Vegetation in Transition: The Southwest's Dynamic Past Century

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Abstract—*Monitoring that follows long-term vegetation changes often requires selection of a temporal baseline. Any such starting point is to some degree artificial, but in some instances there are aids that can be used as guides to baseline selection. Matched photographs duplicating scenes first recorded on film a century or more ago reveal changes that help select the starting point. Interpretation of the observed changes may be strengthened by quantitative measures from permanent long-term study plots established at sites near the photo stations. The gradual infusion of exotic plants and animals into ecosystems may complicate baseline selection. Because these new additions often interact with the native biota, the timing of their appearance on the scene should be recognized, and provides further direction for judging appropriate temporal baselines.*

Introduction

Long-term monitoring may help direct the destiny of ecosystems by providing a foundation from which to judge change. Reconstruction of any region's past vegetation requires establishment of a temporal base from which changes can be measured. Selecting this base is charged with obstacles. Changes undoubtedly occurred during the period prior to European intrusion into southern Arizona and bordering regions, but, in general, detailed descriptions of vegetation and associated fauna are missing from that era. However, by setting the biological clock to a time when descriptions are more precise and human impact still slight, the difficulty of selecting a base is greatly diminished. A method that provides partial access to vegetation history is the art of photographic matching or repeat photography. Fortunately, landscape photography came into prominence in the late 19th century at about the same time that the human population in our region was beginning to expand, making this a convenient point to start the clock. In rare instances, detailed quantitative data are also available, bolstering the photographic evidence and further enhancing our ability to establish an ecosystem time base.

In the following pages, repeat photography will illustrate the importance of defining a temporal base when making judgments about change. Examples will also be provided to show how detailed quantitative measurements may complement findings from photographic matches or the quantitative measures may even stand alone. Whether our forests and creosotebush stands are shrinking or expanding, whether bird and fish populations are declining or irrupting are all judgments that must be made in the context of appropriate time intervals. Any temporal baseline is artificial and requires consideration of what transpired during previous time periods. Some examples will illustrate how matched photographs and quantitative data, alone or together, can assist in defining time zero when conducting monitoring programs. In addition, because many ecosystems have gained new species from afar, the timing of the recent arrivals may help define a baseline.

Cienega Creek and the 90 Percent Decline Myth

One of the region's frequently recited statistics is the assertion that the riparian communities of our area have experienced large declines in extent, quality, diversity, or some other descriptor (Tellman et al. 1997; Arizona Daily Star 2003). Where this notion originated is not easily determined, but it has been amply repeated in the literature, and has sometimes been bolstered by wild claims that the decline in vegetation has been preceded by a large decline in streamflow. The false assertions that "steamboats once navigated all the way to Charleston [along the San Pedro River] to supply Tombstone and Bisbee with goods…" (Blake and Steinhart 1994) or that "When Anglo-Americans first came to the Southwest, much of the Gila River was navigable [by steamboat]" (McNamee 1994) have only deepened the conviction of some that the changes have been very large indeed.

Shortly after the railroad reached Tucson in 1880, Carleton E. Watkins, noted photographer, stepped off the train at a station east of town and recorded a view of Cienega Creek (figure 1A) that serves as a base for judging change in riparian habitats. The freshly laid tracks of the Southern Pacific Railroad run alongside Cienega Creek, a barely discernible treeless runnel that crosses a shrub-free valley floor that is covered by grasses. One-hundred-eighteen years later the scene is vastly altered (figure 1B). The grass-covered valley floor is now dominated by a dense mesquite forest; the Cienega Creek channel is deeper and supports a forest of cottonwoods and willows. The original railroad bridge washed away and has been relocated upstream.

This photograph pair, and many others like it (Turner et al. 2003; Webb et al., in press), reveal the status of many of our

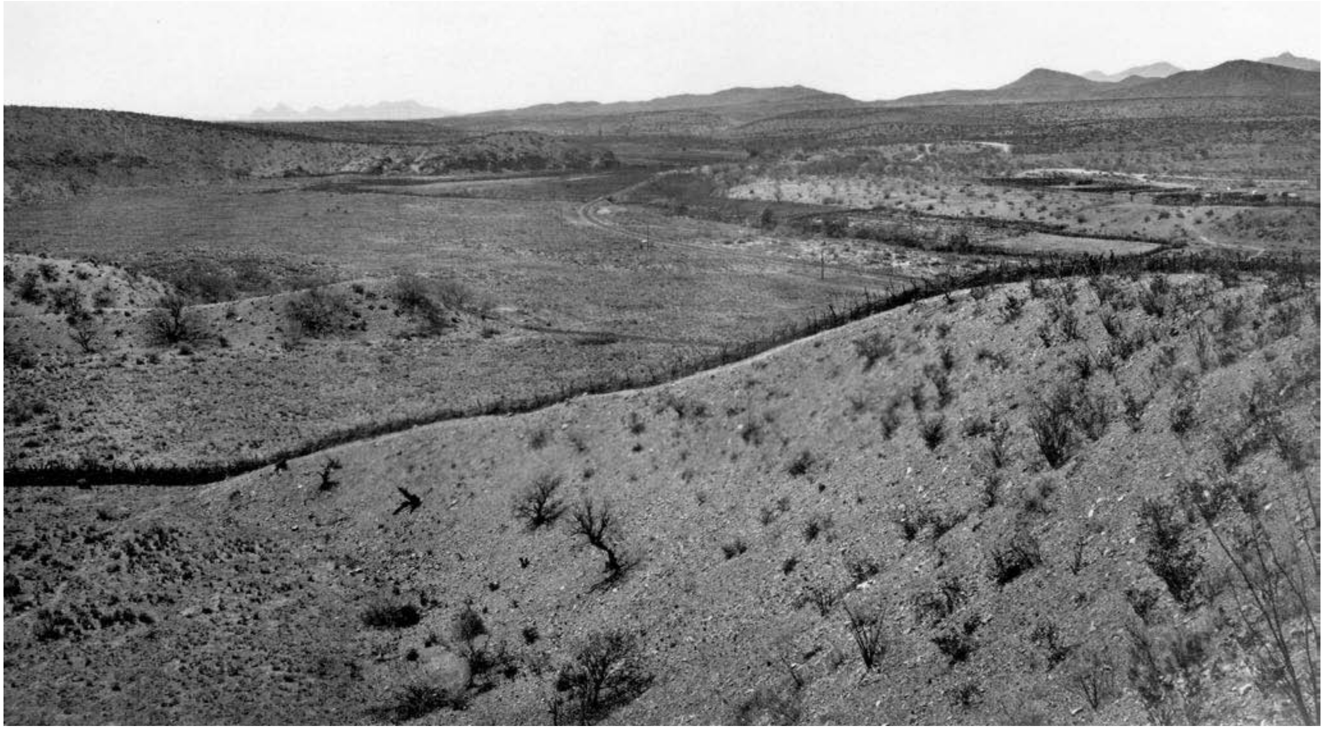

Figure 1A—1880. Freshly laid tracks of the Southern Pacific Railroad run alongside Cienega Creek, represented here by a narrow, essentially treeless channel. The valley floor is covered by grasses and is free of mesquite and other woody plants, although shrubs are common on the adjacent uplands. (Note the brush fence running along the ridge at midground.) C. E. Watkins photograph. Copyright Huntington Library.

Figure 1B—January 1998. The earlier grass-covered valley floor is now occupied by a dense mesquite forest. The Cienega Creek channel is deeper and broader and supports a forest of cottonwoods and willows. The railroad tracks were moved across the river after the original bridge washed away and a new bridge was built upstream in 1912. R. M. Turner photograph, courtesy of the Desert Laboratory Photograph Archive.

river valleys in the late 1800s and establish the foundation for judging subsequent changes in these riparian habitats. The sequence of changes along our major valleys started when sluggish streamflow across flat, seasonally flooded swards of sacaton became forcefully erosive during the last decades of the 19th century. The bottomlands were cut by narrow defiles. The deepened channels produced a drop in the water table, cessation of overland flooding, and, with subsequent widening, a new habitat ideal for the establishment of riparian trees, such as cottonwood and willow. The grassland, now lacking the seasonal flooding and the alternately dry and waterlogged conditions that excluded woody plants, became an ideal habitat for mesquites and shrubs found on the surrounding uplands (Shmida and Burgess 1988).

The vegetation changes were accompanied by dramatic changes in the fauna. The former grassland was ideal habitat for numerous sparrows, including Baird's and Botteri's, both of which are now Federally listed "species of concern." As noted by Phillips et al. (1964), "Until about 1878 [Baird's sparrow was] an abundant transient and doubtless winter resident in the grasslands of southeastern Arizona…; until 1920 decidedly uncommon but still a winter resident about the bases of the Chiricahua and Huachuca Mountains. Now apparently much rarer." And regarding Botteri's sparrow, these authors note that it is a "rather uncommon summer resident… Usually in giant sacaton… Formerly much more common, especially before 1895…"

Although the virtual loss of some grassland sparrows may seem dramatic, the changes in bird life brought about by growth of the new forests of cottonwood and willow are certainly even more dramatic. The new riparian forest along the San Pedro River is home to a biota that reportedly includes two-thirds of the birds known from North America and more mammals than occur in any comparable area on the planet, save for tropical cloud forest in Costa Rica (Glennon 2002). Among the birds in this new gallery forest are the southwestern willow flycatcher and the yellow-billed cuckoo; the first, a "listed" species, and the second, a bird whose numbers are said to be dwindling.

The changes along our streams, probably more dramatic than changes in most other habitats, are stark examples of the importance of defining the starting point in any program designed to monitor long-term changes. In addition to temporal beginnings, one must ask: What species are being affected? For Baird and Botteri sparrows, habitat decline has indeed approached 90%.

The increase in riparian species along Cienega Creek and the San Pedro River represents a large increase in biodiversity, but, as the next example shows, there are implications beyond mere numbers that must be considered.

Exotic Plants at the Desert Laboratory and Biodiversity

Early workers at the Desert Botanical Laboratory, established by the Carnegie Institution of Washington in 1903, were leaders among scientists interested in measuring vegetation change via monitoring. In one study at the Tucson preserve, Volney Spalding carefully mapped the location of all the exotic plants then known to occur on the 869 acre preserve. This 1906 survey uncovered three exotic species: filaree (*Erodium cicutarium*), mouse barley (*Hordeum murinum*), and Bermuda grass (*Cynodon dactylon*) (Spalding 1909). By 1983 this number had swollen to 52 (Bowers and Turner 1985; Turner and Bowers 1988; Burgess et al. 1991), and the distribution of all three species at the Desert Laboratory had greatly expanded (figure 2). In just under 80 years on a preserve protected from livestock since1907, the number of non-native species had escalated to levels more than 15 times greater than at the time of the original survey. (Two woody species, ironwood [*Olneya tesota*] and jojoba [*Simmondsia chinensis*], were lost during the same period. The status of sixteen other less conspicuous forbs and grasses that have not been seen in recent surveys is less certain—they may still be present.) Clearly, monitoring in such rapidly changing habitats as those represented by the Desert Laboratory must deal with the presence of the newly arrived exotics. Looking into the future of our own region, at a time several centuries from now when buffel grass and other exotics will probably have won the battle that we are now waging against them, biodiversity estimates that ignore the exotics will have little meaning. In the British Isles, for example, where "natural" vegetation has long since given way to highly altered landscapes with many exotic species, biodiversity estimates that exclude exotics would be quit meaningless.

Figure 2—Distribution of filaree (*Erodium cicutarium*) at the Desert Laboratory in 1906 (stippled areas) and in 1983 (dots) (from Turner and Bowers 1988).

At a time when the concept of biodiversity has become a critical criterion for judging ecosystem health, the use of this term needs careful definition. These definitions often assume that biodiversity is just a numbers game, yet where exotics are concerned, their numbers are sometimes ignored. In refining the definition, exclusion of exotics from the tabulations may not be wise.

Saguaro National Park (Rincon Unit): Centuries of Change in a Saguaro Forest

In many instances where matched photographs show change, the earlier photograph is too recent to provide a desired temporal baseline. In such situations, long term monitoring plots may serve the purpose. An example from Saguaro National Park illustrates this problem. Photographs from the 1930s greatly under-represent the saguaro numbers that were actually present a century earlier. The earlier population numbers, for a time well before the advent of field photography, are derived by estimating the age of all saguaros present in 1961 when the plot was established.

Saguaro National Monument (now Saguaro National Park) east of Tucson was established in 1932 to protect the dense saguaro forest at the base of the Rincon Mountains. The Santa Catalina Mountains provide the backdrop for a view of that same saguaro forest taken in about 1935, shortly after the Monument's establishment (figure 3A). The camera overlooks a long-term saguaro study plot established in 1961, and although this photograph series does not span a century, saguaro survivorship data from a plot with many plants over 100 years of age allow us to look much further back in time than the 1930s.

Investigators at the time of the first photograph noted the near absence of young saguaros and predicted that this population of predominantly old plants was not sustainable. They anticipated that the old plants, many of which were nearing their upper age limit (ca. 175 years), would inevitably die, leaving Saguaro National Monument without this saguaro forest.

By 1960 (figure. 3B), the predicted decline had begun. A few months after this photograph was taken, a long-term study plot was established on the flat terrain below this station.

By 1995 (figure 3C), the saguaro forest had indeed disappeared, upholding the biological truth that populations cannot be sustained without reproduction. Data from the permanent plot record the saguaro's decline. In 1961, this nine acre plot supported 209 saguaros; by 1983 the number had plummeted to 100. Undetected at that time, reproduction had begun and the many small plants then present were not counted. By 2001, however, when the plot was last examined, they were large enough to be detected and the population stood at 227. Although this is more than the number present in 1961, it is probably well below the value for the 1930s, when the first photograph was taken. An even deeper look into this saguaro forest's past is provided by assigning an age to each of the saguaros located in the plot in 1961. This is made possible by developing a model for converting height to age, based on the annual height growth rate for saguaros of all heights. In figure 4, age distribution of the 201 uninjured and healthy saguaros reveals a robust establishment period from about 1800 to 1870, after which the population has rarely added enough plants to maintain a population of 201. (Eight plants of the 209 were discarded because they had broken tops or some other defect that made age assignment impossible.) It is this 19th-century pulse of establishment that provides the large number of mature plants seen in photographs from the 1930s. If one could view the population in 1870, before mortality took its large toll, most of the saguaros that actually became established during the 1800-1870 period would still be present and the population total would be large, indeed.

The roughly 200-year period spanned by this plot record, with its widely varying population values, provides a complex example illustrating the problem of choosing a baseline for judging change. Use of quantitative permanent plot data sharpens the focus on past conditions and allows a more accurate base with which to compare current conditions than does the use of matched photographs alone.

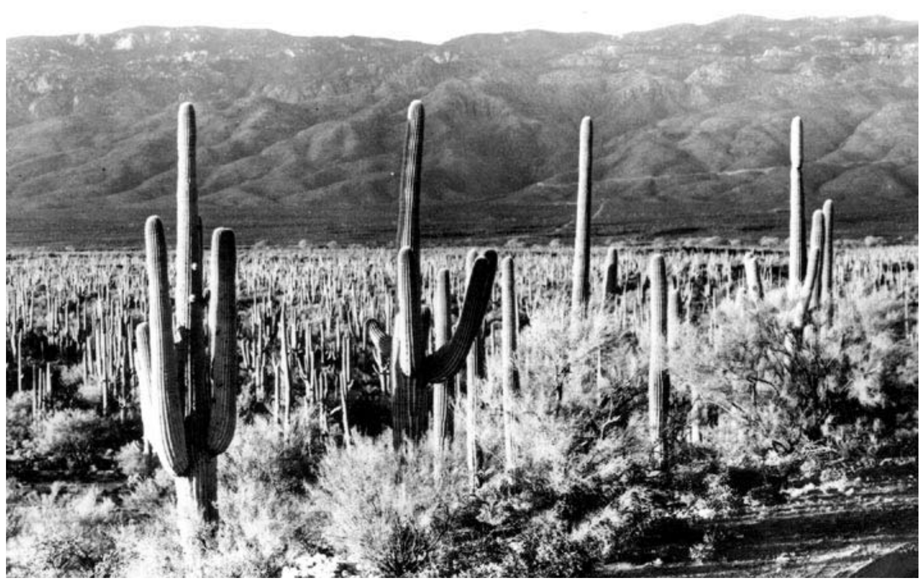

Figure 3A—Ca. 1935.The saguaro forest that prompted establishment of Saguaro National Monument appears across the scene. Photograph courtesy of the National Park Service.

Figure 3B—July 1960. Some foreground saguaros are larger, but many have died here and across the background. Woody vegetation has increased. J. R. Hastings photograph, courtesy of the Desert Laboratory Photograph Archive.

Figure 3C—March 1995. Change is widespread. Most of the saguaros have succumbed to old age, and the distant bajada at the base of the mountain supports many houses. R. M. Turner photograph, courtesy of the Desert Laboratory Photograph Archive.

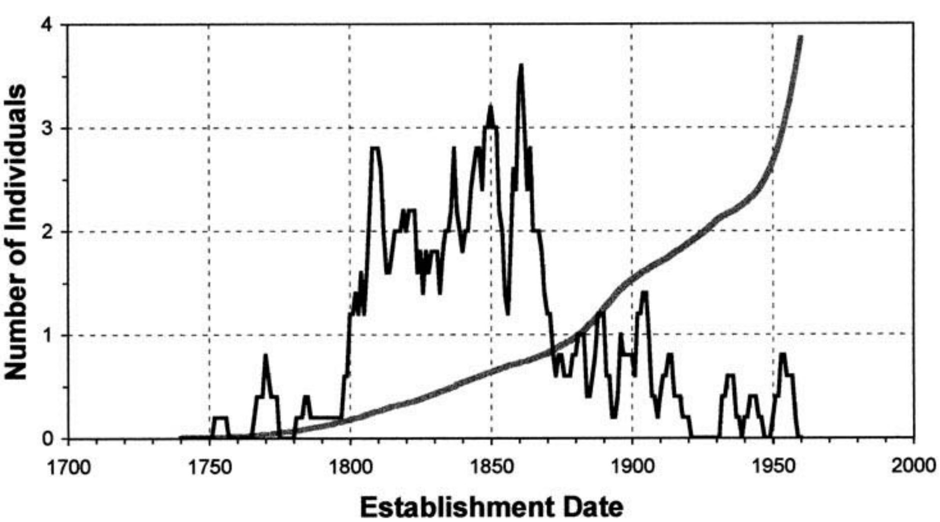

Figure 4—Year of establishment for the 201 healthy saguaros growing in the long-term study plot at Saguaro National Park at the time of plot establishment in 1961. The gray line descending from right to left represents the mortality curve for saguaro populations in this region and shows that a stable population of 201 plants would be maintained by the input of four new plants each year. The black line is a 5-year running mean of establishment numbers.

Conclusions

Monitoring is an indispensable tool for following change in ecosystems, and its application should follow uniform procedures. For those applications aimed at detecting change over long time periods, selection of the temporal base from which to judge change may not be simple because of the lack of adequate ecosystem descriptions from times past. The art of repeat photography can contribute to an understanding of a region's history and be an aid in setting the time from which change is to be measured. Even if the photographs do not record conditions at the exact site of interest, images from nearby locations can provide valuable information for establishing a regional framework. These photographic matches exist in several growing archives and should be used for establishing baselines.

In a few instances, photographic records are bolstered by detailed long-term data that allow refinement of the description of past conditions and may aid in establishing monitoring guidelines.

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