Flood-borne Noxious Weeds: Impacts on Riparian Areas and Wetlands

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Introduction

Native riparian ecosystems, especially in the and Southwest, are disappearing rapidly. Riparian areas, the vegetated areas adjacent to a stream, or other body of water, serve multiple functions in water quality protection, flood control and storm damage prevention, biodiversity, habitat, and recreation. Over half of the wetland and riparian zones have been destroyed in the coterminous 48 states, and few of the remaining zones have not been adversely impacted (Fredrickson and Reid 1986).

The United States Department of Interior (USDI) Bureau of Land Management has estimated that noxious weeds are consuming 4600 acres a day on western public lands. Impacts and costs of this rapid weed invasion include reduced crop yields, loss of forage for grazing livestock, costs incurred for roadside weed control, reduction of property values, degraded water quality, degradation of fisheries, and impairment of recreation availability.

In Nevada, riparian areas represent a tiny fraction of the total land area, but have greater quantity and diversity of plant species than adjoining land. Riparian areas often include wetlands that provide important habitat for Nevada's fish and wildlife. While wetlands cover less than 1 percent of Nevada, they are some of the most economically and ecologically valuable lands in the state (Lico 1994).

Economic benefits of riparian areas, such as recreational activities, are abundant, and include hunting, fishing, boating, bird watching, photography, and camping. The lush vegetation growing in wetlands and surrounding areas provides quality forage for grazing of cattle or sheep as well as a water supply. Undeveloped floodplains also play a critical role in storm damage prevention and flood control.

Many of these benefits can be traced to the functions of vegetation in riparian areas. This paper will explore the role of riparian vegetation and the relationship of flood events to the invasion and proliferation of four noxious weeds.

Benefits of Riparian Vegetation

Riparian vegetation includes species adapted to varying degrees of inundation and groundwater depth. This vegetation serves multiple functions, including flood control and storm damage control, fish and wildlife habitat, and pollution prevention. Proper functioning of riparian areas depends upon maintaining a diverse population of natural vegetation that occupies most of the niches and consumes most of the resources (Sheley et al. 1996). Such dense vegetation thus reduces the relative competitive ability of weeds at the site.

Flood control and storm damage prevention

Rivers and streams are constantly changing in response to changes in flow volumes and changes in land use. Naturally vegetated riparian areas, including floodplains, serve a number of beneficial functions for flood control. When floodplains are maintained in an undeveloped condition, they reduce the force, height and volume of floodwaters by providing space for the waters to spread out horizontally and relatively harmlessly across the floodplain.

Vegetation along the streambank provides friction against moving water. Increased roughness from vegetation causes energy loss which decreases sediment erosion and transport. The vegetation itself provides resistance to streambank erosion by binding the soil with dense networks of roots. Smith (1976) found that the bank erosion rate decreases significantly as the percentage by weight of vegetative roots in a sample increases. In root-free silt, an erosion rate of 160 cm/h occurred, whereas with 16-18% of roots and 5 cm of root 'rip-rap' the rate was 0.02 cm/h (Richards 1982). Figure 1 demonstrates the relationship of erosion to plant cover and soil type.

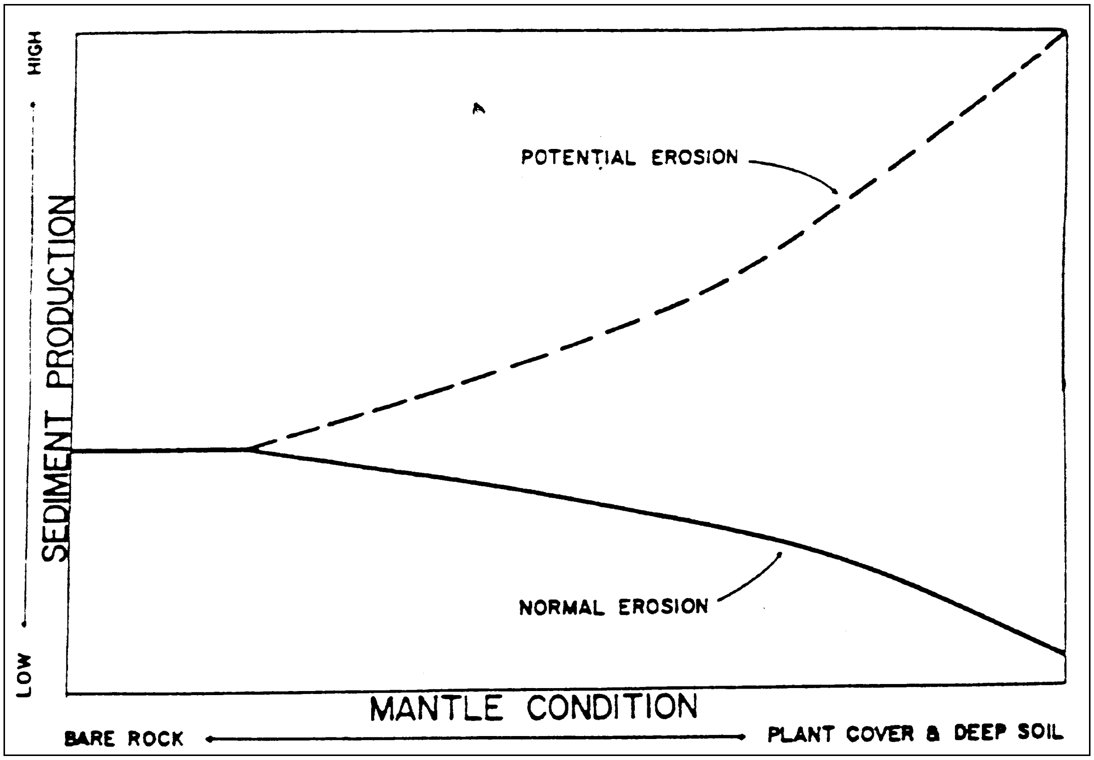

Fig. 1. The decrease in normal erosion that accompanies the protective influence of vegetation (from Branson et al. 1972)

Floodplains are often referred to as nature's "sponge." The extensive root system of riparian vegetation helps keep pores open in the soil, allowing two to three times more water to infiltrate the soil compared to cultivated or grazed lands. It has been estimated that some sedges have an average of more than 100 feet of roots and rhizomes per cubic inch of soil near the soil surface (Swanson 1988).

Flood attenuation via water retention is one important function of riparian areas and floodplains. Vegetation intercepts and detains runoff from adjacent upland areas that would otherwise flow directly into rivers, creating additional peak flows for downstream areas. The trapped water is slowly released, adding to base flows during dry seasons.

Transpiration by trees, shrubs, and herbaceous plants in riparian areas helps dry soils. It has been estimated that as much as several thousand gallons per acre of water are used by plants each day, helping to reduce peak flows and flooding downstream (Cohen 1997a).

Fish and Wildlife Habitat

Wildlife use riparian areas more than any other single habitat (Swanson 1986). In Nevada, riparian wetlands and large marshes provide stopover and breeding grounds for migratory waterfowl. Many of Nevada's threatened and endangered species inhabit wetlands. Wetlands also provide primary productivity for aquatic and terrestrial food webs. These high-value areas provide browse and water for a variety of animals, and more than half the vertebrates living on rangeland need riparian areas or use them for some critical period of their life. Riparian areas also provide critical connective corridors allowing wildlife movement from one area to another.

Vegetation plays a key role in the function of riparian areas as wildlife habitat. Streamside vegetation provides food and shelter for many species. The shade, litter and woody debris provided by riparian vegetation are important for healthy fisheries, which in turn are a key food source for many wildlife species. The riparian tree canopy helps to moderate water temperatures, helping to maintain the relatively high levels of dissolved oxygen needed by trout and other aquatic organisms. Studies have shown stream temperatures dropping from 80 to 68 degrees after the stream had flowed through 400 feet of shaded channel (Cohen 1997b). Streamside forests can also help insulate streams from excessive freezing. The detritus from decaying leaves, twigs, and plant matter which falls into the stream provides a key energy source that fuels the base of the aquatic food chain. Insects failing from overhanging vegetation provide an important food source for fish.

Failure to maintain vegetative cover on riparian areas adjacent to small streams may result in a significant loss of groundwater recharge and may increase the frequency, duration and severity of low flow conditions. In small streams, this reduction in baseflow can be fatal to fish and other aquatic organisms.

Water Quality Protection

Riparian vegetation and soil serve as water filters, intercepting surface-water runoff before it reaches the stream or river. This filtering process removes and recycles nutrients, processes chemical and organic wastes, and reduces sediment loads reaching streams and rivers.

Sediment is probably the most common and most easily recognized of the nonpoint source pollutants. Sediment suspended in water can reduce or block the penetration of sunlight, adversely affecting the growth and reproduction of beneficial plants. Sediment in the water column irritates the gills of fish and makes them more prone to disease. When deposited on the stream bottom, sediment interferes with feeding and reproduction of bottom dwelling fish and aquatic insects, weakening the food chain. It can also smother fish eggs when deposited on spawning gravels. Large deposits of sediment can decrease channel capacity and increase the potential for flooding.

As mentioned above, riparian vegetation plays an important role in decreasing bank erosion and sedimentation. Riparian vegetation also helps remove sediment by reducing the speed of flow of runoff water, acting as "settling basins". As velocities decrease, suspended particles drop out of the water column. More sediment is filtered out by the vegetation and organic litter on the soil surface. Since about 85% of available phosphorus is adsorbed onto the surface of small soil particles, decreasing sediment results in decreased loads of phosphorus to streams.

Some wetland plants are important in purifying water, especially in removing heavy metals from the water column and accumulating them into plant tissue. Plants such as sedges, duckweeds, bulrushes and cattails are valuable in absorbing and storing large amounts of nitrogen and phosphorus, and are also useful in reducing some pathogenic bacteria. Microbes that live on the surface of plant roots in wetlands remove far more nitrogen than the plants themselves, and also function to transform nitrogen available as nitrate to ammonia, which tends to adsorb to soil particles instead of leaching.

Floods and the Spread of Weeds

Water has long been recognized as a mechanism for the spread of invasive weeds (Zimdahl 1993; Pysek and Prach 1994). Water functions as a "transport habitat" for the dispersal of plant materials. Seed dispersal by water is a major route of spread of weeds in the western United States, especially in areas with irrigated agriculture. Estimates suggest 120,000 seeds/acre/year enter fields from irrigation water. Vegetative propagation of plants is especially well developed in aquatic habitats, and often provides the major reproduction and dispersal mechanism for aquatic weeds (Radosevich et al. 1997).

Floods provide an extreme example of the spread of plant species with water. During large flood events, as water velocities increase as a function of flow volumes, the erosive power of the water increases exponentially as a function of velocity, increasing sediment transport rates. Increased stream power results in changes in channel morphology, including scour, widening, deepening, sandbar formation, filling or relocation of the active channel, alteration of substrate particle sizes, damage to riparian and aquatic vegetation, and the addition or removal of organisms from the local community (Friedman et al. 1996). This disturbance to the channel provides an opportunity for noxious weeds to colonize in the riparian areas. Flood frequency and intensity are important influences on vegetation zonation. In and regions, flow variability is relatively high, and extreme events can cause long-lasting channel changes which may alter vegetation communities.

Periodic flooding provides disturbances and openings in vegetative cover (Pysek and Prach 1994). Species favored by disturbance and by newly mobilized dissolved nutrients will rapidly fill these niches. Flood flows likewise act to transport seeds and plant parts from existing infestations into previously weed-free areas. Vegetative reproduction is a common trait of perennial weeds, and allows them to colonize readily in a wide range of disturbed habitats (Bhowmik 1997). As flows recede, the plant matter is deposited on newly formed sandbars and in areas which have been stripped clear of riparian vegetation. For many weed species, invasion of riparian areas by seeds follows an exponential curve (Pysek and Prach 1994).

Weeds have many impacts on riparian areas. They often alter water table depths by tapping into previously unused groundwater resources. Many noxious weeds are capable of outcompeting native species by suppressing native recruitment, consuming water and nutrient resources, or by shading slower growing plants.

Studies have shown that weeds often do not stabilize soils as well as native vegetation, which can lead to degradation of the stream channel. Soil and water losses increase when tap-rooted plants replace fibrous root systems. Surface water runoff and soil erosion increased 56% and 192%, respectively, on spotted knapweed dominated sites (Beck 1993). This resulted in decreased water infiltration and increased erosion, and thus, to increased sediment production. Loss of rooting strength results in reduced ability to withstand flood flows, and increased rates of bank and bed erosion.

Flood-borne Noxious Weeds in Nevada's Waterways

Four noxious weed species, including tall whitetop *(Lepidium latifolium)*, saltcedar *(Tamarix* spp.), purple loosestrife *(Lythrum salicaria)* and Eurasian watermilfoil *(Myriophyllum spicatum)* are becoming established in previously weed-free reaches of the Truckee River drainage system as a result of flood flows from the January 1997 storm event. These four weeds are found on the CaIEPPC List of Exotic Pest Plants of Greatest Ecological Concern in California, with tall whitetop, Eurasian watermilfoil and saitcedar classified as widespread, invasive wildland pest plants, and purple loosestrife considered a species with potential to spread explosively.

These species have in common the ability to reproduce vegetatively, whether by layering (saitcedar), sprouting from roots and crowns (tall whitetop and purple loosestrife) or from floating plant fragments (Eurasian watermilfoil). Their rapid rate of growth allows them to outcompete more desirable riparian vegetation such as cottonwoods, which are normally favored by flood events. This can result in the loss of functional riparian communities, loss of rooting strength and protection against erosion, destruction of habitat for threatened and endangered species, loss of recreation opportunities, and impacts on water quality.

Tall whitetop or perennial pepperweed *(Lepidium latifolium)*

Tall whitetop is native to southeastern Europe and southwestern Asia, and is thought to have been introduced into the United States as a contaminant of sugar beet *(Bela vulgare* L.) seed near the turn of the century. One of the first infestations in California was traced to such seed imported to Yolo County in the Sacramento Valley (Robbins 1940). It has been reported as a pest in all counties in California except the coastal rain forest of the far northwest and the southeastern lower elevation deserts (Young et al. 1995).

Tall whitetop has been reported in the Truckee River basin for several decades. By 1992, it had colonized 12,000 acres of the lower Truckee River, and many more acres are infested today. It is now found in the Carson and Humboldt River basins, the Lake Tahoe basin, and many other locations statewide.

This weed grows optimally in moist, salty soils and is well adapted to Nevada's alkaline conditions. Spread of this weed is usually by water carrying seed from upstream areas. In Utah, spread of the weed was correlated to extremely high flows on the Green River which caused extensive flooding (Reid et al. 1996). Tall whitetop is a rhizomatous perennial that spreads also by creeping underground rootstocks, and it is a fierce competitor, consuming nutrients and moisture and outgrowing desirable vegetation. Its aggressive colonization leads to the establishment of monocultures along streambanks, with the accompanying loss of benefits of native riparian vegetation to wildlife habitat, fisheries, recreation, livestock grazing, erosion control, and water quality.

Tall whitetop influences the nature of surface soils through a buildup of decaying organic matter from leaves and stems. Since the weed is adapted to using water containing high levels of salts, the plant biomass contains elevated levels of salts which are then deposited on the soil surface.

When introduced into native hay meadows, tall whitetop lowers the quality of hay in terms of protein content and digestibility, and the accumulation of old dead stems inhibits grazing. In riparian areas and wetlands, these dead tall whitetop stems negatively impact nesting habitat for wildlife, although no one has measured and quantified the impact of the weed on waterfowl habitat. The weed also interferes with mosquito control because of changes in the vegetation canopy.

During the flood of January 1997, a major amount of streambank erosion occurred along the Truckee River. Damage was especially severe in areas dominated by tall whitetop, with wide swaths of bank lost to a depth of 4 feet and more. Despite its extensive root system, tall whitetop affords little protection from erosion due to high velocity flows. The roots break easily at the nodes, and new plants can grow from each fractured node. Research has shown that new plants will grow from fragments as little as 1/10th of an inch in diameter (Wotring et al. 1997).

As flows slowly receded following the flood, plant material carried with floodwaters was deposited on newly formed sandbars, and, by March 1997, had begun to sprout vigorously. In June, during the critical period for cottonwood recruitment, tall whitetop was 6" or taller and was shading the soil surface, which may have affected the survival of the more desirable tree species. No research currently exists to determine the effects of tall whitetop on cottonwood recruitment.

Tall whitetop was also observed growing after the flood in areas which had previously been weed-free, from inundated lots in the Sparks industrial area to rangelands receiving spillage from irrigation ditches. Once tall whitetop has established during a single growing season, it is able to survive and reproduce even in less-than-optimal conditions, including drought.

Saltcedar (*Tamarix* spp.)

Saltcedar or tamarisk (*Tamarix* spp.) is native to Western Europe, the Mediterranean, north Africa, and northeast China and India. These trees were purposefully introduced into the United States in the early 1800s as ornamentals, for windbreaks, and as erosion control. They were initially cultivated for widespread use by the U.S. Department of Agriculture at the National Arboretum in Washington, until it became recognized that the species easily invades and colonizes drainage systems in arid and semi-arid areas. It has been estimated that tamarisk has replaced most of the native vegetation on more than a million acres of riparian lands in the western United States, with another million acres potentially to be lost to tamarisk in the next ten years.

Tamarix species are found on silty soils and alluvial deposits along lakes, rivers, and other wet areas. In Nevada, this phreatophyte is found in the Truckee, Carson, and Walker Rivers (25,000+ acres), and the Humboldt River basin, where it has consumed 20,000+ acres. Natural Resources Conservation Service (NRCS) personnel estimate that more than 60% of the Humboldt Sink is total saltcedar canopy cover.

Saltcedar impacts riparian areas in a number of ways. These plants increase the soil surface salinity by absorbing salts from deeper soil layers and groundwater and transporting these salts to their leaves, subsequently releasing the salts back into the surrounding soils through accumulation in the leaf litter. This high tolerance for salt provides a competitive advantage over native trees and shrubs (DiTomaso 1996), and increasing levels of soil salinity inhibits germination and growth of most other plant species, with the notable exception of tall whitetop.

Saltcedar is a heavy user of water via evapotranspiration. The root system of saltcedar is extensive, and the primary root grows downward until it reaches the water table, at depths of 3 m or deeper (Brotherson and Winkel, 1986). Some studies have indicated that saltcedar uses from 4 to 13 acre feet of water per year (Davison et al. 1995) with 4 to 6 acre feet/year being a common rate of consumption. Saltcedar is able to access groundwater from deep water tables, while many native riparian trees and shrubs can survive only in saturated soils. When saltcedar replaces native vegetation, it may tap into water sources which were previously untouched, with the end result being a lowered water table in areas dominated by this weedy tree.

Saltcedar is poor forage for livestock and wildlife, but does provide some cover. However, plant diversity is reduced in saltcedar communities compared to native vegetation growing in similar locales (Davison et al. 1995). Wildfires are common in areas with high densities of saltcedar due to the accumulation of leaf litter and woody material. The plant can resprout from its roots after the above-ground vegetation has burned, allowing it to reestablish quickly after fires. This favors the regrowth of saltcedar over more desirable native vegetation.

Saltcedar in river systems is hardy, showing the ability to withstand flooding and submersion in slow moving waters for up to 3 months without detrimental effects (Stevens 1987). Adventitious roots easily develop from submerged or buried saltcedar stems, providing a mechanism for spread during floods. Its seeds will germinate upon direct contact with water, and have been reported to germinate while floating on water (Everitt 1980). Successful seedling establishment appears to depend upon the availability of silt deposits created by flood disturbance (Steven 1987). Ideal conditions for survival include saturated soils for the first two - four weeks following germination, open sunny ground, and the absence of competition, all of which may be found in areas recently disturbed by floods (Everitt 1980). Saltcedar will become established in dry locations that have been temporarily flooded. Once established, saltcedar can survive almost indefinitely in the absence of surface saturation of the soil.

Saltcedar has been implicated in increasing the intensity and frequency of flooding. As stands of saltcedar become dense in a river's floodplain, flood flows are impeded and may inundate areas not normally flooded. The decrease in velocity of water drops out sediment, which can cause channel avulsion. The deposition of sediment results in a narrower channel with lower capacity, increasing the measured flood stage and area of inundation (Blackburn et al 1982).

Many new saltcedar seedlings were noted growing along the Truckee River in September, 1997 in areas disturbed by flooding and areas in which a tall whitetop control project resulted in a decrease in the plant cover. If not controlled, the result will be a large increase in the amount of Truckee River streambank lost to this damaging species.

Purple loosestrife *(Lythrum salicaria)*

Purple loosestrife is an emergent aquatic plant which originally reached North America in the cargo and ballast of ships coming from Europe. The plant subsequently spread to wetlands throughout the northeastern United States by way of canals, irrigation ditches, and roads. The spread and dominance of purple loosestrife in wetlands has shown an exponential increase. By 1900, purple loosestrife had spread to the glacial marshes of the Midwest; by 1940, it had reached the Pacific Northwest; and by 1985, Alaska and Montana were the only states north of the 35th parallel not reporting this weed (Thompson et al. 1987). This showy plant became a favorite of horticulturalists, who aided in its spread. Likewise, its value as honeybee forage has expanded its range.

Loosestrife is an aggressive perennial which invades and degrades wetland habitats, growing from three to eight feet tall. It is easiest to identify when in full bloom in July and August. It can form dense, impenetrable, long-lived stands which are poor habitat for many native wetland animals. Connected waterway systems are at risk for invasion throughout the entire network.

The weed grows well on disturbed, moist soils, and is thus favored by flood flows. Reproduction occurs via seeds (up to 2.7 million seeds per plant annually), by undergound roots, and by resprouting from roots and broken stems. The tiny seeds are readily carried by water, wind, and animals, and must lodge on open, moist soil or saturated organic debris to root. The plant is more successful on slightly acid or neutral soils, but will grow on a wide variety of soils.

Wetlands are harmed when loosestrife crowds out native plants such as cattail and bulrush, replacing more than 50% of the biomass of some wetland communities (Thompson et al. 1987). The weed provides neither food sources nor shelter for most wetland wildlife. It also occludes channels, increasing siltation and decreasing channel capacity, increasing maintenance needs. The plant is also a problem in wetland pastures and bay meadows, since it has low palatability and negligible forage value. Loosestrife forms such dense stands in waterways that they are often impenetrable to boats, impairing recreational opportunities.

Purple loosestrife has been observed in the North Truckee Drain, which flows into the Truckee River, since the 1970's. It has colonized miles of the Drain, sharing the ditch banks with tall whitetop. Its distribution was largely limited to the Drain and isolated ornamental plantings until the wet winters of 1995, '96 and '97. Following the flood flows of January, 1997, small stands of purple loosestrife have begun to appear in the lower Truckee River, with fears that it has moved throughout the irrigation system to the Carson River and Lahontan Reservoir. The U.S. Fish and Wildlife Service in Reno has allocated post-flood technical assistance funds for the identification and mapping of purple loosestrife in the Truckee River system. The Nevada Division of Agriculture will then take appropriate control measures once the plants have been identified. The invasion is small and new enough that immediate, concerted efforts may allow eradication of the weed from the River. Control in the Sparks Drain will be far more difficult due to the very large number of mature plants present.

Eurasian watermilfoil *(Myriophyllum spicatum)*

Eurasian watermilfoil is a submerged, rooted aquatic plant introduced into the United States from Europe in the 1880's. It slowly spread across the United States primarily by contamination on boats, but also by water birds. Watermilfoil is commonly found in eutrophic, alkaline, hardwater systems where it can form thick underwater stands of tangled stems and vast mats of vegetation at the water's surface. The formation of a plant canopy also limits the light available for existing plants, which favors the expansion of watermilfoil. The overgrowth interferes with water recreation, fowling propellers and clogging air intakes on boats.

Eurasian watermilfoil will grow in water about one to three meters deep, or deeper if light can penetrate. The plant forms long vines which can grow to four times the original size in one year. It reproduces sexually via cross-pollination, and also vegetatively from plant fragments released from stems. These fragments float, develop roots, new stems, and leaves, before sinking and adhering to the bottom substrate.

There is some dispute about the value of this species. When it forms a mat at the water surface, it provides calm water for waterfowl. It may also help improve lake clarity by out-competing undesirable algae for dissolved nutrients. On the other hand, it grows and spreads rapidly, invading and replacing native plant species which may be necessary to support waterfowl. In a study of a newly invading population of Eurasian watermilfoil in Lake George, New York, Madsen et al. (1991), found that over a three-year period, the cover of Eurasian watermilfoil increased from 25% to 97%, and the total number of species dropped from 21 to 9, as shown in Figure 2. Dense canopies result in decreased oxygen exchange (Figure 3), increased nutrient loading, and increased water temperatures (Madsen 1997).

Watermilfoil has been present in Lake Tahoe in the Tahoe Keys area since the 1960's, probably introduced by boats. In the last three years, new pioneer populations were discovered in small marinas outside the Keys. Many fragments of watermilfoil were observed floating at near-shore and off-shore locations, indicating movement by wind, waves, and water currents. Populations in these smaller sites expanded by as much as three-fold in one year, and new sites were discovered in 1996 and 1997, including the Truckee River downstream from Tahoe City Dam.

Since Lake Tahoe is currently phosphorus limited, there is concern that the watermilfoil might mobilize phosphorus from the lake sediment and return the nutrient into the water column, increasing the rate of loss of clarity of the lake. Of equal concern is the appearance of the weed in the Truckee River system. While it has not yet been noted in the Nevada portion of the river, the long duration of high flows which occurred during and after the January 1997 flood suggest that watermilfoil may have been distributed throughout the entire river system. No full-scale monitoring program is currently in place to detect and map new infestations.

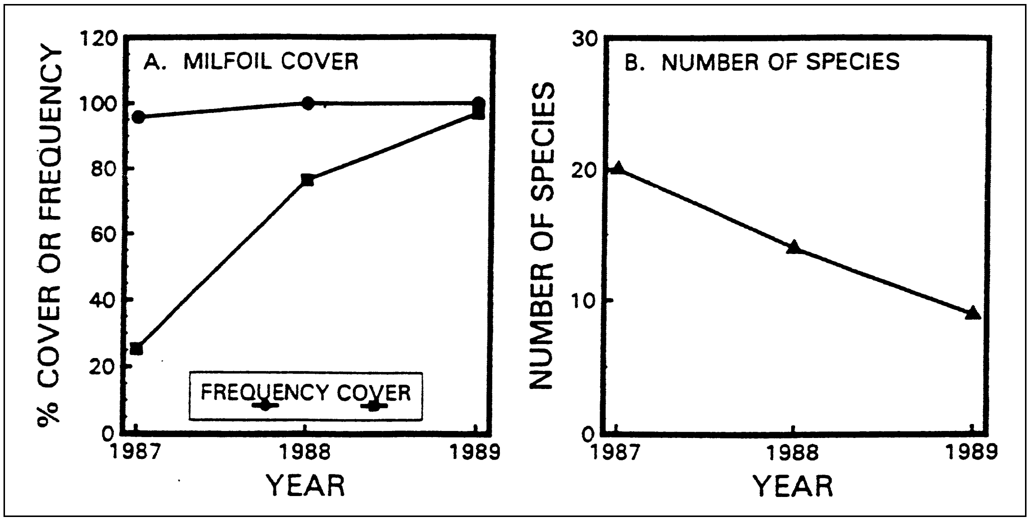

Fig. 2. Change in (A) Eurasian watermilfoil percent frequency and percent cover, and (13) total species richness (from Madsen et al. 1991).

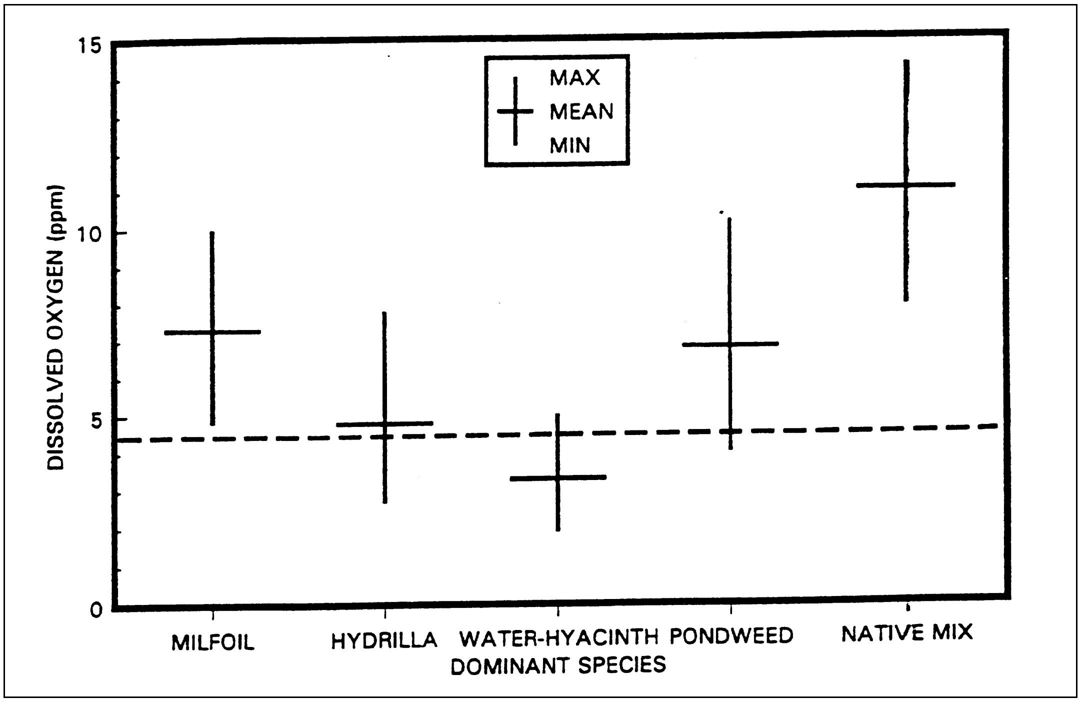

Fig. 3. Changes in dissolved oxygen concentrations in ponds planted with five different vegetative types (from Madsen et al. 199 1)

Management of Flood-borne Noxious Weeds

As always, preventing the introduction of weeds into riparian areas is the first line of defense. Prevention is the most cost-effective element of weed management. Once a single plant becomes established, it may produce thousands of seeds, which can float and spread rapidly in river systems. Disturbance from spring flooding and channel readjustment favors invasion by weeds. Methods of prevention include monitoring vehicles and boats and trailers for seed or rootstock contamination, using weed-free hay or feed, educating hunters, fishers and other sportsmen about the need to monitor for weed contamination, and excluding livestock that have been grazing on weed-infested areas for 7 to 10 days before allowing access to riparian areas (Sheley et at. 1995).

Control of new noxious weed species in the first growing season following flood-borne spread is essential. Whenever possible, weed management efforts should focus not on well established stands, but on mapping the extent of spread of new, small-scale invasions and controlling them prior to reproduction. At this point, eradication of small weed patches can still be achieved. Once the plants have become established through a full growing season, eradication is unlikely. Field personnel should be assigned to document all locations of the weed throughout the entire drainage system (no small feat!). After mapping, the plants should be destroyed by the best control method, and removed from the site if appropriate. Long-term planning should include a revegetation program and follow-up monitoring to make sure initial efforts were successful. This will often require a concerted effort involving many agencies and funding sources, and by volunteer groups like Adopt-a-Stream.

Creative approaches may be needed. Involving local hunters and fishermen, recreationists and other volunteers may make the difference in the success of weed control efforts. A vigorous public education media campaign can be used to alert citizens to the problems posed by noxious weeds in riparian areas. In Nevada, citizen volunteer groups are active in controlling weeds, including "Tamarisk Tamers" in the Humboldt River Basin, and soon-to-be trained Master Gardener "Weed Warriors" in the Truckee River Basin. Labor forces can be augmented by the use of community honor inmate crews who are available through county and state prisons. Efforts are currently underway to map the occurrence of all noxious weeds in Nevada aided by volunteer groups including County Roads crews, Conservation Districts, power companies, endurance riders, hikers, trout fishers and others.

In the aftermath of flood disasters, finding funds for weed control may be difficult. For many years, both the USDA Forest Service and USDI Bureau of Land Management have devoted the majority of their small weed management budgets primarily to control (78 to 82%) vs. detection (11 - 12%) (Dewey et al. 1995). As with wildfires, detection and early reporting will bring far greater returns via rapid response and suppression.

Summary

Riparian areas serve multiple functions in water quality protection, flood control and storm damage prevention, biodiversity, habitat, and recreation. In Nevada, riparian areas represent a tiny fraction of the total land area, but provide more vegetation per acre than any other part of the landscape. During large flood events, as water velocities increase proportionally to flow volumes, the erosive power of the water increases exponentially, increasing sediment transport rates. The result is changes in channel morphology, commonly including scour, widening, deepening, sandbar formation, and avulsion. This disturbance to the channel provides an opportunity for noxious weeds to colonize.

Water has long been recognized as a mechanism for the spread of invasive weeds. Flood flows act to transport seeds and plant parts. As flows recede, the plant matter is deposited on newly formed sandbars and in areas which have been stripped clear of riparian vegetation. Species which are favored by disturbance and by newly mobilized dissolved nutrients will rapidly fill these niches.

Four such species, including tall whitetop *(Lepidium latifolium),* saltcedar (*Tamarix* spp.), purple loosestrife *(Lythrum salicaria)* and Eurasian watermilfoil *(Myriophyllum spicatum)* have been found in previously weed-free reaches of the Truckee River drainage system as a result of flood flows from the January 1997 storm event. These species have in common the ability to reproduce vegetatively, whether by layering (saltcedar), sprouting from roots and crowns (tall whitetop and purple loosestrife) or from floating plant fragments (Eurasian watermilfoil). Their rapid rate of growth allows them to outcompete more desirable riparian vegetation such as cottonwoods, which are normally favored by flood events. Such competitive advantages result in the loss of functional riparian communities, loss of rooting strength and protection against erosion, destruction of habitat for threatened and endangered species, loss of recreation opportunities, and impacts on water quality.

Control of these weed species in the first growing season following flood-borne spread is essential. Management efforts should focus on mapping the extent of spread and control of new invasions prior to maturity.

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