PLANT INVASIONS, WATERSHEDS, AND NATIVE ECOSYSTEMS: PRELIMINARY THOUGHTS ON THE EAST MAUI WATERSHED

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The phenomenon of native *vs.* alien species is rarely if ever treated in textbooks of watershed management. In fact, we have not been very successful in finding literature on the subject. Overwhelmingly, the best documentation of degradation of watersheds by invasive plants is from South Africa (e.g., Huntley 1996; LeMaitre *et al.* 1996; Van Wilgen *et al.* 1996; Turpie and Heydenrych. 2000.). In the South African example, invasion of pines and other woody plant genera (*Hakea, Acacia*) in the fynbos (a shrubland) ecosystem has been shown to result in substantial water loss through evapotranspiration, and hence substantial loss in the quantity of water produced by the important fynbos watersheds in the vicinity of Cape Town. The impact of invasions on watersheds in Hawaii is more subtle, but nevertheless very damaging.

The important relationship between Hawaiian watersheds and Hawaiian ecosystems is becoming increasingly recognized by watershed management authorities in Hawaii, especially in Maui County. Although average rainfall values are extremely high on Maui's windward slopes, frequent and intense droughts are a common occurrence, and there is much reason for concern for the sustained availability of high-quality water for human consumption and agriculture. The resident human population of the island of Maui has increased rapidly in the recent past -- from 39,000 in 1970 to 95,000 in 1990 -- and continued growth is occurring. Annual tourist visitation to Maui has increased from 169,000 visitors in 1957 to over 2 million in the late-1980s and 1990s. Additionally, approximately half of the 728 square-mile island is devoted to agriculture; sugar cane, the primary crop, requires abundant irrigation water.

On East Maui, the water supply comes primarily from runoff, collected in a complex ditch system which carries water from the watershed to users. (The small towns of Hana, Nahiku, and Keanae get their water supply from wells, and the underlying aquifers are increasingly seen as possible future water sources for the island.) The storage function of the watershed (Black 1997) is particularly crucial and vulnerable because of the very steep slopes in the watershed. Sustained discharge during periods without precipitation is highly dependent upon a healthy watershed.

Windward East Maui comprises one of the most important and productive watershed areas in Hawaii. Through the East Maui Watershed Partnership (EMWP), established in 1991, this area is being managed to maximize water quality, sustained production of water, and protection of Hawaiian biological diversity. The EMWP recognizes that healthy, intact, Hawaiian ecosystems comprise the optimal cover for Hawaii's watersheds because 1) they promote high water quality and sustained water production, with gradual runoff and ground-water recharge; and 2) they are important in their own right for Hawaii's economic health, since their maintenance assures Hawaii's sustained beauty and uniqueness.

The importance of Hawaiian forests to watersheds was recognized early in this century by forester W.M. Giffard (1918), who pointed out that "where wild cattle and hogs are at large in the forest, general destruction is caused by their roaming around grubbing and feeding on and trampling down the herbaceous undergrowth so necessary for soil and water protection." Giffard went on to explain that "it is well understood by all having knowledge of the peculiar nature of these virgin forests that much of their natural undergrowth, composed as it is of climbing vines and herbaceous plants, ferns and mosses, not only protects the soil from erosion, but furnishes a protective cover for the surface growing roots of our indigenous trees." And further: "From rainfall records, it is believed that sufficient rainfall is precipitated on the Hawaiian Islands to supply all possible needs, if the forests are properly maintained to regulate the run-off of this rainfall."

A few years later, Lennox (1949) reviewed the special conditions affecting Hawaiian watersheds which make careful watershed management crucial for sustainable output of water for human use: 1) very heavy rainfall, averaging 100-400 inches per year; 2) very steep terrain; and 3) soils which are relatively impervious "thus resulting in heavy losses of runoff to the sea if forces are not at work to aid in retarding the surface flow and encourage a more rapid rate of penetration into the soil." Lennox explained how "Under a situation of steep terrain, small drainage basins and high rainfall intensities, the water losses from surface runoff accounts for the greatest wastage of moisture falling on Hawaiian watersheds.. the major objective.. is to maintain a growth.. which will retain the greatest possible percentage of the total rainfall for deep percolation."

Unfortunately, the wisdom of early Territorial foresters has not been followed as closely as it should have been followed. After statehood in 1959, political pressure from hunters as well as strong competition of social welfare needs vs. funding for natural resource management led to a general neglect of watersheds, degradation of forest understories by feral animals, and the beginning of massive spread of invasive plant species into forests -- which in some areas has begun to threaten the very survival of the forest, with ominous implications for watershed sustainability.

The East Maui Watershed Partnership is in the process of getting feral pigs, the greatest degraders of Hawaiian ecosystems and watersheds (Loope 1998), under control through fencing and snaring in inaccessible areas and through increased hunting in accessible areas. The Partnership is also focussing on eradication of the invasive tree *Miconia calvescens* (see below), the worst known invader of Pacific rain forests. But steps need to be taken to head off future plant invasions.

Plant invasions can destroy the forest structure, shade out the water-holding understory layer, and create unstable slope conditions. For example, the weedy vine banana poka (*Passiflora mollissima*) covered over 150 square miles of forest on the island of Hawaii as of 1986 (La Rosa 1992). Banana poka and similar vines climb over tree crowns, thus occluding sunlight and reducing photosynthesis, growth, and reproduction of the host tree. Limb breakage (due to weight of the vines) often results in vulnerability to pathogens; accompanied by substantial reduction of photosynthetic capacity, the eventual end result is tree death and forest collapse (Stevens 1987; La Rosa 1992).

Especially on steep slopes, forest demise in a watershed is a definite cause for concern. The stability of the soil mantle on steep slopes depends on the balance between shear stress in the soil and shear strength of the soil (Cassells *et al.* 1982). Where the forces are finely balanced, the mechanical anchoring of the soil mass by tree roots is a factor of major significance. This anchoring will be lost when tree roots decay following forest death.

Smothering vines or extremely dense shading (as in a bamboo forest or *Miconia* forest) also eliminate any forest understory, including the important fern and moss layer characteristic of the floor of undisturbed Hawaiian cloud forests (Medeiros *et al.* 1995). The forest floor under canopies of the invasive Australian tree fern (*Cyathea cooperi*), an invader of Maui rain forests, is largely devoid of either mosses or vascular plants (Medeiros and Loope 1993). The moss layer is especially important in slowing runoff and aiding infiltration.

The case of the invasive tree *Miconia calvescens* further illustrates the nature of the threat posed by invasive alien plants and the desirability of early detection and eradication. *Miconia calvescens* is native to New World tropical forests at 1000-6000 ft elevation. Introduced to two botanical gardens in Tahiti in 1937, dense thickets of *Miconia* had by the 1980s replaced the native forest over most of the island (Meyer 1996); 40-50 plant species endemic to Tahiti are now on the verge of extinction primarily because of the invasion of *Miconia* (Meyer and Florence 1997). More research is needed to clarify the watershed situation in Tahiti, but watershed damage is suspected; the dense stands of *Miconia* tend to shade out all understory vegetation, leaving a bare forest floor, with opportunities for water quality degradation. *Miconia* invasion appears to set things up on steep slopes for erosion and possibly for landslides, since *Miconia* has a very shallow root system. At any rate, the government of French Polynesia is now aggressively involved in preventing *Miconia* from taking over forests in islands neighboring Tahiti (e.g. Meyer and Malet 1997).

By the time *Miconia calvescens* was first discovered in the East Maui watershed in 1990, it had already been present for about 20 years. It took about 3-5 years to fully understand and communicate the seriousness of the situation. In 1991, one agency started an education program and started removing plants with the help of volunteers (Hurley 1991; Gagne *et al.* 1992). Eventually, the full extent of the population and the severity of the threat statewide were recognized (Conant *et al.* 1997; Medeiros *et al.* 1997). The reproductive capacity of *Miconia* is truly formidable. As of mid-2000, roughly $2,000,000 had been spent or committed to *Miconia*-control efforts in Hawaii, with undoubtedly much more yet to be spent in order to achieve success.

In summary then, over the long term, invasive alien species threaten sustainable production of optimal amounts of high-quality water in the East Maui Watershed (and similar watersheds of Hawaii and other oceanic islands), especially because of the very high rainfall, steep slopes, and low permeability of substrates. As far as we know, undisturbed native Hawaiian forests, with their lush forest floor covered by mosses and ferns, are the optimal cover to maximize sustainable yield of high-quality water. The understories of native forests of the East Maui Watershed have been degraded by feral pig digging; feral pigs are now being removed in the upper reaches of the watershed, with the goal of restoring forest understories. With feral pigs being managed, alien plant invasions -- which can also transform forest understories and even destroy forests -- will pose the greatest inadequately managed threat to the watershed.

There is another major consideration for delineating the relationship between invasions and watersheds in Hawaii. Invasions are overwhelmingly the primary threat to Hawaiian biodiversity (Loope *et al.* 1988; Loope and Mueller-Dombois 1989; Loope 1998; Loope *et al*. in press). Because of Hawaii's small land area, sizeable human population, and history of biodiversity loss, sites for sustained long-term preservation of biodiversity are few. The East Maui Watershed and adjacent lands represent one of the best such sites in the Hawaiian Islands, whereas formerly equivalent sites are rapidly undergoing degradation. This circumstance leads to the conclusion that long-term political support for protection of Hawaiian biodiversity in the East Maui Watershed can work in synergy with the need for watershed protection. Pressures for development projects which would encroach upon the watershed are likely to be resisted because of joint watershed protection and biodiversity concerns.

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