters in the central United States. Some entomologists hope that the more docile common honey bee—itself a European native—may be maintained in beekeepers' colonies, but others expect that the southern United States will simply have to adjust to Africanized bees.

O.R. TAYLOR

Attack squadron. *Africanized bees buzz a group of beekeepers in Panama.*

■ **Kudzu.** This Chinese vine, intentionally planted throughout the South in the 1930s to control erosion, now covers between 2 million and 4 million acres. With growth rates of up to 1 foot per day, *Pueraria lobata* can swiftly transform trees and shrubs into shapeless mounds of greenery. It costs an estimated $50 million annually in lost farm and timber production, according to the U.S. Department of Agriculture (USDA). Latest idea for management: harvest the enormous roots for starch, to be sold in Oriental food markets.

■ **Asian tiger mosquito.** Despite the name, the "killer" mosquitoes are neither larger nor more ferocious than the garden variety mosquitoes common in the United States. But these striped Japanese natives are potential carriers of serious diseases such as dengue and break-bone fever. First observed in the United States in 1985 in Houston, *Aedes albopictus* apparently hitchhiked in aboard old tires. The mosquito is now thriving in much of the Southeast and Midwest and can apparently outcompete or coexist with native mosquitoes. Ominously, it appears to be adapting to tropical climates and is now headed toward the Caribbean, where dengue is already epidemic.

■ **Zebra mussel.** The infamous bivalve continues to breed happily throughout the Great Lakes, and slowly to infiltrate watersheds in the eastern United States. The upper Mississippi has been colonized, as have the Illinois and Hudson Rivers, the Susquehanna drainage system, and Kentucky Lake in Tennessee. In addition to millions of dollars spent on raking mussels from utility inlet pipes, ecologists worry about the fate of North America's freshwater bivalve fauna. But many also credit alarm over *Dreissena polymorpha* with focusing public attention on exotic species (also see story on p. 1444).

■ **Purple loosestrife.** This European weed is so pretty that in some states florists still use them to grace bouquets. But elsewhere, natural areas managers douse *Lythrum salicaria* with herbicide in hopes of saving native wetland plants. Brought over from Europe in the late 1800s, purple loosestrife has already colonized much of its preferred habitat in the eastern United States and is eagerly swallowing up Midwestern wetlands. USDA hopes to check its spread with insects now being tested as biological controls. ■ E.C.

three-quarter-inch zebra mussel can filter all the organic matter from a liter of water each day, expends half its body weight as gametes during spawning, and has free-swimming larvae with the potential to spread throughout an entire lake.

Ecologists know less about what makes a community open to invasion. But it appears that the combination of disruption of natural areas and movement of species is increasingly perilous to natives. For example, disturbed areas, which tend to have relatively few species, tend to be vulnerable to invasion, said ecologist Mack at the Indiana meeting. Mack also believes many communities that seem to resist invasion, such as the Arctic, are in fact simply off the beaten path. If so, then remote communities too will suffer an onslaught of exotic species as they are opened to commerce.

Unfortunately, the pattern of human activity tends to give itinerant organisms a perfect setup. First, says fish biologist Moyle, we disturb large areas—by logging, burning, plowing, damming—and often wipe out or weaken some native species in the process. Then, by trafficking in and out with a diverse cast of stowaways, we can introduce new immigrants into a disturbed area, setting in motion another round of species extinctions. "It's like a one-two punch. The exotics are the ultimate method of extinction after weakening species by habitat loss and disturbance," Moyle says.

The notorious zebra mussel provides a case in point. North America happens to have an unusually diverse fauna of freshwater bivalves. Many of these already have a tenuous hold on survival, thanks to pollution and habitat alteration. Enter the zebra mussel, which attaches itself to any hard surface it finds, including other clams, which it buries with extra weight and outcompetes for food. The result is a recipe for extinction. "We have over 20 species of endangered mussel in Tennessee," says ecologist James Drake of the University of Tennessee. "When the zebra mussel hits I suspect we'll lose them all."

No one knows whether the current flurry of interest in exotic species will be sustained when zebra mussels fade from the news. Meanwhile, a rising tide of organisms continues to accompany people and cargo in their travels around the world. In recent weeks, U.S. Department of Agriculture officials have become alarmed over a new intruder in the Northwest: the Asian gypsy moth, whose flying females disperse even faster than their established European cousins. While ecologists and managers gather their voices, such troublesome examples may help keep less visible exotics on the unwanted aliens list. ■ ELIZABETH CULOTTA

Baltimore Resigns at Rockefeller

New York—Following weeks of behind-the-scenes turmoil, Rockefeller University president David Baltimore has submitted his resignation to the university's board of trustees, ending an 18-month term of office that never escaped the shadow cast by Baltimore's involvement in a disputed 1986 paper on genetics and immunology that appeared in *Cell*. Baltimore's letter of resignation, dated 2 December, was expected to be accepted by the board at a meeting on 3 December. In the letter Baltimore said he planned to stay on as professor and continue to head his own laboratory group. Richard M. Furlaud, chairman of the board, said Nobel laureate neurobiologist Torsten Wiesel would serve as acting president until a permanent replacement can be found.

"The reason I have decided to take this step," Baltimore said in his letter, "is that the *Cell* paper controversy created a climate of unhappiness among some in the university that could not be dispelled." Baltimore added that he "did not anticipate that this matter would become such an extended personal travail for everyone involved. Trying to govern the university under these conditions has taken a personal toll on me and my family which I can no longer tolerate."

Baltimore's administration won high marks in some respects. Since taking over from retiring president Joshua Lederberg in July 1990, Baltimore began restoring fiscal equilibrium at Rockefeller, which had operating deficits of nearly $30 million over the last 2 years. In addition, he pushed to reform the university's academic structure so that gifted younger researchers would not have to wait years to become heads of their own laboratories. Those reforms won him support among the university's junior faculty.

But the 1975 Nobel laureate (he shared the prize with Howard Temin of the University of Wisconsin for the discovery of reverse transcriptase) was vehemently opposed by many members of the university's senior faculty. His appointment in the fall of 1989 prompted an unusual show of public opposition by some senior faculty, who questioned his handling of the controversy surrounding the *Cell* paper, which has been the focus of two university inquiries, two NIH investigations, and a highly charged congressional hearing on scientific fraud during which Baltimore tangled with Representative John Dingell (D–MI).

Baltimore's critics faulted him for failing to heed the warnings of Margot O'Toole, the postdoc who first raised the possibility of inconsistencies in certain data in the *Cell* paper contributed by Baltimore's collaborator Tereza Imanishi-Kari—and for attacking the motives of the Dingell inquiry. Those criticisms simmered for a while, then boiled over when a draft report from the NIH Office of Scientific Integrity concluded that some of Imanishi-Kari's data had, in fact, been fabricated. An informal poll of tenured faculty taken last April, after the OSI report was leaked to the media, indicated that more than half of Rockefeller's roughly 45 full professors opposed Baltimore continuing as president, according to faculty sources.

During the late summer and fall Baltimore's support among the senior faculty deteriorated still further, and two senior faculty members, Anthony Cerami and Gerald Edelman, announced they were leaving for other institutions (though both tried to separate their decisions from the Baltimore controversy). The deep rift between the tenured professors and the board, who continued to support Baltimore, became clear during a confidential meeting on 17 October. In terms described by participants as "venomous" and "very confrontational," a dozen faculty members expressed to representatives of the board their concerns about continuing negative publicity associated with the *Cell* paper and its effect on Baltimore's ability to raise funds and recruit faculty. "What's very clear," said one participant, "is that people who were initially Baltimore's supporters spoke out against him at this meeting."

Another precipitating event seems to have come on 26 November, when James E. Darnell Jr., vice president of academic affairs, and a respected Rockefeller molecular biologist, tendered his resignation as vice president. The trustees had not decided whether to accept it at press time, according to university sources. Darnell did not return repeated phone calls to his office. Baltimore's decision to resign apparently was made during the week of 25 November. He called chairman Furlaud over the Thanksgiving holiday. "He said he'd been thinking it over and thought he ought to resign," said Furlaud. ■ STEPHEN S. HALL

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