3 Threats to Springs: Human Impacts

Introduction

Human activities have greatly reduced the ecological integrity of many wetland, riparian and springs ecosystems through competing exploitative uses, including groundwater depletion, fuel wood harvest, recreation, livestock grazing, and wildlife management (Fig. 3–1). Overall estimates of springs and riparian habitat loss range from 40% to greater than 93% in the arid southwestern United States, but assessment and understanding of human impacts at springs is only now emerging. Below we describe the array of human threats on springs and the ecological consequences of those impacts.

Altered Regional Groundwater

Alteration of springs flows may arise from several potential anthropogenic impacts on aquifers. Anthropogenic climate change may reduce precipitation, infiltration and aquifer dynamics. Land-use change may alter the processes for recharge to an aquifer. For example, urbanization leads to an increase in impervious surface area over an aquifer, increasing the amount of surface runoff and decreasing the potential for recharge. Also, changes in land use by fire suppression or grazing can change the role of plant water use in a watershed and subsequently recharge to the aquifer. Reduction of the water-table elevation or well-drilling may allow inflow of lower-quality groundwater into an aquifer. In addition, pollution of percolating surface water or groundwater may reduce the quality of an aquifer's water. Extraction of groundwater from the aquifer may partially or wholly dewater individual springs or entire complexes of springs resulting in fragmentation of habitat, increasing isolation of springs ecosystems, and interruption of biogeographic processes at microsite-regional spatial scales in perpetuity. Groundwater augmentation may occur when aquifers are artificially recharged by urban run-off, when reservoirs increase water tables, or through climate changes that increase precipitation. Increased springs flow is often accompanied by a change in flow chemistry and pollutants.

Pollution

Groundwater and surface water pollution strongly alters springs ecosystem integrity and is a common phenomenon in agricultural and urban areas. Agricultural groundwater pollution may shift ecosystem nutrient dynamics to entirely novel trajectories creating conditions to which

Fig. 3–1. Even Spring, is a previously unmapped spring in the Gila Wilderness, western New Mexico. Many springs are missing from databases and topographic maps, leaving land managers with insufficient information to understand and protect these important resources.

few native species may be able to adapt. Non-point-source agricultural fertilizers have contaminated virtually all of the springs in Florida which emanate from shallow aquifers (Scott et al. 2004). Such increases in pollutant concentrations constitute a "push" form of disturbance on springs with effects lasting at least for more than the duration of the recharge cycle. Local contamination may also affect springs microhabitats by polluting surface waters. Such impacts are abundant at springs on the southern Colorado Plateau where springs sources are often fenced and concentrate ungulate use.

Flow Regulation and Diversion

Springs have long been the target of human alteration to improve water supplies for culinary, livestock, and other uses. Following the lead of the Environmental Protection Agency, most states require that groundwater used for culinary purposes remain below-ground, thereby avoiding exposure to surface contamination. The implications of this legal requirement have commonly meant that springs sources are dewatered before point of emergence or that facilities are constructed over the springs (springboxes, spring houses, etc.), voiding their ecological functions. We have noted several forms of springs flow alteration including diversion from the pre-orifice (prior to the point of emergence) or post-orifice (after emergence) environment. Pre-orifice diversion is often achieved by: 1) sealing the springs orifice from bedrock (and sometimes sealing the surrounding bedrock fractures) and installing piping; or 2) excavating the springs source in colluvium or alluvium, installing a slotted pipe catchment system, back-filling the excavation, and piping the water. We also have noted that diverted springs flows on the Arizona Strip were sometimes piped more than 30 km from the source to the delivery point.

Post-orifice diversion is also common, particularly for livestock watering and development of ponds. Spring flows are commonly captured into open excavated ponds or into covered tanks and then piped to troughs or ponds. These alterations may preserve some ecological function at the springs source, but often eliminate spring channel and cienega (wet meadow) functions.

Interruption of Disturbance Regimes

Humans commonly influence the frequency and type of disturbance, impacts that strongly affect springs ecological development. Surface-flow dominated springs are characterized by frequent flood events and considerable interannual flux in vegetation cover and diversity. For example, Grand Canyon Wildlands Council (2004) reported 10-70% variation in vegetation cover in one such spring that was monitored for three years. Moderate to high variability in the size and spatial arrangement of vegetation patches or aquatic invertebrate composition in such settings is a normal system attribute, and resilience to disturbance may be the only useable metric of ecosystem health other than wetted area or flow. Flow regulation may stabilize normally highly disturbed streamside springs ecosystems altering structural, functional, and trophic characteristics of springs. For example, Stevens et al. (2001) reported that flood control of the Colorado River in Grand Canyon by Glen Canyon Dam resulted in a 40 percent increase in vegetation cover of Vaseys Paradise spring. This increase in habitat area likely allowed a large expansion of the endangered Kanab ambersnail population there. Flow regulation of ephemeral stream channels on the Colorado Plateau commonly occurs through the construction of cattle tanks, and such structures undoubtedly affect disturbance regimes of channel springs downstream; however, such effects have yet to be studied.

Herbivore Impacts

Foraging: The foraging of large ungulates, such as cattle, horses, sheep, elk, and deer, can alter springs ecosystems by removing vegetation cover, altering plant and invertebrate assemblages, increasing erosion, and contaminating surface water (Grand Canyon Wildlands Council 2002). While such impacts occur at naturally functioning springs with native mammalian populations, anthropogenic modification of springs for ungulate grazing degrades springs ecosystem function. Grazing impacts may be further intensified if the source is fenced to control ungulate movement. Native herbivores also may include beaver, whose activities (tree clearing, dam construction, den construction, etc.) may be regarded as either detrimental or beneficial influences on springs ecosystem functioning.

Trampling: Livestock grazing continues to exert pervasive adverse influences on springs and other riparian habitats because riparian zones provide water, shade, and succulent vegetation (Fig. 3–2). Although livestock grazing impacts on springs have received relatively little attention, much attention has been devoted to understanding, assessing, and improving management of grazed wetland and riparian habitats.

Fig. 3–2. A severly trampled spring in Cibola National Forest, New Mexico.

Exotic Plant and Animal Invasions

Widespread introduction of non-native species may similarly greatly compromise ecological functioning at springs. The susceptibility of springs ecosystems to invasion by exotic (non-native) species is a complex function of interactions among abiotic and biotic factors, introduction history, and invading species autecology. Non-native species are abundant at springs across the southern Colorado Plateau (Grand Canyon Wildlands Council 2002; Stevens and Ayers 2002). Stevens and Ayers (2002) found that non-native species in northern Arizona and southern Utah include at least 247 plant, 7 invertebrate, 39 fish, 1 amphibian, 2 reptile, 8 bird, and 13 mammal species. Exotic plant and animal species were abundantly but unevenly distributed across seven groups of ecosystems in the Grand Canyon region. A total of 155 non-native vascular plant species (10.4% of the total flora) and 33 non-native vertebrates (7.3% of the total vertebrate fauna) were detected there. In contrast to Elton's prediction that invasibility should be negatively correlated with diversity (1958), recent studies report spatial scale-dependent and fertility-related positive correlations among non-native and native plant species diversity. The Colorado River corridor, other riparian areas including springs, and areas with high densities of roads and livestock trails had the highest densities of non-native species. Richness and density of exotic species vary among ecosystems in relation to relative productivity and relative disturbance intensity, and alien diversity was positively correlated with native biodiversity (Stevens and Ayers 2002). Therefore, it appears that highly diverse ecosystems, such as springs, are most prone to species invasions and attendant changes in composition, trophic structure, and function. These studies provide welcome insight into habitat invasibility and population eruptions which are among the most significant, long- lasting and complex anthropogenic impacts on the world's ecosystems.

Although the life history strategies of invasive exotic species have been studied, many efforts to predict which introduced species will erupt and where eruptions compromise ecosystem integrity have met with limited success. In part this is because population eruption often occurs irregularly across spatial scales and among habitats and ecosystems within a biome (Horvitz et al. 1998). Also, the eruption of a non-native species population may be greatly delayed after initial colonization: Kowarik (1995) reported that 147 years elapsed between introduction and eruption of exotic species populations around Brandenburg, Germany.

Fire Effects

The impacts of anthropogenic fire on springs have been little studied. Graham (2008) presented data on the slow recovery responses of a hanging garden to visitor-caused fire in southern Utah. The Grand Canyon Wildlands Council (2002) presented limited data indicating the potentially more rapid recovery of a spring than adjacent coniferous forest in northern Arizona. Evidence from the White Mountain Apache Tribe indicates that springs wetland vegetation at White Mountain springs may recover relatively quickly after forest fires, but that springs were collaterally damaged by increased sheet flow erosion and channel-cutting (Long et al. 2003). Research in progress in Hart Prairie, northern Arizona by Springer indicates that reintroduction of fire to upland forests above wet meadows has the potential to increase water yield to the wet meadows.

Visitor Impacts

Recreational use impacts at springs have long been a concern in some National Park Service units, with management attention focused at Vaseys Paradise and other recreationally heavily used springs in Grand Canyon and at hanging gardens in Zion National Park. In most cases, creation and maintenance of discrete trails greatly reduced visitor impacts at springs; however, focused visitation is likely to affect larger wildlife populations and reduce springs-uplands trophic linkage (Fig. 3–3).

Mining Impacts

The impacts of mines on springs may involve ground and surface water abstraction, diversion, regulation, or pollution, as well as construction and processing disturbances. Mine-related pollution and dewatering operations can significantly alter groundwater discharge to springs. Also, for submarine springs, mining of geothermal mineral deposits can do much damage to spring source geomorphology and biota. Recent controversies over potential uranium mining in northern Arizona have highlighted the many information gaps in our understanding of short- and long-term mining impacts.

Fig. 3–3. A sign installed by local land managers to remind visitors of their impacts on fragile riparian ecosystems, located at White Rock Spring in Red Rock Canyon National Convservation Area, Nevada.

Traditional Use and Science Impacts

Trampling may occur during traditional uses and research activities at springs, including the assessment efforts undertaken in this project. Such disturbances may or may not affect springs ecosystem processes depending on the size and type of the spring, its susceptibility to disturbance, and the intensity of activity. Overharvesting may be an issue in ethnobiology, and handling of rare fish or other vertebrate species may reduce population viability. For example, concern exists that tag-marking and electro-shocking of a great percentage of the total adult humpback chub may be implicated in the decline of this endangered fish species in Grand Canyon.

Management Impacts

Management actions to protect springs often simply involve site closure, prohibiting visitation, or creation of discrete trails to allow visitors to reach the springs but limit their impacts. If done without inventory and assessment information, such actions may actually damage, rather than help recover, the springs ecosystem (Kodrick-Brown et al. 2007). For example, fencing livestock out of a spring source may allow excess vegetation to develop eliminating surface water and threatening aquatic species persistence. Maintaining a sufficient disturbance regime to create some open water and space may be an important management decision. Creation of a surfaced trail to facilitate visitation (e.g., as occurs at some hanging garden springs) may eliminate leaf litter and prohibit movement of land snails and other invertebrate species. However, erosion can become a serious influence on springs geomorphic integrity if management fails to construct and maintain a trail to a regularly visited springs.

Restoration actions also may affect springs ecosystems, particularly if restoration goals fail to consider the range of natural variability of discharge, habitat area, and natural environmental impacts, such as fire, flooding, or rockfall.