develop a 1-centimorgan map.

Lander, one of the coauthors of the *Cell* paper, thinks there are legitimate reasons for publishing at this stage, although the map itself "is not a big deal," he says. "It is incremental progress. But what is exciting is that both groups are at the stage where the markers are dense enough that maps are condensing out. Now it makes sense to change strategy. Once you pass the 95% threshold, it makes sense to fill in the gaps in a much more directed fashion. So it is a bit of a milestone. But there is lots more to do."

But it sounded like more than "a bit of milestone" when the company heralded the "first genetic map of the entire human genome" at its press conference. And that is what McKusick and several others object to. "Collaborative is doing a disservice to the field by giving the impression that they have finished the map," McKusick says. "There is a tension," admits Lander, "because a company needs publicity."

"Collaborative has done a great service to the scientific community in creating a lot of markers," says Robert Cook-Deegan of the Office of Technology Assessment. "We are 2 years ahead of where we would have been if they had not been in the field. But the fact that they are a company means they have to parade their wares. It is not unjustified that they want a return on their investment."

In the grand scheme of things, who got there first—or who claims to have done so—matters very little, except to those involved. What is of concern to the research community, however, is what effect this dispute will have on progress toward a fully detailed map. The answer, it seems, is not much. Lander is convinced that the competition has quickened the pace of research, "but it probably hasn't made either of them any happier." Both groups have developed far more markers than anyone would have anticipated even a year ago and have made major strides toward what was once considered an impractical goal. And if these markers were combined, the eagerly awaited 5-centimorgan map would be in hand.

"It's a real shame that the only two groups in the world who are doing this haven't communicated and shared probes," rues Leroy Hood of the California Institute of Technology. "Together, it could be a tremendous map."

But the beauty of the CEPH collaboration is that this integration will occur anyway, regardless of the tension between the two groups. Both Donis-Keller and White will submit their latest markers and genotypic data to CEPH in December, the data will be integrated, and a 5-centimorgan map will emerge—whether or not they resolve their current spat. ■ LESLIE ROBERTS

Ecological Invasions Offer Opportunities

Ecological communities are constantly under threat of invasion by exotic species: how successful a particular invasion will be is often difficult to predict

WHEN the Polynesian discoverers of Hawaii settled on the islands 1500 years ago, they brought with them dogs, pigs, rats, chickens, and as many as 30 species of plants. This initial invasion of a once pristine environment was extended massively following European contact a couple of centuries ago. As a result, many endemic species of animals and plants have succumbed to extinction on the islands, many others cling on precariously, while at the same time hundreds of exotic species thrive.

> ***"We are biased in our views of invasions. We tend to notice the very obvious successes, while the failures often go undocumented."***

"These invading species have altered the face of the community to such an extent that formerly common species can no longer be found on the islands," comment Harold Mooney and James Drake of Stanford University and the University of Tennessee, respectively. "Once the phenomenology and mechanics of invasions are understood, any generalities that emerge may be useful in predicting, managing, and possibly preventing the changes that accompany an invasion." The challenge is to understand the fundamentals of species' invasions, in Hawaii and elsewhere, a task that is turning out to be a tough proposition indeed.

The British ecologist Charles Elton first drew serious attention to the impact of invading species, saying almost three decades ago: "we are seeing one of the great historical convolutions of the world's fauna and flora." In recent times, a major effort has been launched, under the flag of the Scientific Committee on Problems of the Environment (SCOPE), to assemble global information on invasions, from which practical and theoretical benefits should flow.

"There are two fundamental questions you want to address concerning invasions by exotic species," explains Drake. "First, what makes a good invader? And second, what makes a particular community susceptible to invasion?" Underlying these questions is the issue of community assembly: what are the "rules" by which species come together and interact? Clearly, if ecologists had a complete understanding of the rules of assembly, then answering Drake's two questions might be quite tractable. But this is a two-way street, because ecologists are also analyzing specific instances of invasions as one approach to trying to understand the rules of assembly, which so far remain rather elusive.

There have been a number of efforts to characterize good invaders in this overall context, but so far the results have been surprisingly disappointing. "You can come up with a list of characteristics, such as fast growth rate, broad dispersal abilities, and so on," notes Simon Levin of Cornell University. "But that is tautological. We are finding that such generalizations are often so trivial as to be useless, or they are simply wrong."

One reason why it is difficult to come up with an all-purpose profile of "a good invader" is that potential target communities offer such very different environmental conditions. "What you require is a good match between the invading organism and the environment," says Levin. He points out that the process can be broken down into several stages, such as initial establishment, growth, and geographical spread. "Of these, probably the most unpredictable stage is the initial establishment of the species within the community. Here, you are dealing with populations at very low densities, a characteristic that puts the invaders at high risk from stochastic factors leading to local extinction."

Given the caveats about the inadequacy of generalities, University of Tennessee ecologists Stuart Pimm and M. P. Moulton have come up with a set of statements relating to potential success of invading species. Based on data from Hawaiian birds, they are: First, although large ranges make successful invasion more likely, geographic origins per se are not good predictors of the outcome of invasions. Second, communities with many species are less likely to be colonized than those with few species. And third, invasion success is not necessarily blunted by the presence in the community of species of the same genus as the invader, unless those species are morphologically similar to the invader.

Ecologists' abilities in predicting potential success by an invader are in fact greater than many often allow, as is evidenced by the results of attempts at biological control, which in essence is a deliberate attempt at invasion. Of the 600 or so species of parasites and predators of insects that have been released in biological control programs, about one-third have worked as planned. By contrast, the great majority of natural "attempts" at invasion apparently fail. "This may come as a surprise," says James Kitchell of the University of Wisconsin, "but we are biased in our views of invasions. We tend to notice the very obvious successes, while the failures often go undocumented."

The effect of an invading species, once it is established, will often depend on the structure of the community itself—specifically the complexity of the food web—as much as on the nature of the species itself. Introduce a herbivore into a community that already has several, and the result may be very little change. But where there are no existing significant herbivores, catastrophe can ensue—you are adding a new level in the trophic structure. The introduction of goats onto otherwise pristine oceanic islands is a cogent example, where vegetation can be virtually stripped, not only denuding the island of plants but also setting soil erosion in train.

Natural ecosystems are often regarded as resting at some kind of stable equilibrium, erroneously as ecologists have come to realize. Nevertheless, the rules of interaction between species in a community are altered when that community is subject to significant disruption, either through natural agents or human action. And it appears that one thing that does make a community more susceptible to invasion is disturbance.

"In disturbed communities resources become available," explains Levin. "And one of the basic resources is space, as in a forest when you get tree falls. That presents an opportunity for colonization, both for native species and any exotics that may be present." In other words, disturbance allows the opportunity for establishment by an exotic species. But once the immediate effects of local disturbance are passed, other properties will then determine whether the invader will thrive or not.

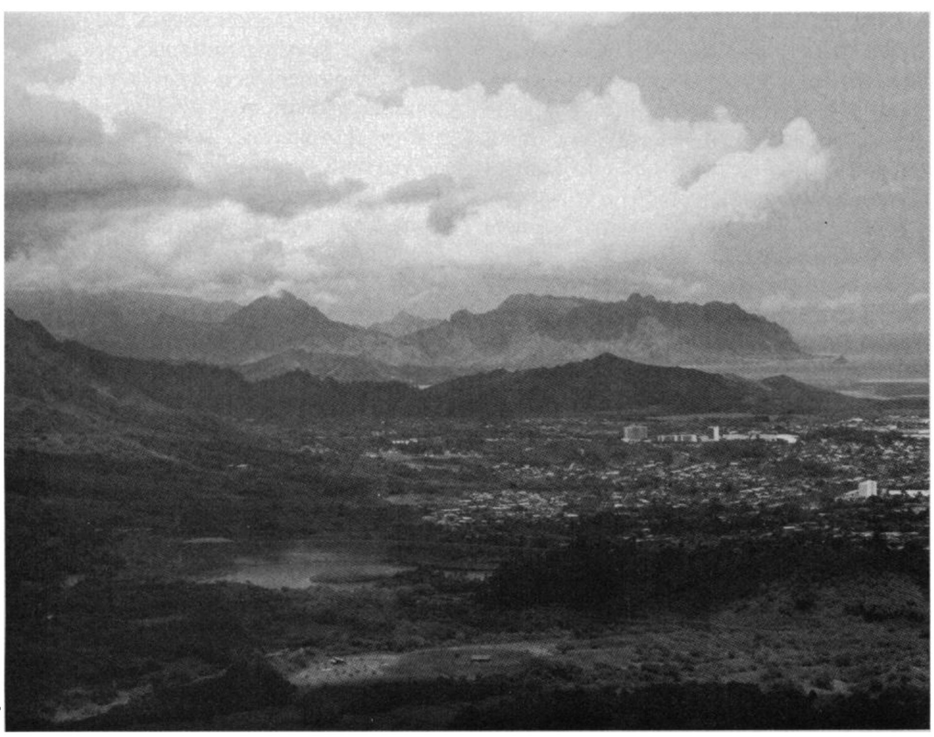
The most obvious effects of invasions, therefore, is at the level of the community—the mix of species you see living together. Sometimes, however, there are larger effects, specifically at the ecosystem level, which includes patterns and regulation of productivity, nutrient cycling, hydrological balance, and disturbance. "Pigs, for instance, so turn over the soil in their rooting that soil structure and nutrient flow can be dramatically altered," explains Peter Vitousek of Stanford University. "It is, however, much more difficult to demonstrate ecosystem effects of exotic plants, perhaps because most plants are more similar to each other in resource requirements than are most animals."

Nevertheless, Vitousek and his colleagues have recently been studying a striking example of ecosystem modification by an invading plant, details of which they present on page 802 of this issue. Introduced to Hawaii from its native Azores and Canary Islands in the 19th century, *Myrica faya*, a tree that has nitrogen-fixing symbionts, has proliferated on young volcanic soils, which are poor in nitrogen. By generating biologically available nitrogen in areas that previously lacked the element, this exotic tree is effectively altering the nutrient cycling, an ecosystem property.

The initial stages of the investigation, which demonstrated the input of nitrogen into the ecosystem, is to be followed by population studies; these include monitoring the dynamics of colonization by the invading tree and determining precisely the effect of the extra nitrogen on subsequent community structure.

"Traditionally, ecosystem people and population biologists have remained rather separate," notes Levin. "They look at the world in different ways, seeing different things as important." Put crudely, ecosystems researchers are strongly empirical, being concerned with large-scale geochemical cycles, with individual species playing a small role. Population biologists are much more theoretically based, in terms of population aspects of evolutionary biology, where individual and species properties are paramount. "Peter Vitousek's work links the two together in a very useful way."

"An understanding of the effects of invading species at the ecosystem level is important for conservation biology as well as for basic ecology," noted Vitousek recently, writing with his colleagues Lloyd Loope and Charles Stone. "Where an exotic species changes ecosystem characteristics, it changes the rules of the game for all native and exotic species. The number and success of invaders makes Hawaii an excellent location for such studies." ■ ROGER LEWIN



Nagele/FPG

Invaded islands. *Hawaii has been successfully colonized by hundreds of exotic species of insects, plants, and animals, the result of which is an environment in turmoil.*

ADDITIONAL READING

P. M. Vitousek *et al.*, "Introduced species in Hawaii," *Trends Ecol. Evol.* 2, 224 (1987).
H. A. Mooney and J. A. Drake, "The ecology of biological invasions," *Environment* 29, 10 (1987).