Perceiving patterns in nature is a beginning to understanding the basis of biological diversity, sensing some order in what may otherwise seem chaotic or random spatial arrays. Spatial patterns in genetic diversity, also called 'genetic structure' or 'spatial genetic structure,' often reflect biologically meaningful processes. Recognizing these patterns, giving genes a 'physical address,' and understanding their basis can provide a stronger scientific basis for conservation and restoration decisions by making use of biologically meaningful units. These patterns are the result of natural processes, the characteristics of the species, and historical events.

[patterns of genetic diversity are the result of natural processes, the characteristics of the species, and historical events]

Spatial patterns reflect the natural genetic processes (described in Volume 3) — migration, natural selection, and genetic drift. For example, if pollen and seeds are distributed widely for a particular species, one might expect little evidence of genetic structure within a local geographic area. Conversely, if the plant is capable of self-fertilization or has heavy seeds that tend to germinate within short distances of the parents, one might expect to find more local or fine-scale patterns in genetic diversity. In fact, in the absence of any direct genetic data, certain features of the plant species (such as its type of pollen and seed dispersal, its mating system, and its natural range) can be used to establish a reasonable idea of its spatial genetic pattern. Sometimes environmental features are indicators of the spatial genetic patterns if a species is adapted to changes in these features. For example, a species that occurs at a range of elevations may show a gradient in genetic diversity that corresponds with adaptations to various elevations. However, these natural processes may not all be consistent or pushing in the same direction. For example, a population may be locally adapted to microclimate and moisture availability (which would suggest local genetic structure) but also have long-distance seed and pollen dispersal (that would tend to mix up the genes with other populations and undermine local adaptations). So direct genetic studies are needed for confirmation of the genetic structure.

A traditional approach to describing spatial patterns in genetic diversity of plants is to sample individuals widely across the species' range and present a picture of the overall genetic structure based on various kinds of data. However, with further or more detailed studies, it is common to discover that spatial genetic structure often varies within a species — both over the range of the species and over time. The spatial scale at which the genetic diversity is studied — over its entire range, in relation to large-scale physical features such as mountain ranges or drainages, or in a specific locale — will affect the genetic pattern that we observe. For example, in some areas of the species' range there may

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be strong selection pressures (for example, climate may be very limiting) resulting in fine-scale genetic structure; in other areas, the same species may show only weak spatial genetic structure (that is, genetic diversity seems randomly distributed) because of little local adaptation or countervailing influences of gene flow. Similarly, different kinds of genetic data may yield different patterns (see Volumes 5 and 7 for further discussion on this topic). These differing patterns are not inconsistent messages — each is providing a part of the story about how the genetic diversity of the species has been influenced by the environment and its own biological characteristics over time.

Spatial patterns also may change over time — for example, in response to changes in direction or intensity of natural processes. Over the short-term (generations), the spatial genetic pattern exhibited by the adult plants may differ substantially from that seen in the seed produced in any particular year, in the resulting seedlings, and in later life stages. Genetic drift and natural selection continue to shape the

spatial genetic patterns over time. Over the longer term (evolutionary time scales), these influences are compounded and may be supplemented with extreme events (such as glaciations or continental drift) that severely reduce the species (and its genetic diversity), fragment its natural range and disrupt gene flow, allow hybridizations between formerly unconnected populations (or sometimes species), or shift genetic diversity dramatically if only a small fraction is adapted to the emerging environmental conditions. Thus, current patterns of genetic diversity may reflect historic conditions or events, even if these influences are no longer present.

[recognizing genetic patterns can lead to better conservation and restoration decisions]

Finally, spatial genetic patterns reflect the regional dynamics of a species — how plant populations interact on a larger regional or landscape level. Different plant species display different regional dynamics: they differ in the amount and direction of genetic connection (gene flow) among the populations. Sometimes there are larger populations that are relatively stable over time and act as the source of new genes for smaller, less stable populations or as foundation stock for new populations. For other species, the

populations may be more equal in their size and longevity, and exchange genetic material on a more equitable level. Understanding genetic patterns at the regional level, and the underlying reasons for them, is important for effective conservation and restoration decisions. For example, the loss of a population through habitat conversion can have a range of impacts for the species on a regional level, depending on the genetic interactions among populations. Similarly, this information assists decisions about whether gene flow corridors (re-establishing connections between plant populations) are advised, the importance of conserving suitable but currently unoccupied habitat, and whether the better conservation strategy is to conserve one large or several smaller populations for a particular plant species. ■

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