The greatest amount of phosphorus—7.02 mg/kg soil—was in burned soils where there had been a fall application of chlorsulfuron, followed by burned soils with the spring application of chlorsulfuron (6.3 mg/kg soil) and spring application of picloram (5.73 mg/kg soil). All other treatment combinations had similar levels of phosphorous (3.9 to 4.8 mg/kg soil). Apparently, fire increased levels of soil phosphorous and the application of herbicides prevented the target species from phosphorous uptake. Because Dalmatian toadflax is the major forb affected by the herbicides, we suspect that it may be using phosphorous in plots where the herbicides were not applied.

Burning increased soil NO_3, which was more than two times higher in burned soils than unburned, but did not increase NH_4. Likewise, herbicides increased NO_3, especially in plots sprayed with chlorsulfuron, but not NH_4. Chlorsulfuron may have reduced the ability of forbs to capture NO_3, or, perhaps, in some way affected soil nitrification microbes. The treatments did not affect soil potassium.

The increased soil nutrients that result from combining burning and herbicide may leave a site susceptible to establishment of unwanted, robust perennials that respond to high fertility, such as Dalmatian toadflax. Therefore, restorationists who use this approach should seriously consider introducing desirable species that can exploit the increased nutrients.

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Adaptive Cluster Sampling: An Efficient Method for Assessing Inconspicuous Species

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Restorationists typically evaluate the success of a project by estimating the population sizes of species that have been planted or seeded. Because total census is rarely feasible, they must rely on sampling methods for population estimates. However, traditional random sampling designs may be inefficient for species that, for one reason or another, are challenging to survey. Based on our effort to restore a longleaf-pine wiregrass (*Pinus palustris-Aristida beyrichiana*) community, we believe that adaptive sampling methods—specifically adaptive cluster sampling—may provide restorationists with efficient and reliable estimates, especially when contractual agreements specify performance standards.

Adaptive sampling refers to sampling designs in which sample unit selection depends on the value of the variable being estimated, such as the number of individuals. This contrasts with conventional sampling designs, such as simple random sampling, in which all of the sample units can be selected prior to the survey. The purpose of adaptive sampling is to obtain the most precise estimate of abundance or density for a given sampling effort or cost. These techniques are particularly advantageous for sites where the target population is rare, clustered, unpredictable, elusive, or hard to detect.

Here, we briefly describe adaptive cluster sampling. Detailed descriptions of theory, methods, calculations, and other applications are available elsewhere, including Thompson (1990), Thompson and Seber (1996), and the March 2003 issue of *Environmental and Ecological Statistics*. First, we divide the study area into a known number of equally sized sample units from which we select an initial random sample. We then survey the selected units in turn. If the unit meets a predetermined condition (such as a specified number of the target species), we then survey adjacent units. If adjacent units meet the condition, we add them to the sample, and continue surveying and adding adjacent units until units that do not meet the condition are reached.

Figure 1 illustrates this process. In this example, the goal is to estimate the mean number of points, which could represent individual plants or another variable, in the area. We divide the area into 324 units and then sample ten randomly selected units, represented by the shaded squares in the top figure. Each time we encounter at least one point (our predetermined condition) in a unit, we add the units to the top, bottom, left, and right to the sample. We continue this process until we reach the final sample of 35 units shown in the bottom figure.

Finally, we use the appropriate calculations (see references for equations and calculations) to determine an unbiased estimate of the number of points in the study area. The researcher modifies the sampling design according to the following decisions: 1) the size of the sample unit, 2) how the initial sample is chosen (number of initial units, simple versus stratified random sampling), 3) the condition to be met for continued sampling, and 4) which adjacent units to sample. Care must be taken when designing adaptive samples—if the population is more abundant or less clustered than expected, or if the condition is too easily met, the researcher may end up sampling unit after unit, which significantly diminishes the efficiency of adaptive methods.

We used this technique to sample wiregrass seedlings in a restoration project at Fort Gordon Military Reservation near Augusta, Georgia. Historically, the study site was a longleaf pine forest with wiregrass as the dominant groundlayer species. The main restoration goal was to facilitate reintroduction of fire by establishing wiregrass from local seed. Our objective was one wiregrass plant/m^2. In March 2002, we used a hay blower to spread wiregrass seed onto 2 acres (0.8 ha) that had been clearcut and planted with longleaf pine seedlings.

Seedlings established in depressions and near logging debris, resulting in a sparse and clustered distribution at the end of the

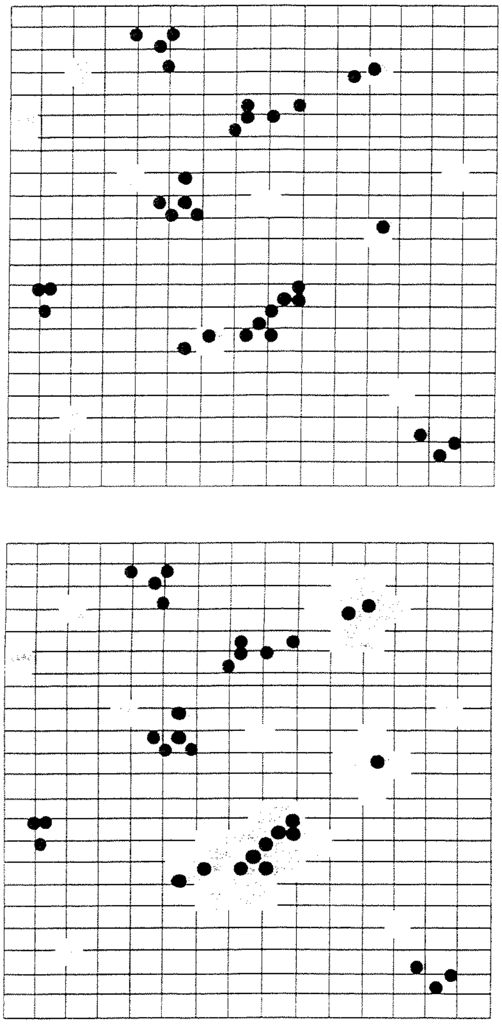

Figure 1. Illustration of the basic adaptive cluster sampling technique. The researcher takes an initial random sample of ten units (shown as the shaded squares in the top panel) from the 324 total units. Adjacent neighboring units are added to the sample whenever at least one point is observed in a selected unit. The resulting total sample is shown as the shaded section in the bottom panel.

first growing season. We were concerned that traditional random sampling would cause us to spend much time sampling plots with no wiregrass, and that our estimate would not reflect the actual density. We used adaptive cluster sampling to estimate populations in four 0.5-acre (0.2-ha) plot and compared those results with population estimates using the initial random sample. While population estimates were similar for both methods, we found that the variance of the adaptive sampling estimate was always smaller than that calculated from simple random sampling. Although differences in sample size prohibit direct comparison, this suggests that the estimate from adaptive sampling was a more reliable population estimate than the one obtained from simple random sampling. We believe that further investigation of these methods will show them to be helpful to ecological restorationists.

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FROM: Abstracts of the CALFED Science Conference 2003

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Fish Assemblages in Newly Restored Tidal and Flood Plain Habitats in the Napa River/Napa Creek Flood Control Project. Dietl, M.L., U.S. Army Corps of Engineers, Sacramento, CA 95814; L. Dusek, S.H. Kramer and S.D. Wilcox. P. 43.

The Napa River Fisheries Monitoring Program is studying fish assemblages in the Napa River estuary to assess fish species use of restored tidal wetlands, riverside marsh terraces, floodplains, and open water river habitats. The project's objectives include documenting the presence, relative abundance, life stages, and seasonal use of fish species in the restored and created habitats. In addition, researchers are attempting to determine any correlations between fish species and environmental conditions at each sampling site. In 2001 and 2002, workers detected 26 fish species—11 non-native and 15 native—including the endangered Sacramento splittail (*Pogonichthys macrolepidotus*), delta smelt (*Hypomesus transpacificus*), and Central Valley steelhead (*Oncorhynchus mykiss*). The project's Web site, www.napariverfishmonitoring.org, provides additional information.

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Effects of Fire on Fish Populations: Landscape Perspectives on Persistence of Native Fishes and Nonnative Fish Invasions. 2003. Dunham, J.B., U.S. Forest Service, Rocky Mountain Research Station, Boise Forestry Sciences Laboratory, 316 East Myrtle, Boise, ID 83702, 208/373-4380, Fax: 208/373-4391, jbdunham@fs.fed.us; M.K. Young, R.E. Gresswell and B.E. Rieman. **Forest Ecology and Management** 178(1-2):183-196. **Status of Native Fishes in the Western United States and Issues for Fire and Fuels Management.** 2003. Rieman, B., U.S. Forest Service, Rocky Mountain Research Station, 316 East Myrtle, Boise, ID 83702, 208/373-4386, Fax: 208/373-4391, brieman@fs.fed.us; D. Lee, D. Burns, R. Gresswell, M. Young, R. Stowell, J. Rinne and P. Howell. **Forest Ecology and Management** 178(1-2):197-211.

The authors of the first article reviewed studies that documented the responses of fish to disturbances, particularly fire, to determine the effects of fire and fire management on native fish populations. They found that species with narrow habitat needs in highly fragmented and degraded systems were most vulnerable to fire and fire-related disturbance. Fire-related disturbance may also facilitate non-native fish invasions. Of the management alternatives—prefire management, postfire management, fire fighting, and monitoring and adaptive management—the authors especially recommend prefire management activi-