Sources and Sinks Complicate Ecology

Landscapes are mosaics of habitats, some more equipped to support populations than others; the result is a less than immediately obvious interaction among the mosaic

THINGS ARE NOT ALWAYS what they seem to be—especially in ecology, where threads of complexity may be woven into deceptive patterns. And University of Georgia researcher Ronald Pulliam infers from his population dynamics modeling that there may be yet more elements of complexity that many ecologists overlook. If these theoretical conclusions are confirmed among natural populations, "some basic ecological notions concerning niche size, population regulation, and community structure must be reconsidered," warns Pulliam.

The focus of concern here is that the overall success of different populations of the same species will vary among different habitats: variation in resource abundance and predator pressure, for instance, will determine whether, generation by generation, a population will grow, remain stable, or shrink in one habitat as against another. Nothing apparently very profound about that, but, says Pulliam, "ecologists often study population growth and regulation with little or no attention paid to the differences in birth and death rates that occur in different habitats."

In other words, although a researcher may carefully study the dynamics of a population in one habitat, comparisons with nearby, different habitats typically are not carried out. There may in fact be a mosaic of habitats, each with its own demographics and—crucial to Pulliam's argument—each influencing or being influenced by nearby populations. Those interactions depend on whether a particular habitat can support a net population increase (a "source" habitat) or results in a net population decrease (a "sink" habitat).

These terms are not new to ecology, but the implications of these different states have yet to make a great impact on the science, particularly in theoretical modeling. The most immediate implication, as Pulliam shows clearly in his model, is that if two different habitats—one a source, the other a sink—are near neighbors, then migration of the surplus from the source to the sink can maintain two separate populations in apparent demographic equilibrium. Study of the sink population in isolation would produce the puzzling observation that, although birth rates are below death rates, the population remains constant.

Is this a source or a sink? *Populations will fare better in some habitats than in others, as a result of differences in food resources and predator pressure, for instance. Habitats that can support a population surplus (reproductive output exceeds deaths) are known as sources, those with a deficit, sinks.*

"I've had people come up to me after talks I've given, saying, 'this must be what's happening in my study'," Pulliam told *Science*. "People frequently imagine their techniques must be wrong when they see this kind of result. But what is wrong is that they are looking at only half of the picture."

Pulliam's model shows, for instance, that "if reproductive surplus of the source is large and the reproductive deficit of the sink is small, a great majority of the population may occur in a sink habitat." For instance, if the per capita surplus of the source population is 1.0 and the deficit in the sink population is 0.1, then "less than 10% of the population occurs in habitats where reproductive success is sufficient to balance annual mortality." And that can seem puzzling, if the picture is incomplete. It also has implications for niche occupation, for conservation, and for community structure.

The idea of niche is somewhat controversial in ecology, but at its simplest it is where environmental resources match a population's requirements. In 1958 G. Evelyn Hutchinson pointed out that the niche a species actually occupies may be smaller than its basic (or fundamental) niche, because of the costs of competition and other factors that might detract from a habitat's ability to support a specific population. However, if source and sink habitats operate in the manner Pulliam believes they do, then a species' realized niche can be larger than its fundamental niche: a sink habitat, by definition, cannot be counted among a species' fundamental niche.

In the realm of conservation, biologists increasingly are forced to identify populations that might be saved in isolation, with habitat destruction going on all around. "Given that a species may commonly occur and successfully breed in sink habitats, an investigator could easily be misled about the habitat requirements of a species," notes Pulliam. And superficial assessment of the suitability of one habitat over another may lead to disastrous results.

"For example, 90% of a population might occur in one habitat," explains Pulliam. "On the basis of the relative abundance and breeding status of individuals in this habitat, one might conclude that destruction of a nearby alternative habitat would have relatively little impact on the population. However, if the former habitat were a sink and the alternative a source, destruction of a relatively small habitat could lead to local population extinction." This would be a catastrophic outcome of appearances being deceptive.

The most important implication of the source/sink idea, says Pulliam, is in community ecology, in which researchers try to understand what factors underlie the assembly of a group (community) of species in one habitat. The nature and abundance of food resources and potential competition among species are clearly influential here. But, says Pulliam, ecologists frequently make the mistake of focusing only on the habitat in question, ignoring the mosaic of neighboring habitats. This tends to lead to the assumption that a species is part of the community because its niche requirements are met there. The assumption may be unfounded.

For some of the species in the community, the habitat may represent a sink, and survival there depends on nearby source habitats. "In extreme cases, the local assemblage of species may be an artifact of the type and proximity of neighboring habitats and have little to do with the resources and conditions at the study site," observes Pulliam. "This is not to imply that local studies of the mechanisms of population regulation and species coexistence are unnecessary, but rather that they need to be done in concert with 'landscape' studies of the availability of habitat types on a regional basis." Pulliam's goal is "to draw attention to some of the implications of habitat-specific demographic rates."

There are sufficient data from field studies to indicate that the phenomena of source and sink habitats exist. However, the extent of their influence on the ecological issues identified by Pulliam remain to be established. "I hope that my model, like any new model, will stimulate new research and lead to the reexamination of existing data sets," Pulliam told *Science*. ■ ROGER LEWIN

ADDITIONAL READING

H. R. Pulliam, "Sources, sinks, and population regulation," *Am. Nat.* **132**, 652 (1988).

Feeding the Monster in the Middle

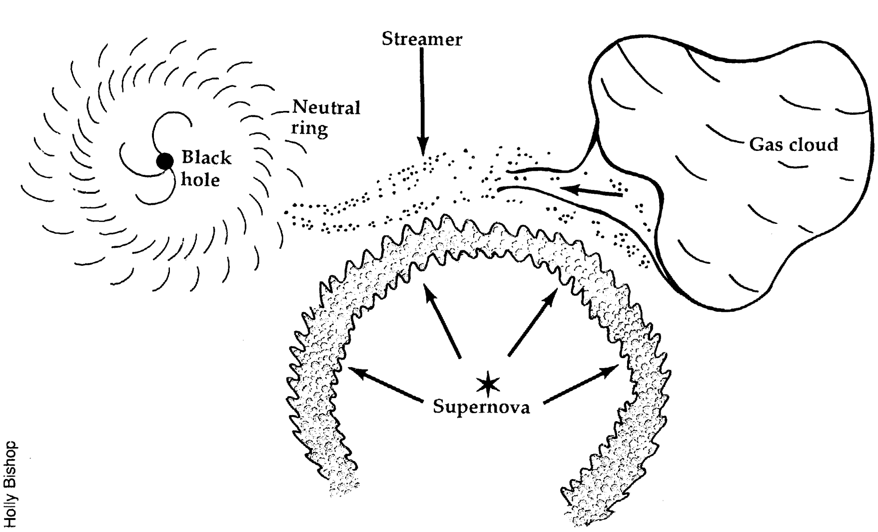
Anywhere from 10,000 to 100,000 years ago, says astronomer Paul Ho of the Harvard-Smithsonian Center for Astrophysics, a cloud of interstellar gas orbiting near the center of our galaxy was violently disturbed by a supernova. Today, he says, the material knocked loose in that event is visible to our radio telescopes as a thin streamer of gas and dust plunging down into the core itself—an energy source that many astronomers believe to be a black hole roughly 1 million times as massive as the sun.

"The results [on the streamer] are very preliminary. But if true, they are very exciting," says Ho, who discussed his observations at a recent meeting of the American Astronomical Society.* Our galaxy's black hole is a tiny thing compared to the billion-solar-mass monsters thought to power quasars and other active galactic nuclei. But the principle of its energy output is the same: matter falling into the hole is compressed and heated to a fierce luminosity just before it disappears. Moreover, our galaxy's black hole is only 25,000 light-years away, whereas the quasars are billions of light-years away. So it offers Earth-bound astronomers their best opportunity to study precisely what happens in the environs of such an object.

In particular, says Ho, if the central streamer and supernova are real they may illustrate one important mechanism for keeping massive black holes supplied with fuel. His model is based on high-resolution observations of the galactic center that he made last year at the Very Large Array (VLA) near Socorro, New Mexico, in collaboration with researchers from the Max Planck Institute in Munich, the University of Cologne, and the Massachusetts Institute of Technology. As shown in the accompanying sketch, Ho believes that the original gas cloud started out in a stable orbit about 25 light-years out from the galactic center. But with the impact of the presumed supernova shock wave, some of its material was knocked inward. And as that material fell, it was stretched by the tidal influence of the hole like so much taffy. Thus the streamer, which is at least 15 light-years long, but only a few light-years wide. Ho points out that Doppler shifts from the VLA observations, which detected the 1-centimeter emission line of ammonia molecules in the gas, indicate that the streamer is indeed flowing toward the hole.

Given the observations to date it is difficult to be sure what happens when the gas actually reaches the center, says Ho. But he suspects that the material actually cascades downward in a series of stages. For example, about 2 to 3 light-years out from the center is a well-known ring of neutral hydrogen gas, which seems to be feeding ionized gas directly into the hole along a complex series of spirals. Perhaps, says Ho, the ring simply marks the point where gas from his supernova-generated streamer accumulates before taking the final plunge. ■ M. MITCHELL WALDROP

*The 173rd meeting of the American Astronomical Society, 8 to 12 January 1989, Boston, Massachusetts.



At the core. *Has a supernova knocked gas into the central black hole?*