AN ABSTRACT OF THE THESIS OF

Derek A. Risso for the degree of Master of Science in Wildlife Science presented on December 14, 2007.
Title: Floodplain Vegetation Following Over 80 Years of Intensive Land Use and De-watering: Lower Owens River, California.

Abstract approved:

J. Boone Kauffman

Riparian areas in the arid western United States are critical ecosystems that have been severely degraded by a variety of land and water uses over the last 100 years. In this study, the composition and structure of floodplain vegetation along the Lower Owens River in eastern California was quantitatively described following over 80 years of de-watering, grazing, groundwater pumping, and other land uses. The Lower Owens River is a heavily impacted and invaded riparian system which has suffered long-term hydrologic alteration and degrading land use. This study is part of the Lower Owens River Project, an effort to restore ecosystem function to this riverine landscape.

Using a stratified design, five 2km long study plots were established in five river reaches within the 86 km study area. Within these plots, dominant species were ranked by cover in six structural classes along 105 line-intercept transects and species canopy cover and ground cover was estimated at 525 2m x 2m sub-plots in 2001 and 2002 to determine vegetation type composition and condition. Twenty–two vegetation types were delineated by cluster analysis and Indicator Species Analysis (ISA). Based on species composition and dominance, cluster analysis and Non-metric Multi-dimensional Scaling (NMS) were employed to examine relationships between vegetation types and environmental parameters. Vegetation composition and species diversity indices were strongly correlated with geographic and hydrologic variables. A weighted wetland indicator index elucidated a shift toward more xeric species and communities in the completely dewatered reaches, as well as a negative correlation with diversity measures. Completely dewatered reaches were dominated by communities that have shifted from native to exotic vegetation types. Five of the 22 distinct vegetation types delineated were dominated by exotic species, mainly salt-cedar (*Tamarix spp.*) and Russian thistle (*Salsola tragus*). These communities covered approximately 24% of the study area, and dominated the most severely dewatered reach. Conversely, native communities remained dominant in reaches where surface water was present. Native vegetation types covered 96% of these reaches, an increase of 64% (p=0 from a randomization test) over the severely dewatered reach. The native willow (e.g. *Salix goddinggii and Salix exigua*) and wet meadow vegetation types exhibited the highest species diversity, and therefore represent target vegetation types for restoration. The results of this study elucidate the changes in vegetation type cover and composition following dewatering and degrading land use in an arid western riparian system.

Floodplain Vegetation Following Over 80 Years of Intensive Land Use and De-watering: Lower Owens River, California

by

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I understand that my thesis will become part of the permanent collection of Oregon State University libraries. My signature below authorizes release of my thesis to any reader upon request.

Derek A. Risso, Author

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Chapter 1. General Introduction and Literature Review

Natural riparian areas have been suggested to be among the most diverse, dynamic, critical, and complex terrestrial biophysical habitats on earth (Naiman and Decamps 1997). These vital interfaces between aquatic and terrestrial systems have disappeared at an alarming rate -- riparian and aquatic systems are currently being altered, impacted, or destroyed at a greater rate than in any time in history (National Research Council 1992). These areas of critical habitat have been some of the most heavily impacted areas of the arid west with an estimated 70%-90% of the natural riparian areas of the United States extensively altered (Hirsch and Segelquist 1978). These imperiled ecosystems occupy a relatively small percentage of the landscape but their unique vegetation assemblages provide habitat for many common and rare plant species that provide important habitat for animals (Lohoman 2004). This is especially true in arid western North America where sharp ecotones between hydric riparian vegetation and more xeric surrounding landscape exist.

The importance of riparian vegetation to riverine/riparian system function is well known and their restoration and management has been recognized as a key issue for government organizations and other land managers (National Research Council 2002). Riparian vegetation provides a linkage between aquatic and terrestrial systems (Gregory et al. 1991). Riparian systems are historically diverse, species-rich mosaics of varying age and structure that perform a myriad of important ecosystem functions including stabilizing streambanks, dissipating flood energy, trapping sediment, and moderating stream temperature (Gregory et al. 1991, Elmore and Kauffman 1994, Gurnell 1997, Tabacchi et al. 1998, 2000). Many western riparian zones are dominated by forests of riparian-obligate species, such as cottonwood (*Populus spp.*) and willow (*Salix spp.*) Because of the keystone roles these species play in many western riparian systems, their degradation and restoration have been the subject of many studies of western riparian areas, with the most emphasis on cottonwood ecology (eg. *Populus balsamifera* ssp. *trichocarpa* and *Populus fremontii* ssp. *fremontii*) (Bradley and Smith 1986, Stromberg and Patten 1992, Auble and Scott 1998, Merigliano 1998, Rood et al. 1998, Shafroth et al. 1998, Rood et al. 1999, Rood and Mahoney 2000, Sher et al. 2000). Consequently, our understanding of cottonwood ecology has improved in recent years. However, the ecology (especially the response to managed flow regimes) of many other important riparian species and communities is poorly understood.

The restoration of riparian zones is a critical need to maintain and restore proper ecosystem function in the North American west. Of the most important ecosystem linkages that must be addressed when restoring degraded riverine/riparian systems are those between hydrology, vegetation, and geomorphology (Kauffman et al. 1997). These three components interact with climate to influence important ecosystem components such as channel morphology and floodplain development. Understanding these key components is critical to successful restoration of riparian systems.

Land Use and Water Diversion: Effects on Riparian Vegetation

For millennia, humanity has constructed dams and water diversions to avert the adverse economic impacts associated with flooding and increase the ability to store and transport water for future and distant uses (Jackson et al. 2001, Patten et al. 2001). This has been prevalent in western riparian areas, including California, where there are over 1200 non-federal dams, 181 federal dams, and over 8000 km of levees whose purpose is to control and divert river flows (Mount 1995, Elderd 2003). Damming and diversion of water, livestock grazing, and the conversion of floodplains into agricultural landscapes are principal anthropogenic causes for the decline of western riparian systems (Obedzinski et al. 2001). The construction of dams for flood control, hydroelectric power generation, and water diversion has severely altered many western riverine-riparian systems (Scott et al. 1996). Riparian vegetation can be dramatically affected by the changes caused by damming and diversion to a river's hydrograph; the most important changes being the change in timing and duration of base and peak flows and the reduction in annual flow (Stromberg and Patten 1992, Scott et al. 1996, Auble and Scott 1998, Molles et al. 1998, Rood et al. 1999). Understanding the effects of present diversions or impoundments on downstream riparian vegetation is integral to constructing successful restoration and management plans.

Reservoirs and diversions limit the magnitude of high flow events that create sites with suitable substrates for recruitment of cottonwoods, willows, and other riparian species. The absence of suitable sites for establishment can lead to a change in age-class structure from a diverse forest of various ages to a rapidly senescing assemblage of older age classes (Molles et al. 1998). In the Eastern Sierra Nevada, (California) many streams have experienced an extreme decline in riparian vegetation following stream diversion (Harris et al. 1987, Kondolf et al. 1987, Stromberg and Patten 1990, Smith et al. 1991, Stromberg and Patten 1992).

Aquifers and groundwater are recharged by high flow events and base flow. Dams and stream diversion may lower the water table below the rooting zone of some species downstream, increasing drought stress, which can lead to a change in vegetation cover from riparian obligate to more xeric upland species (Johnson 1976, Reily and Johnson 1982, McBride and Strahan 1984, Stromberg and Patten 1992). In a study of Eastern Sierra streams, streams showed significant differences in vegetation cover, community composition, or community structure between pairs of diverted and undiverted reaches (Harris et al. 1987).

Exotic Species

Many exotic species have invaded western riparian areas, including Russian-olive (*Eleagnus angustifolia*) and tamarisk (*Tamarix spp.*) (Stromberg 1998b). These species alter ecosystems in undesirable ways, frequently homogenizing flora and fauna, reducing diversity and negatively impacting populations of native species (MacNally et al. 2004). Often these species invade native riparian systems because land use and hydrologic alterations create conditions favoring their dominance. Smith et al. (1991) found that dams create downstream environments suitable for invasion of dry upland facultative species, such as *Aretmesia tridentata* and *Rosa woodsii* in the eastern Sierra Nevada, CA. The altered hydrological cycles in many western riparian ecosystems are likely a primary cause of decline in native riparian vegetation and successful tamarisk colonization (Howe and Knopf 1991, Busch and Smith 1995, Stromberg 1998a, Taylor et al. 1999, Sher et al. 2002).

Tamarisk, a native of Europe, was introduced in the early 1800s while Russian-olive, a native of Europe and Asia was introduced around 1900 (Horton 1977, Borell 1962). These species are associated with declining water tables and altered hydrological regimes (Horton and Clark 2001). Tamarisk has a 5 month fruiting period while Russian-olive has a fall to spring period of seed viability enabling these exotic riparian invaders more frequent periods with suitable germination conditions (Obedzinski et al. 2001).

Tamarix is more drought resistant than many native riparian species (Cleverly et al. 1997), and therefore has an advantage over native species in diverted reaches. For example, Shaffroth et al. (1998) found that following a drought in Arizona, 0-13% of tamarix died, while 92-100% of *Populus fremontii* and *Salix gooddingii* died along the Bill Williams River. Tamarisk's high salt-tolerance, coupled with its ability to increase the concentration of soil salinity through autogenic processes, gives it a competitive advantage over many native species (Stromberg 1993) in dewatered systems with high soil salinity. In addition, tamarisk can also grow rapidly in wet years (Cleverly et al. 1997). These adaptations can give tamarisk a competitive advantage over many native species in western riparian areas with heavily modified hydrologic regimes.

Invasive species, especially tamarisk, produce difficult and expensive challenges for restoration and management of western riparian areas. Zavaleta (2000) estimated that tamarisk invasions will result in billions of dollars in economic losses over the next 50 years. Understanding the complex interactions of water and land use with exotic and native species is paramount to successful riparian management.

Domestic Livestock Grazing

In the arid west, cattle are attracted to riparian zones because of their shade, forage quality and microclimate. One study found that a riparian zone in eastern Oregon comprised only 1.9% of the grazing allotment area, but 81% of the forage consumed by cattle (Belsky et al. 1999). Riparian meadows are the most prefered riparian habitat by cattle (Kauffman et al. 1983a, Kauffman et al. 1983b).

Although some studies have suggested that domestic livestock grazing can induce plant growth at low intensities (Huber et al. 1995), the body of scientific evidence suggests that plant biomass, herbaceous cover, productivity and native biodiversity decline (Huber et al. 1995). In a grazing simulation study involving exclosures and simulated grazing (clipping and compaction) at three diverse sites in the western United States, the most consistent results of the study were a reduction in height growth and biomass production following grazing treatments (Clary 1995). Other studies have found similar results in Colorado (Popolizio et al. 1994, Shultz and Leininger 1990) and Oregon (Kauffman et al 1983b). The intensity of the effect of grazing on biomass can be affected by the timing of the grazing, as sedges in southeast Oregon were found to regrow only 1% of standing cover following grazing after mid-July (Sheeter and Svejcar 1997). This is an important result, as late season grazing is often seen as a sustainable grazing strategy involving exclosures.

Exclusion of cattle from riparian areas has resulted changes in plant species composition. The exclusion of cattle from riparian meadows in northeast Oregon caused a significant increase in species richness after a 10-year rest from grazing pressure but for all years, species richness and species diversity were significantly lower in exclosed areas than grazed areas, possibly because often the most impacted areas are chosen for exclosures (Green and Kauffman 1995). After three years of livestock exclusion at another stream in northeast Oregon, changes in species composition were evident in a moist meadow community. For example, areas with gravely, loosely structured soils, cheatgrass dominated the areas utilized by livestock, while quackgrass dominated similar substrates following cessation of grazing (Kauffman et al 1983b).

Not only has grazing been found to alter species composition, but to increase the overall abundance of exotics. Grazing has increased the abundance of weedy exotics that thrive in severely disturbed systems (Hobbs and Huenneke 1992, Popolizio et al. 1994, Shultz and Leininger 1990). Possible causes are increased disturbance due to trampling of vegetation, selective grazing of palatable species by livestock, lowered water table, and the increase in temperature and exposure following grazing (Belsky et al. 1999). Exclusion of cattle from a moist riparian meadow for 10 years in northeast Oregon caused a decrease in the frequency of the exotic species *Phleum pratense* of 33% to 3.3%. Similarly, another exotic, *Ranunculus acris,* decreased in frequency from 55.5% to 12.2% in exclosed sites while remaining relatively constant in the grazed treatment over the same time period. Conversely, the native sedge *Carex rostrata* Stokes was the dominant species in ungrazed moist meadow communities (Green and Kauffman 1995), illustrating the use of exclosures to restore native plant diversity.

A dramatic change in compositional and structural diversity of vegetation has been associated with grazing riparian forests shrubs (Case and Kauffman 1997, Kauffman et al. 2000, Shultz and Leininger 1990). Grazing can affect not only vertical and horizontal physical structure, but age structure of the plant community as well. Cattle tend to trample and graze seedlings, resulting in an even-aged non-reproducing vegetation community (Kauffman et al 1983b). Grazing increases the amount of bare ground in riparian meadow communities (Popolizio et al. 1994, Shultz and Leininger 1990) and the removal of grazing decreases the amount of bare ground (Kauffman et al. 2000)

Changes in litter layer properties have also been associated with the exclosure of cattle in riparian meadows. A study in Colorado found that exclusion of grazing for 30 years doubled the litter cover observed in a treatment with reduced grazing pressure (Shultz and Leininger 1990). Similarly, the litter layer in ungrazed dry and moist meadows in northeast Oregon was approximately twice that of grazed counterparts after 10 years of exclusion of cattle (Green and Kauffman 1995).

Classifying Vegetation

The discussion concerning how to classify vegetation started decades ago (Gleason 1939). Various classification systems, scales of analysis, levels of detail, methods and applications have been developed. Several different classification systems may be used in the same region or even within the same project. Classification systems serve the purpose of allowing researchers and managers to communicate about the vegetated landscape. Although arguments concerning the advantages and disadvantages any classification system can be made, the best classification system for any given study is the one that is the most useful to project goals. It is imperative that vegetation be classified to meet project objectives. Alternative classifications of the same vegetation may be better suited to other purposes or goals. There is no one best classification system.

Delineated vegetation types can be related to the extent and quality of wildlife habitat (Shaffer et al. 1992, California Department of Fish and Game and California Interagency Wildlife Task Group 2000). If vegetation types indicate habitat quality, then changes in vegetation types can be used to monitor changes in habitat (Alpert and Kagan 1998). To the extent that the distribution of vegetation types relates to species distribution and diversity, it can be used to provide a “coarse filter” estimate of biodiversity (Noss 1993).

Three persistent questions about how to classify vegetation concern (1) whether to include heavily impacted, early successional, anthropogenic, or non-native vegetation, (2) whether classifications should be based on "target" or "potential" vegetation or existing vegetation, and (3) how finely to split vegetation types. The solutions to these questions clearly lie in the goals of the investigation or classification. However, it appears that classifications that are hierarchical systems, nesting local vegetation types within more general, widespread physiognomic types are most useful (Alpert and Kagan 1998). In his review of western riparian vegetation classification systems, Alpert and Kagan (1998) suggested that there were 3 essential features of these hierarchies: that higher levels correspond to larger spatial scales, each scale has different criteria for distinguishing types, and types on the lower levels are nested within types at higher levels. When dealing with fine-scale patches or vegetation types, Winward and Padgett (1987) suggested grouping sets of co-occurring, fine-scale vegetation types in "riparian complexes." This approach has been applied (Manning and Padgett 1991, Girard et al. 1995).

Beyond the difficulty of spatial differentiation, lie the temporal aspects to vegetation science. Although there are a limited number of vegetation types that can persist in a given area, due to climate, elevation, soils, and other factors, the composition, location, and condition of vegetation changes through time. Environmental disturbances play a key role in determining species composition of a given site (Helm and Collins 1997). This is especially true in riparian zones, as these areas are uniquely adapted to disturbance. Riparian systems have undergone a great deal of change due to anthropogenic disturbance as well. Some classification systems are based on "potential" or "climax" vegetation types, which may fit the goals of upland systems under some circumstances, but are less applicable to riparian zones. For riparian restoration and management studies, researchers have indicated that current condition may be most useful (Platts 1987). For this study, vegetation was defined using current composition and not based on hypothesized targets or potential vegetation types. The vegetation described must be viewed in the context of its hydrologic and land use history.

Methods have been devised to discern community associations (Gauch 1982, Jongman et al 1987, Bonham 1989, Kent and Coker 1992). It is must be recognized that these boundaries are somewhat arbitrarily drawn. Boundaries between vegetation patches, communities, or types are determined not just by the sampling and analysis methods utilized, but the investigators (Sawyer and Keeler-Wolf 1995, Coles-Ritchie et al. 2007). Each individual observer may view the gradients between vegetation stands, complexes, associations, and patches differently. The California Native Plant Society described the difficulty in defining vegetation as:

> Although we can agree that a dense lodgepole pine forest is qualitatively different from an adjacent wet mountain meadow, the closer we look, the harder it is to discern where a meadow begins and a forest ends. We see individual sedges, asters, and buttercups trailing off in decreasing density into the forest as it closes overhead, and young pines and scattered mature trees stationed well out into the meadow. The problem of fuzzy boundaries is characteristic of vegetation science. (Sawyer and Keeler-Wolf 1995)

Whether vegetation patches are classified into community types, vegetation types, complexes, or series, classifying vegetation creates targets for management, restoration, and conservation. At coarse scales, vegetation can be classified using broad environmental categories (e.g. aquatic or terrestrial) or physiognomic class (e.g. forest, shrubland, grassland, wetland, or herbaceous). In this study, dominant species within structural strata were used to define vegetation types, as other systems have done at finer scales, most notably for vegetation series (Daubenmire 1959, Sawyer and Keeler-Wolf 1995) and vegetation formations (Barry 1989).

No vegetation measuring technique is universally applicable, and each method has its own strengths, weaknesses, features, and limitations (Sawyer and Keeler-Wolf 1995, Albert and Kagan 1998) . Most vegetation studies use large plots e.g. (50 – 500 m^2) centered in selected vegetation types selected by researchers (Alpert and Kagan 1998). In riparian zones, they are often located next to the stream bank and orientated parallel to the stream flow (Daubenmire 1959). Since riparian areas contain many narrow, irregularly shaped vegetation patches, these plots may limit the sample population only to vegetation patches of a certain size and shape. Sample plots are often established within the interior of selected patches, with the intent of not sampling the transition areas between vegetation patches (Platts 1978). Line-intercept sampling, described by Canfield (1941) and Winward (2000) passes through the floodplain, and is capable of sampling the entire riparian area from terrace to terrace, including small, linear patches and transition areas, giving a more complete picture of these complex areas.

Vegetation communities are difficult to define or even prove their existence (Sawyer and Keeler-Wolf 1995). For this reason, vegetation data was classified into what is termed vegetation types. Vegetation types are difficult to define. Other researchers have used clustering algorithms such as TWINSPAN (Kovalchik 1987, Crowe and Clausnitzer 1995) ordination (Busch and Smith 1995), and Indicator Species Analysis (Abella and Covington 2004). Dominant species are often emphasized, and rare species are rarely used to define types and are often excluded from the analysis (Auble et al. 1994, Lehmkuhl 1994, Nilsson et al. 1994, Abella and Covington 2004). The results of formal statistical analysis are frequently slightly modified by common sense and project goals (Evenden 1989, Hansen et al. 1991, Jones and Walford 1995).

Chapter 2. Study Area and Land Use History

Physical Setting

This study was located on the heavily regulated Owens River in eastern California (Figure 1). It flows in a southerly direction from its headwaters near the resort town of Mammoth Lakes to Owens Lake (now dry) near the town of Lone Pine, a drainage area of 8,550 km^2. This study was conducted on one stream section of the river, termed the Lower Owens River, which begins at the Intake to the Los Angeles Aqueduct (1167 m), southeast of the town of Big Pine (Figure 1) and ends at a pump back station at the top of the delta to Owens Lake (1093 m). From the Los Angeles Aqueduct Intake to the Owens Lake the river descends 74m over 104 km, a gradient of (.72 m/km), or 0.07%. The last 18 km of the river are classified as the Owens River Delta (Delta Habitat Area), has its own flow regime and is managed differently than the riverine-riparian area. Flows for the riverine-riparian area are released from the LA Intake and are recaptured at a pump back station at bottom of the Lower Owens River. The pump back station is capable of releasing water into the delta downstream or back into the LA Aqueduct system. The sampling protocol described below was designed specifically for the riverine-riparian area and was not performed outside that area.

The Owens Valley is set between two mountain ranges, the White and Inyo Mountains to the east and the Sierra Nevada to the west. The Sierra Nevada, which rise over 2800 m above the valley receive approximately 76 cm of precipitation near the crest (Groeneveld et al. 1986a and 1986b, Duell 1990, Hollett et al. 1991). However, due to the rain shadow effect, the Owens Valley is an arid to semi arid landscape, receiving between 10 and 15 cm of precipitation per year (Hollet et al. 1991). The bedrock of the area is mainly granitic, but a complex geologic history, including volcanic events and numerous geomorphologic processes, make specific geologic classification difficult. The riparian substrates of the study area consist mainly of unconsolidated alluvium (Smith 2000). The alluvium consists of moderately to well-sorted, unconsolidated lenses and layers of sand, silty sand, and gravely sand and layers, lenses, or massive beds of silty clay (Hollett et al. 1991). The alluvium depth to the bedrock ranges from 600 m below the valley surface just north of the Intake to 2500 m at the Owens Dry Lake (Danskin 1998). The river flows along the east side of the valley because tributaries flowing out of the Sierra Nevada form large coalescent fans on the west side of the valley which slope down to the river channel for miles. The Inyo Mountains have no such fans (Danskin 1998). A major fault runs nearly the length of the valley (Figures 1 and 2), also influencing the river's current course (Danskin 1998).

The study area straddles two ecoregions, the Great Basin and the Mojave Desert (The Nature Conservancy 2001) and is very close to a third, the Sierra Nevada east (Figure 1). Much of the northern section of the Lower Owens is completely dewatered, and is a disconnected patchwork of degraded remnant riparian areas. The landscape has been heavily modified for at least 100 years. Intensive grazing is the principal land use throughout the study area and the surrounding uplands. Abandoned orchards, dams, ditches, railroads, as well as current use OHV trails and 4-wheel drive roads are present.

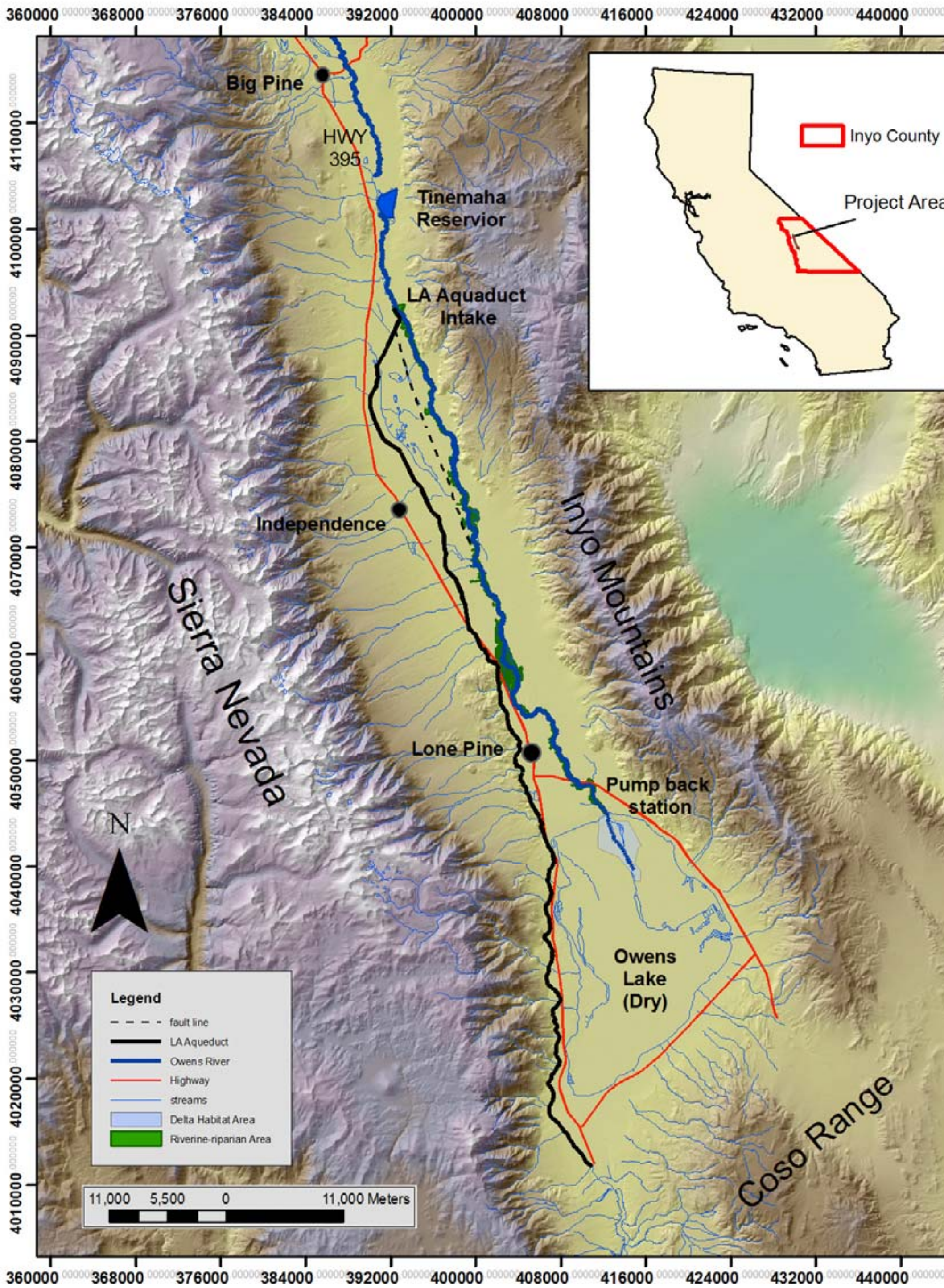

Figure 1.Project Location and Setting. The Lower Owens River (study area) begins at the LA Aqueduct Intake and flows south (roughly parallel to US HWY 395) to the pump back station located at the historic lakebed shoreline, south of the town of Lone Pine.

Hydrologic History

The hydrology of the Owens valley has changed significantly over the last century due to extensive water diversions. The hydrology of the Owens valley occupies and interacts with physical components that can be conceptually grouped into three main parts: (1) an unsaturated zone affected by precipitation and evapotranspiration; (2) a surface water system made up of the Owens river, tributary stream canals, ditches, springs and ponds, as well as the Los Angeles Aqueduct and their associated groundwater; and (3) a saturated groundwater system flowing through the western alluvial fans to vast groundwater reservoir in the deep alluvium of the valley (Danskin 1998). These three zones and their interactions with each other have changed over the last hundred years, resulting in severe impacts on riparian vegetation.

Prior to the large scale development of water diversions in the Owens Valley, the Owens River was the primary outlet for both the surface water and groundwater systems. Surface water from the upper watershed and western tributaries flowed into the river (Figure 1). Little surface water reached the Owens River from the east, as the White and Inyo mountains lower precipitation caused its tributaries to disappear into alluvial fans well before reaching the Owens River, as was the case with many of the smaller Sierra streams. The groundwater of the valley also flowed into the river under pressure into the river channel to give it a perennial flow (Danskin 1998). The groundwater system, low gradient and low valley precipitation led to a fairly stable historical flow to the river (Brothers 1984, Danskin 1998). The ratio of maximum to minimum river discharge from Pleasant Valley reservoir (upstream of Lower Owens) was 2.8 over the period of 1919-1940. This is much lower than other rivers that are driven by southern sierra snowmelt including the Kaweah (53.6 to 1), the Kern (13.4 to 1) and the Kings River (46.4 to 1) (USDI Geological Survey 1959). No accurate long-term record of historic natural flows in the Lower Owens is known to exist. Researchers have estimated pre-diversion flows for various sections of the river (Danskin 1998, Smeltzer and Kondolf 1999). Based on estimates by Smeltzer and Kondolf (1999) for the Owens River Gorge base flows (6 m^3/sec), annual high flow (17 m^3/sec), 100 year flood (41 m^3/sec), and 10,000 year flood (93 m^3/sec) and the 15-20 % increase in flow from the bottom of the Owens river gorge to the Lower Owens by Danskin (1998), pre-diversion flows in the Lower Owens were likely in the range of 7-9 m^3/sec for base flow, 18-21 m^3/sec for annual peak flows, and 100-115 m^3/sec for the 10,000 year flood at the top of the study area. Throughout the study area another 10-15% was likely added to that flow (Danskin 1998) before the river emptied into Owens Lake. As a system driven by the melting of the Sierra snowpack, the Owens River's maximum monthly discharge normally occurred in June and often in May or July and minimum discharge in August or September under natural conditions (Brothers 1984, Smeltzer and Kondolf 1999).

The Owens Valley is a closed drainage system. As surface and groundwater historically flowed south to a terminus at Owens Lake. The Coso range, at the southern end of the valley, forms a barrier to movement (Figure 1) of both surface water and groundwater (Danskin 1998). The Owens Lake was historically a large body of water, over 6 m deep and covering over 250 km^2 (Danskin 1998). However, with the construction of diversion canals and LA aqueduct system have altered the water budget of the lake so that in all but the wettest years evapotranspiration exceeds inflow.

Native Americans utilized the river floodplain for resource extraction, including minor water diversions. Soon after settlers arrived in the valley, diversions increased. By 1904, the diversions that began in the late 19^{th} century on the Owens River and its western tributaries were diverting an estimated 75% of the annual runoff within the valley (US Reclamation Service 1904). These diversions drastically altered the natural flow regime. Maximum and minimum flows were reduced, winter flows increased, and total discharge decreased (Brothers 1984).

The natural hydrologic regime has never returned to the Owens Valley. The Los Angeles Department of Water and Power began to divert water from the valley beginning with the completion of the 375 km long Los Angeles Aqueduct in 1913. The aqueduct system capacity was increased to 407,000,000 m^3/year with the addition of the Mono basin north of the Owens valley. In 1970 the second aqueduct was completed increasing the capacity of the system to 696,000,000 m^3/year.

Until the completion of Tinemaha Dam upstream of the intake in 1929, reduced base flows and periodic pulse flows continued in the channel below the intake at the upper end of the study area. The completion of Tinemaha Dam allowed LADWP to store high flows and regulate the aqueduct flow, and subsequently only rare flows have occurred in the main river channel since. The combination of diverted upstream flow with the interception of Sierra tributary streams by the aqueduct caused the river to soon drain the surface-groundwater system (Danskin 1998). Since 1929 flows have only been released into the channel when system capacity was exceeded (1936-39, 1967, 1969, and 1975) or for specific scientific studies (1993). The flows in the channel were relatively large in 1938 and 1969, approaching 8.5 m^3/sec, while the flows in 1967 and 1969 (Figure 2) were prolonged releases lasting through most of the summer (Brothers 1984) due to snowpack and run-off conditions. A flow study was performed in 1993 in which the releases from the intake peaked at 3.4 m^3/sec over a one week period to inform management prescriptions for the restoration of the Lower Owens River system.

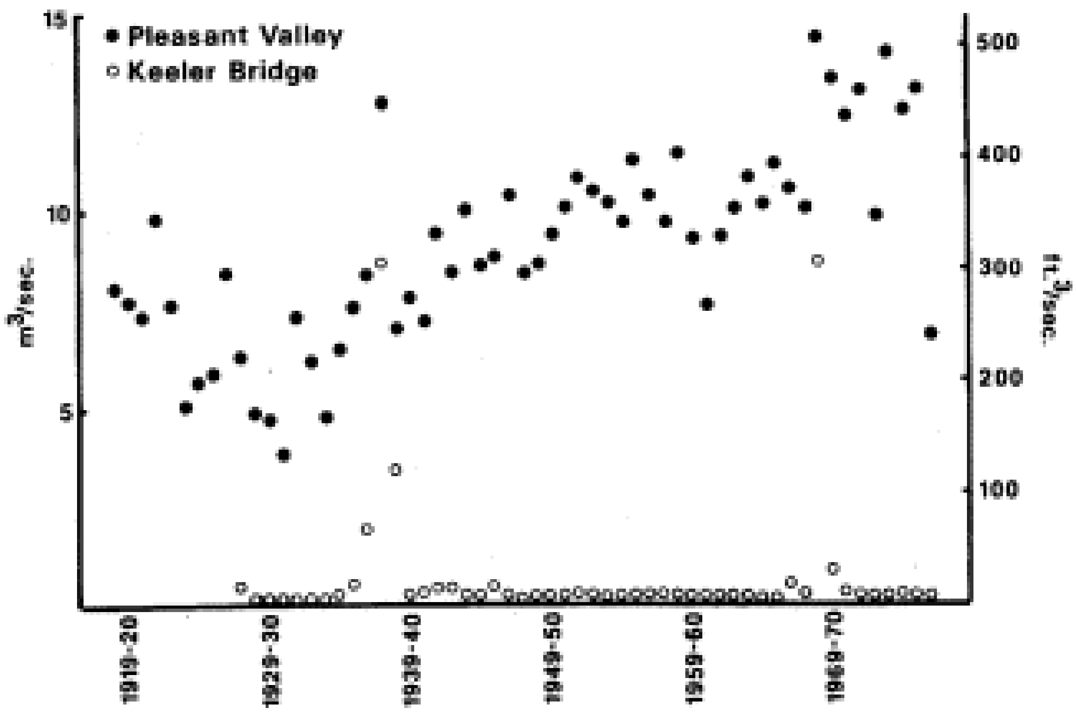

Figure 2. Annual discharge of Owens River between 1919 and 1980. Annual discharge at two measuring stations on the Owens River are presented in m^3/sec. Pleasant Valley is located above the study area and represents the amount of water traveling though the river-aqueduct system above the Intake structure. The Intake structure has historically diverted most if not all flow from the Lower Owens River channel. The Keeler Bridge site is at the bottom of the study area and best represents flows through the study area. High flow events were rare in the Lower Owens, occurring mainly in the late 1930's and 1960's when the aqueduct capacity was exceeded. Adapted from Brothers (1984) presentation of unpublished streamflow records.

Approximately 170 wells were drilled after a prolonged drought in the 1930's and 40's to supplement surface diversions (LADWP 1966). The first period of pumping was from 1919-1935. Most the 170 wells were north of the intake (Figure 1) and released into the river channel thence into the aqueduct. There was likely little initial effect on the Lower Owens from this period. No pumping occurred until the dry years from 1960-1962 (LADWP 1979). Groundwater pumping accelerated again in 1970 and continues to this day (Danskin 1998).

Current Hydrologic Condition

At the time of this study, surface flow in the channel downstream of the Intake was non-existent. The complete diversion of surface water from the Los Angeles Intake coupled with reduce groundwater inflow to the river system has left sections of the river virtually dry. Groundwater has always been a major source of flow in the Owens River (Danskin 1998). However, an 1872 earth quake fault restricts the eastward flow of groundwater south of the Poverty Hills (Figure 1), a formation north of the LA Aqueduct Intake (LADWP 1966). Groundwater seepage gradually increases below the intersection of the fault and the river north of Manzanar road. From there south to Lone Pine many small springs in and along the river bring water into the channel. In addition, south of the fault, there are several irrigated pastures that have returns to the river, providing additional flows. These hydrological conditions likely result from the combination of channel entrenchment connecting the river channel to the groundwater system, proximity to the earthquake fault (connecting the river to groundwater), inflow from the Sierra alluvial fans (Brothers 1984), and irrigation water returns (both surface and subsurface flow).

In 1986 the Lower Owens River Rewatering Project was initiated by LADWP and Inyo County. The project called for 22,200,000 m^3/year to be released from Billy Lake into (Figure 3) the wet reaches to maintain a continuous flow in the channel to benefit existing warm water fisheries, waterfowl, and shorebirds in the lower reaches. Flow into the river channel from Billy Lake has been maintained, supplying the lower section of the river with permanent surface flow. Over the last two decades the lowest gauging station on the river, Keeler Bridge, has ranged between 0.15 and 0.33 m^3/sec (Table 1).

Table 1. Lower Owens River monthly discharge over two water periods. With the completion of Tinemaha reservoir upstream of the LA Aqueduct Intake by water year 1927/28, LADWP only released water into the Lower Owens River when aqueduct capacity was exceeded. Beginning in water year 1986/87, a rewatering project introduced water into the channel at Billy Lake return. Data below is adapted form Whitehorse Associates (2002) tabulation of LADWP monthly stream flow records. These records should be viewed as only generally accurate, as the monthly averages they are based on were often based on only one reading within a given month, and that reading was then applied to all days within the month.

	Water Year					
	1986/87-2000/01			1927/28-1985/86		
	Mean	Max	Min	Mean	Max	Min
Oct	0.9	1.8	0.5	1.0	20.0	0.1
Nov	1.1	1.7	0.7	0.9	13.3	0.2
Dec	1.2	1.8	0.7	1.5	22.6	0.3
Jan	1.2	1.7	0.7	1.8	24.5	0.3
Feb	1.3	1.8	0.7	2.6	29.6	0.4
Mar	1.3	2.6	0.7	3.0	41.0	0.1
Winter	1.2	1.7	0.7	1.8	17.8	0.3
Apr	1.0	1.7	0.5	3.0	41.8	0.2
May	0.7	1.7	0.2	1.4	24.4	0.2
Jun	0.4	1.0	0.1	3.3	89.8	0.1
Jul	0.6	2.9	0.0	2.9	83.3	0.0
Aug	0.9	2.3	0.0	1.7	35.6	0.0
Sep	0.8	1.7	0.2	0.6	10.8	0.0
Summer	0.7	1.2	0.2	2.1	41.7	0.2
Annual	1.0	1.2	0.4	2.0	25.5	0.2

Domestic Livestock Grazing

The first settlers to the area arrived due to a mining boom between 1860-1864 (Chalfant 1922). This mining boom established four towns in the valley, all of which have since disappeared (Brothers 1984). With this mining boom, the first cattle grazing was reported in the valley in 1859 (Brothers 1984). Shortly thereafter, in 1861, the first permanent ranches were established near the modern day town of Bishop (Chalfant 1922, Davidson

1976). Cattle and sheep were driven through the area for use as winter pastures. Domestic livestock grazing is still the dominant land use in the area today.

Grazing throughout the basin continued uninterrupted until the large scale purchase of land by the Los Angeles Department of Water and Power beginning in 1923. The local ranchers were bought out, and the cattle were moved off the land. This decline in grazing was short lived, as LADWP soon introduced a leasing program, which remains in effect today.

Between 1936-1940 the combination of a series of wet years and the completion of the second aqueduct from Mono County brought a feeling of abundant water resources to the area, and the grazing lease program was expanded (Brothers 1984). Over the years, the management of leases has evolved with the implementation of large managed pastures, fencing, and plans that include timing and utilization prescriptions.

Non-native Wildlife

A herd of 54 Tule Elk (*Cervus elaphus nannodes*) were introduced into the valley from 1933-1934 (McCullough 1969). An elk herd is maintained within the valley, with the population fluctuating between 500 and 1500. They browse on alfalfa fields on LADWP leases, as well as on willows and other riparian vegetation. Elk have been reported to browse more heavily on willows than cattle (McCullough 1969).

Beaver were introduced by California Fish and Game at Baker Creek in 1948 to improve fisheries habitat (Brothers 1984). They have spread through out the Owens valley including the Lower Owens River. Their cutting of native riparian trees, water impoundment, and habitat modifications are often viewed as obstacles to riverine restoration goals (Naiman et al. 1988).

Agriculture

Agricultural development by settlers began in the valley roughly the same period as the introduction of mining and grazing in the 1860's. There were a number of irrigation canals built on many western valley creeks in the Bishop and Big Pine area. Canals were later built along the river channel. Many of these canals and their diversion structures can still be found along the river channel. Although there are some remnant orchards and crop fields along the river, most of the canals appear to have been designed to create irrigated pastures (Brothers 1984). By 1930, following acquisition by LADWP of land and water rights, irrigation for agriculture had all but stopped. However, as mentioned above, by the late 1930's irrigation began to be available to supplement leases.

Native Vegetation

Descriptions of the area prior to European settlement are rare and variable. Early historical descriptions by the first European visitors to area (1849-1890) describe the area as wooded with willow and cottonwood (Fremont 1849), devoid of viable timber, except for cottonwoods (Davidson 1976), containing no trees at all in the valley (Brewer 1930), and as a river bordered by grassy plains containing no timber of any kind (Anon. 1886). However, an early settler recalled the large willows lining the river east of the town of Independence (Earl 1976). The distribution of trees through out the valley was likely scant immediately prior to Euro-American settlement; however, it is unlikely that the river corridor was ever completely devoid of willows, cottonwoods and other riparian vegetation.

In a 1979-80 study examining the vegetation and land use history of the Owens River, Brothers (1984) observed few trees in the floodplain below in the LA Intake south to Mazurka Canyon Road. The riparian trees consisted of Goodding's Willow (*Salix gooddingii*) and Fremont cottonwood (*Populus fremontii*). Coyote Willow (*Salix exigua*), Wood's rose (*Rosa woodsii*), rabbitbrush (*Chrysothamnus nauseosis*), Nevada saltbush

(*Atriplex torreyi*), and desert olive (*Forestiera neomexicana*) formed the native riparian shrubland (Brothers 1984). Most of these species were found near the channel or inside the historic channel on the channel bed. In fact, Brothers observed as much as 61% of *Salix gooddingii* plants to be growing in the channel at his sites (Brothers 1984). Areas that had access to moisture for much of the year were dominated by *Typha*, *Scirpus, Carex,* and *Juncus* species. However, a large portion of the floodplain was described as a dense perennial layer dominated by *Sporobolus airoides, Disticlis spicata,* and *Juncus balticus* (Brothers 1984).

A 1988 aerial photograph of the area suggests an abundance of riparian vegetation along the Lower Owens floodplain – mainly within to the channel itself. Along with occasional woody vegetation, tule and cattail wetlands were common where the river channel was moist to the surface (Danskin 1998).

Exotic Vegetation

Like many arid western riparian areas, the most common exotic riparian trees along the Owens River are Russian olive (*Eleagnus angustifolia*) and tamarisk (*Tamarix spp.*). Russian Olive was first documented in 1942, though likely present prior to this date (Brothers 1984). Today, the distribution is concentrated near the town of Independence (Figure 3). Tamarisk was first documented in 1944 aerial photographs, mainly along the earthquake fault (Brothers 1984). Current distributions are throughout the entire valley, with a concentration in the dry reaches above Billy Lake return and in the Islands reach near the Alabama Gates Spillway (Figure 3). The alteration of the natural flow regime by water diversion and grazing management has likely contributed to the spread of Russian olive and tamarisk within the valley. This has been caused by both dewatering and infrequent high flows. Local residents suggest that tamarisk was only widespread following the flows of 1967 and 1969. In his vegetation survey in 1979-1980, Brothers (1984) recorded saltcedar (*Tamarix ramosissima*) and Russian olive (*Eleagnus angustifolia*) at nearly half of his study sites along the Lower Owens river channel.

Among the many other exotic plants spread throughout the Owens valley, the weedy annual *Bassia spp.*, as well as many grasses, are widespread.

Chapter 3. Floodplain Vegetation of the Lower Owens River

Introduction

This study was one element in a larger project: the Lower Owens River Project (LORP). The goals of the overall project include "the establishment of a healthy, functioning Lower Owens River riverine-riparian ecosystem . . . for the benefit of biodiversity . . ." (County of Inyo v. City of Los Angeles et al. 1997). Understanding the effects of present diversions or impoundments on downstream riparian vegetation is integral to constructing successful restoration and management plans. The primary goals of this study were to establish the baseline riparian vegetation condition for the restoration of the Lower Owens River and to describe the current condition as a reflection of land use and disturbance history. The study was designed to assess the riparian vegetation structure and condition at a site-specific scale utilizing quantitative methods that minimize observer bias.

This study fits into a framework of integrated monitoring efforts operating on at different spatial and temporal scales. These efforts include wildlife habitat transects, landscape scale mapping of the entire river corridor, landform elevation modeling, water quality testing, rangeland monitoring, and several other efforts. This study was designed within a framework of monitoring protocols that are hierarchical in their degree of specificity and applicable to short and long-term adaptive management strategies designed to improve ecosystem function and ecosystem health. The results of this study will serve as a baseline from which mangers will be able to measure vegetation trends through time. The LORP will utilize adaptive management, and under the tenets of adaptive management, monitoring must serve to inform managers about system function and the usefulness of management actions. Within this framework, the research objectives of this study were as follows:

1) Define vegetation types specific to the area using an objective and quantitative method at an appropriate scale.
2) Place the study area's vegetation types within a hydrological, environmental, and land use context.
3) Establish a baseline condition of floodplain vegetation from which change will be measured through time.
4) Identify vegetation types with high diversity measures to inform managers about restoration targets.

Study Design

Plot Selection

The 85.7 river kilometers of the Lower Owens River within the study areawas divided into 5 reaches (Table 2 and Figure 3) based on ecologic, geographic, environmental, and logistical criteria. The first reach begins at the LA Aqueduct Intake structure and runs south roughly 33 kms to Mazourka Canyon road. This reach is heavily dewatered with little or no water in the channel. Reach 2 is from Mazourka Canyon Road roughly 20 kms south to the islands area. This reach is currently watered, as groundwater and surface water enter the channel from the west. Reach 3 is an 8 km wetland aggraded reach (Whitehorse Associates 2000) in which the river divides into several small channels dividing the area into a mosiac of wetlands and forest "islands." Reach 4 begins as the many channels of the islands converge to reform the main channel just south of the historic Alabama Gates release point from the LA Aquaduct. As the river meanders south and east around the town of Lone Pine, the floodplain begins to widen significantly. Reach 5 is the southernmost reach and begins just south of Lone Pine and continues south meandering through a broad floodplain confined by steep slopes south to the pump back station, the end of the project area.

Five 2 km long study plots were established throughout the study area. The five large study plots covered 10 linear kilometers of the approximately 50 linear kilometer study area. Therefore the study plots represent roughly 20% of the study area. The study plots were selected to be representative of each reach; they encompass the range of vegetative, geomorphic, and environmental conditions, as well as grazing management approaches in the Lower Owens River (e.g. two reference plots are 50 % inside a grazing lease and 50% outside the lease to enable managers to examine grazing effects on the restoration project). It was determined that because the Islands reach is a short (8.2 km) section of river composed of a vast, complex wetland with numerous channels creating access

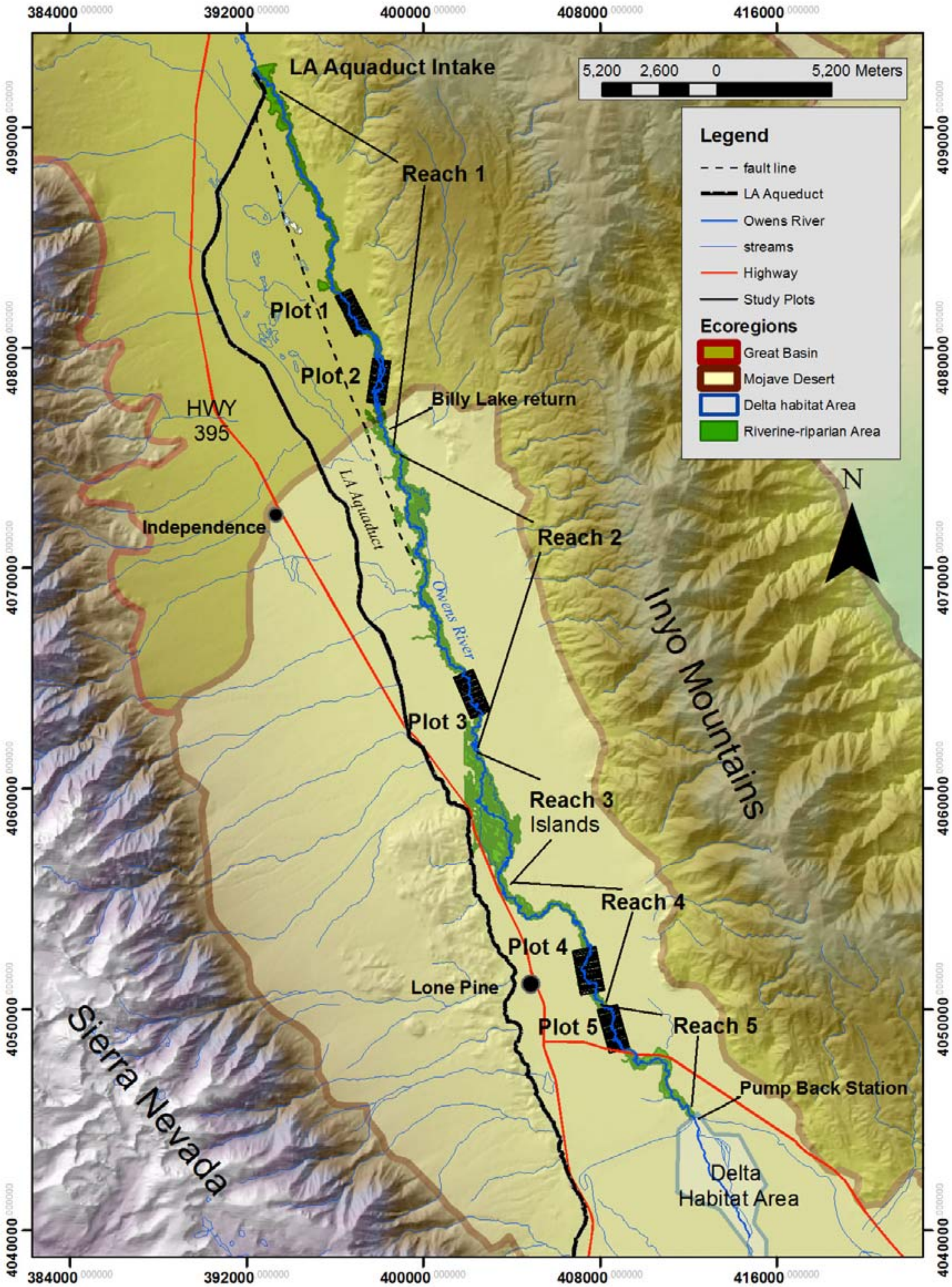

Figure 3. Study Area and Study Design. The study area and design are shown in relation to five reaches, floristic province, the Los Angeles Aqueduct, major roads, diversions, and important geologic features.

problems, more useful data would be produced by placing a second study plot in the dry reach (reach 1). The dry reach (1) is four times larger than the islands reach and will likely respond more drastically and dynamically to management actions. No plot was established in the short Islands reach. The study was designed to detect change within areas that managers will have the ability to effectively manage through flow and land management.

Table 2. Reference reaches and study plots of the Lower Owens River. Reach designations and descriptions, the number of study plots within each reach, and the length of each reach in river kilometers are presented.

Reach	# of Study Plots	km
1. The LA Aqueduct intake to Mazourka Canyon Road (dry reach)	2	33.3
2. Mazourka Canyon Road to Islands	1	20.6
3. Islands (wetland reach)	0	8.2
4. Islands to South of Lone Pine	1	12.2
5. Lone Pine Station Road to The Pumpback Station	1	11.4
Lower Owens River	5	85.7

Study sites were aligned with the river channel. Each study plot was 2 km in length (longitudinally) and encompassed the entire riparian zone from historic terrace to historic terrace on each side of the river channel (usually between 200m and 1000m width) (Figures 4 and 5). The outer boundaries of each study plot were identified in the field and then mapped using a geographic information system (ESRI's ArcView). To determine species composition of riparian vegetation communities, lateral transects were established in each of the 5 study plots. Because of the meandering nature of the Lower Owens River, it was logistically practical and more scientifically meaningful to have all transects within each plot parallel to each other rather than perpendicular to the river channel. To establish an axis to which all transects would be perpendicular, the center of the channel at the top and bottom of each study plot was used as endpoints of a central axis. Transects were established every 100m at each plot (21 transects over 2000m), extending from both sides of the wetted area (or former wetted channel) into the riparian zone. Transects extended laterally (perpendicular) from the center axis of the plot to the edge of the riparian vegetation, as judged by examination of aerial photography and a site visit (Figure 4). Fenceposts were installed beyond the current edge of existing riparian vegetation or the top of the terrace (Figure 5) to mark the end of each transect. Each fencepost was labeled according to its site and transect number. GPS locations of each fence post was recorded.

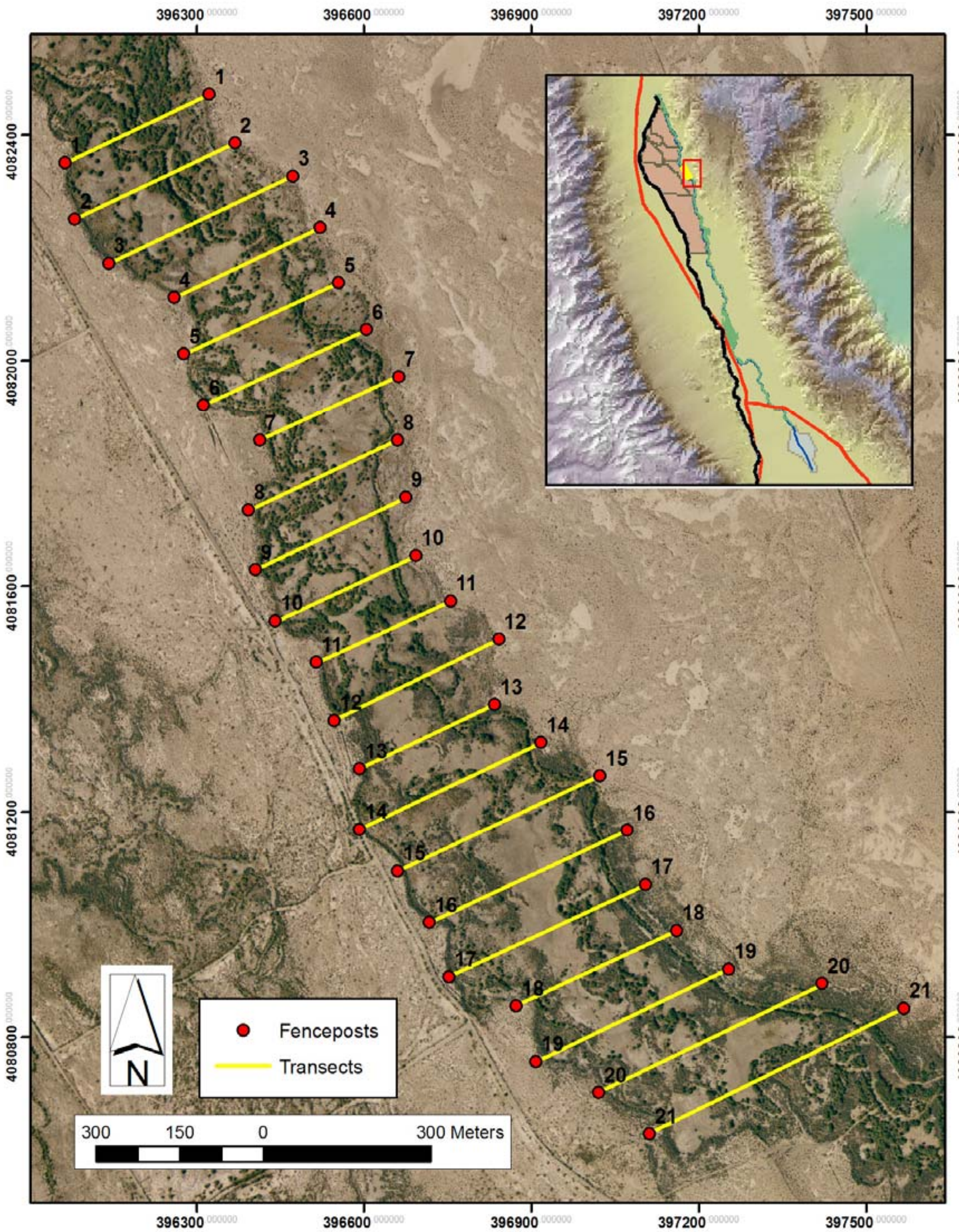

Figure 4. Transect Layout of Plot 1. Twenty-one parallel transects connect with endpoints located on historical terraces, and marked by fence posts. Transects were 100 m apart and generally between 200 and 1000 m in length. Plot 1 is located in driest reach. The historic floodplain adjacent to the dry channel (dark green vegetation) was dominated by tamarisk (*tamarisk ramosissima*) and Russian thistle (*Salsola tragus*).

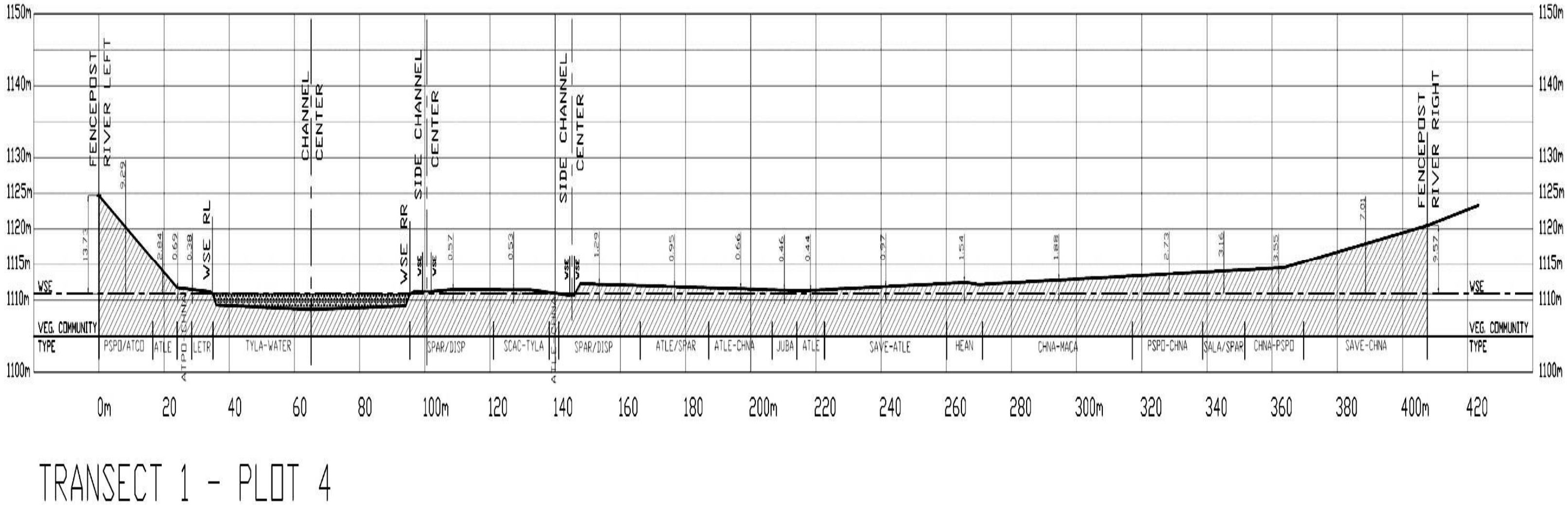

Figure 5. Cross Section of Transect. A cross section of a transect in Plot 4 is represented. Data was measured as part of another study with a laser range finder and survey pole. The cross-section is viewed facing downstream with the river left fencepost (east side of the river) on the left. The water surface elevation (WSE) is shown. Elevations are shown in meters above sea level. The historic terrace was approximately 15 meters in this section, but ranged between only a few meters and 20 meters. The 4-letter acronyms represent dominant vegetation found along the transect.

Field Methods

Transect Data Collection

Transect data was collected from June to August in 2001 and 2002. Along each transect, the linear distance covered by distinct plant communities was determined via a modified line intercept method (Winward 2000). Patches of relatively homogonous vegetation (an area with the same dominant species in each structural layer) were visually identified by researchers in the field (Figure 4). Dominant species were ranked by percent cover within each vegetation patch (sample unit) in each of 6 vegetation layers (upper canopy, lower canopy, high shrub, low shrub, high grass/herb, low grass/herb). The three species with the highest estimated canopy cover in each of layer were ranked and recorded as dominant, first sub-dominant, and second sub-dominant. A minimum of 5% canopy cover was required for a species to qualify for dominance ranking. Species were recorded by their 4-letter acronyms. Dominant species within the same layer were recorded in order of dominance and separated within each layer by dashes (-). Structural layers were separated by slashes (/). The length of the transect segment that covered each patch was measured with a sonar range finder or a measuring tape. When this was impractical or impossible, a visual estimate was made and a description written. In the lab, these estimated distances were verified, or amended, using GIS and aerial imagery. The minimum patch size diameter was two meters. Additional information recorded included the presence or absence of open water, bare ground, dead trees, dead shrubs, dead reeds, and dead grasses (Appendix A: Data Sheets). Fencepost locations, maps, compass, and GPS units were all utilized to facilitate navigation.

Sub-plot Sampling

A series of 2m x 2m sub-plots were established to provide more detailed information about vegetation types. After transect data had been collected, 5 vegetation patches were randomly selected without replacement from the delineated patches. A sub-plot was then established at each of these randomly selected communities. Sub-plots were located adjacent to the transect line (sharing one 2 m side) in the center of a vegetation patch

(Figure 6). Sub-plots shared their downstream edge with the transect on which they are located.

Within each sub-plot, canopy cover was recorded for all species within the plot. Canopy cover was defined as the percent of the 2m x 2m area covered by each species when viewed from above. Because several structural layers may exist, the cover percentages could collectively total more than 100%. For example, a willow may have 90% canopy cover in a plot, with a rush having 70 % canopy cover in that same plot. To be considered for inclusion in canopy cover estimates herbaceous plants must be rooted within the sub-plot, while trees and shrubs need not be rooted within the plot. Species were recorded using their 4-letter acronyms and a percent cover estimate (to the nearest whole percentage).

Ground cover was also determined for each sub-plot. Unlike canopy cover estimates, ground cover estimates always totaled 100%. Ground cover was divided between litter, rock, bare ground, downed wood, vegetation, cow manure, and other.

Figure 6. Aerial view of Plot 5 transect 17. A transect from plot 5 (#17) is shown with actual measured dominant species identified by color and their 4-letter acronym. Fence posts were located on the historic terrace, and transects traversed the entire historic channel, passing though many different vegetation patches. Sub-plots were located in the center of randomly selected patches (locations are shown as black boxes with red outlines).

Laboratory Analysis

The data analysis sought to integrate all data collected and perform quantitative data analysis (e.g. hierarchical agglomerative cluster analysis) with qualitative evaluations of visual representations of data structure (e.g. ordination) to delineate and describe the vegetation sampled (Figure 7).

Data Screening

The field data were entered into an Excel spreadsheet. The software programs PC-ORD (McCune and Medford 1999) and R (R Project 2007) were chosen for the analyses. The raw transect data, which was composed of species ranked by dominance within each of six structural levels for each patch sampled, was converted into a matrix of values recognizable by the PC-ORD software package using Microsoft's Excel. Ranked scores were assigned to each species in each transect patch sampled as follows: dominant species = 3, first subdominant = 2, second subdominant =1. These ranked scores were assigned to dominant species within each of 6 structural levels. All non-dominant species received zeros. The transect data set suffered from many of the common problems that species-based community data sets generally encounter, including non-normal distributions and a large number of zeros (96.8%).

The data matrix was originally composed of 2084 transect patches (stands) x 81 dominant species. The sites that were devoid of species were removed. These sites were eventually classified as barren ground or open water cover types. Because the analysis was species based and focused on community structure and composition, removal of these sites did not affect results. The final matrix used for the cluster analysis was 1999 transect patches x 81 species. An outlier analysis based on standard error distances from the grand mean revealed none. No transformations were performed.

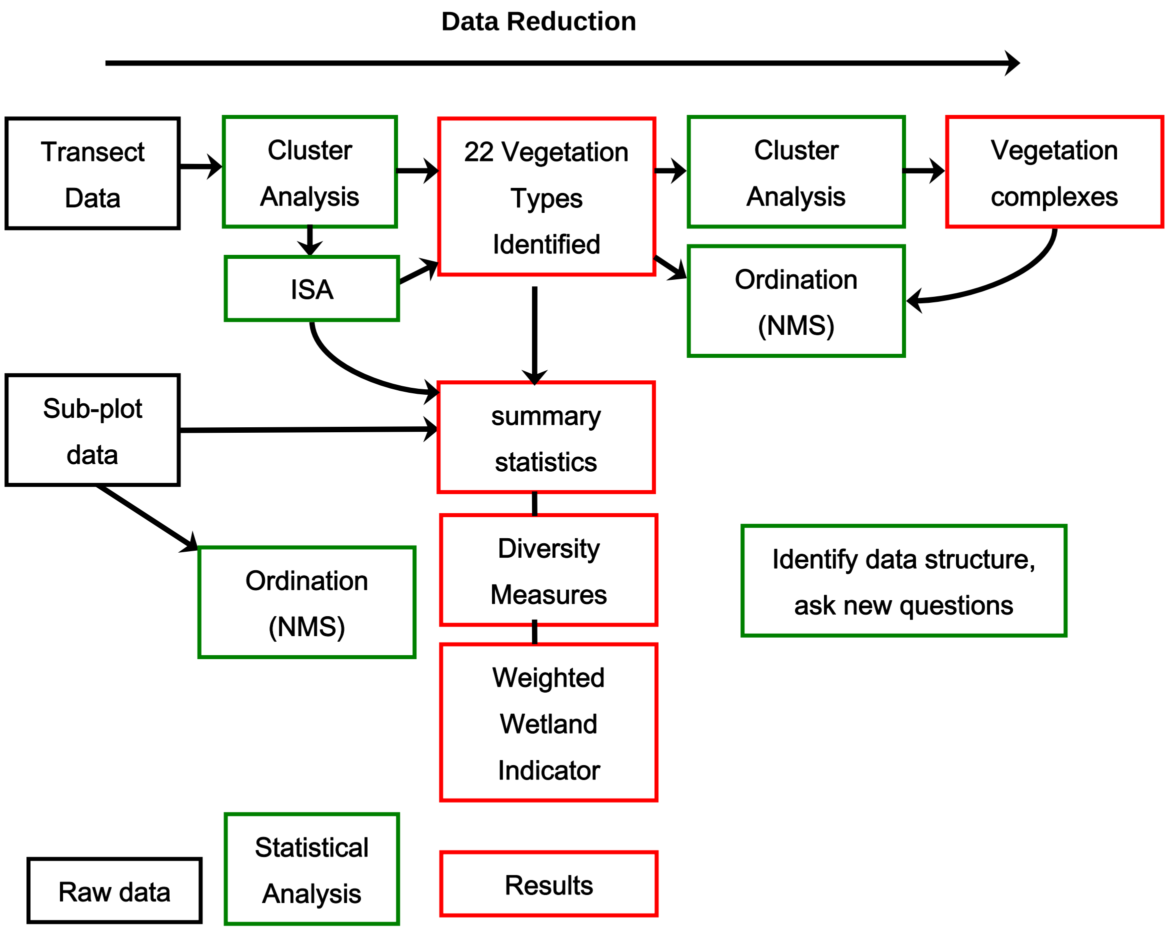

Figure 7. Overall Data Analysis Flow Chart. Conceptual diagram illustrating the different analyses performed in this investigation. Black boxes depict raw data used, green boxes statistical analyses employed, and red boxes the results of those analyses. The statistical procedures Indicator Species Analysis (ISA) and Non-metric Multidimensional Scaling (NMS) are abbreviated.

Hierarchical Agglomerative Cluster Analysis

Hierarchical agglomerative cluster analysis was used to find groups of vegetation patches with the strongest species associations (vegetation types). The basic idea behind this method is to find the two entities (original vegetation samples) that are the closest to each other in species-space, merge them by combining their attributes, and then find the next two closest entities, merge them, and so on until there is eventually one group (McCune and Grace 2002). Sorrenson's (Bray-Curtis) distance measure was chosen because its use of a proportional coefficient based on the ratio of shared abundance to total abundance fit the grouping goal of defining vegetation types by dominant species. Ward's (Orloci's) linkage method was chosen both because it is a space-conserving method and its intuitive basis in the minimization of the error sum of squares. Examination of the dendrogram revealed a satisfactory structure (chaining = 1.40).

The result of the cluster analysis was a dendrogram (Appendix B). Dendrograms are visual representations of the clustering procedure. Depending on study objectives, the number of groups desired is either pre-defined or is determined by examination of the dendrogram structure. The dendrogram is "pruned" or "trimmed" at the appropriate place to delineate the desired number of groups. If the number of groups is not pre-determined, often visual examination of a dendrogram is sufficient to decide where to prune the tree and create the most meaningful groups. For example, the existence of long tails (long horizontal lines) on the dendrogram are often used as an indicator of a good pruning point. Visual examination of the dendrogram did not provide an obvious pruning point. To determine where to trim the dendrogram to produce the most desirable number of groups, Indicator Species Analysis (ISA) was used. Once the number of groups (vegetation types) was determined, a second hierarchical agglomerative cluster analysis was performed on the vegetation types to determine relationships between the communities. The matrix was populated with the mean ranked dominance scores for each species within each vegetation type.

Indicator Species Analysis

Indicator Species Analysis was used to provide more information about the quality of the different grouping scenarios. Indicator Species Analysis is a species data specific procedure developed by Dufrene and Legendre (1997). Indicator Species Analysis is based on the Indicator Value (IV). IV scores (% of perfect indication) are based on a combination of relative abundance and relative frequency of each species within each group, using the following formula:

$$IV_{kj}=100(RA_{kj} \times RF_{kj})$$

Where IV=Indicator Value RA=Relative Abundance and RF= Relative Frequency

High IV scores indicate that species are both loyal to that group (rarely occur in other groups) and frequent within that group (are present in most patches within the group). Therefore, well grouped patches would have species with high IV scores. Each species receives a p-value derived from a monte-carlo randomization. The observed values were compared to values derived from 1000 shuffles of the data, in which group membership was reassigned. The null hypothesis of the significance test was that the maximum indicator value (IV_{max}) observed was no larger than would be expected by chance.

Indicator Species Analysis was run on each of the vegetation groupings determined by the cluster analysis ranging from 10 clusters to 35 clusters. Given the geographic scale, including minimum patch size (2m) and the position of this study in the hierarchical context of the greater project, it was determined that the appropriate number of vegetation types would within this range. The vegetation types defined by this study must be small enough to detect subtle shifts in vegetation type over a relatively short period of time (2-10 years), while remaining simple enough for managers to be able to easily identify types in the field and quickly see vegetation response to management action within these communities. The results of the ISA were graphically examined by plotting the number of species with significant p-values at both $p<.05$ and $p<.01$ levels of significance (Figure 8) and the average p-value (across all species) (Figure 9) for each of the grouping scenarios. The groupings with the lowest average p-value in relation to the number of groups (represented by low points on the Figure 9) and highest number of species with significant p-values in relation to the number of groups (a peak or beginning of a plateau in Figure 8) were sought.

The graphs (Figures 8 and 9) suggested 16, 21, and 33 groupings as the most statistically desirable. Species' composition of each vegetation type determined by 16, 21, 22, and 33 groupings were compared side-by-side. After balancing the data from all the tools used, and the species composition of the vegetation types that would result from each grouping, the dendrogram was trimmed to create 22 groups or vegetation types. This determination was made by evaluating the combination of statistically and ecologically significant factors.

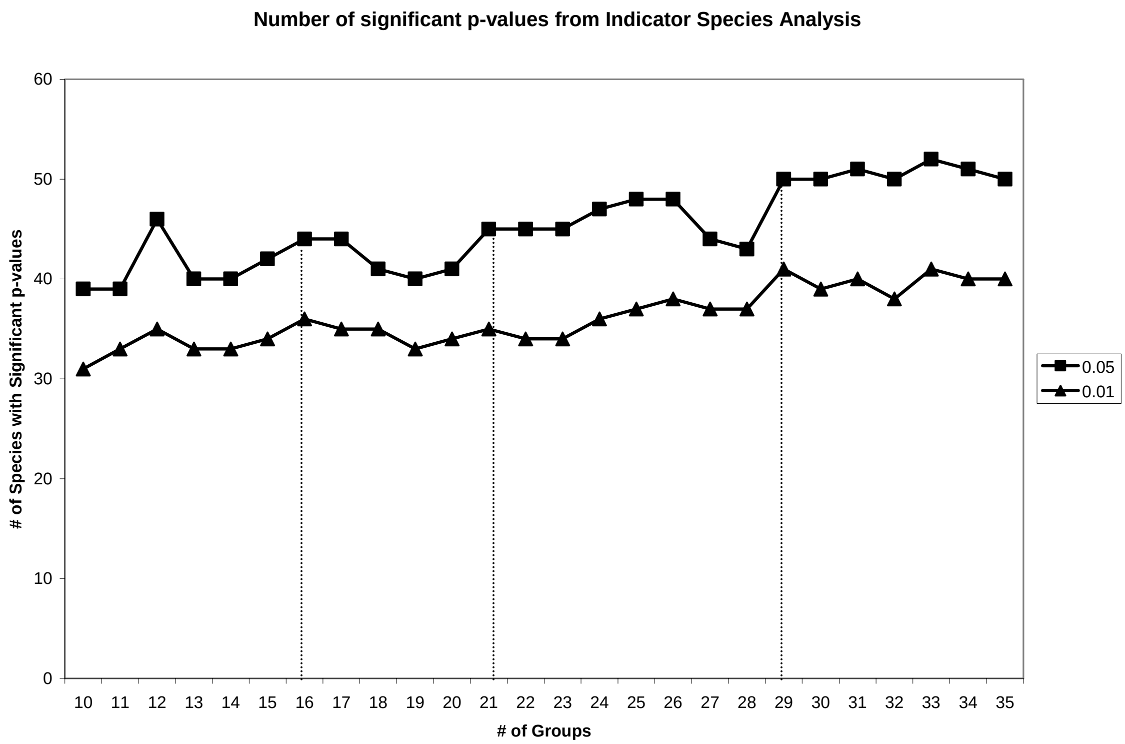

Figure 8. Number of Significant P-values from Indicator Species Analysis. The number of species with p-values at two levels of significance ($p<.05$ = squares and $p<.01$= triangles) for each grouping scenario between 10 groups and 35 groups. The best groupings would be those that have the highest number of significant p-values in comparison with the lowest number of groups. The best groups would therefore be those that have a large increase in the number species with significant p-values relative to the groupings to the left on the x-axis while also possessing a relatively similar number of species with significant p-values to those groupings to the right on the x-axis. The best groupings identified through visual examination are identified by dashed vertical lines.

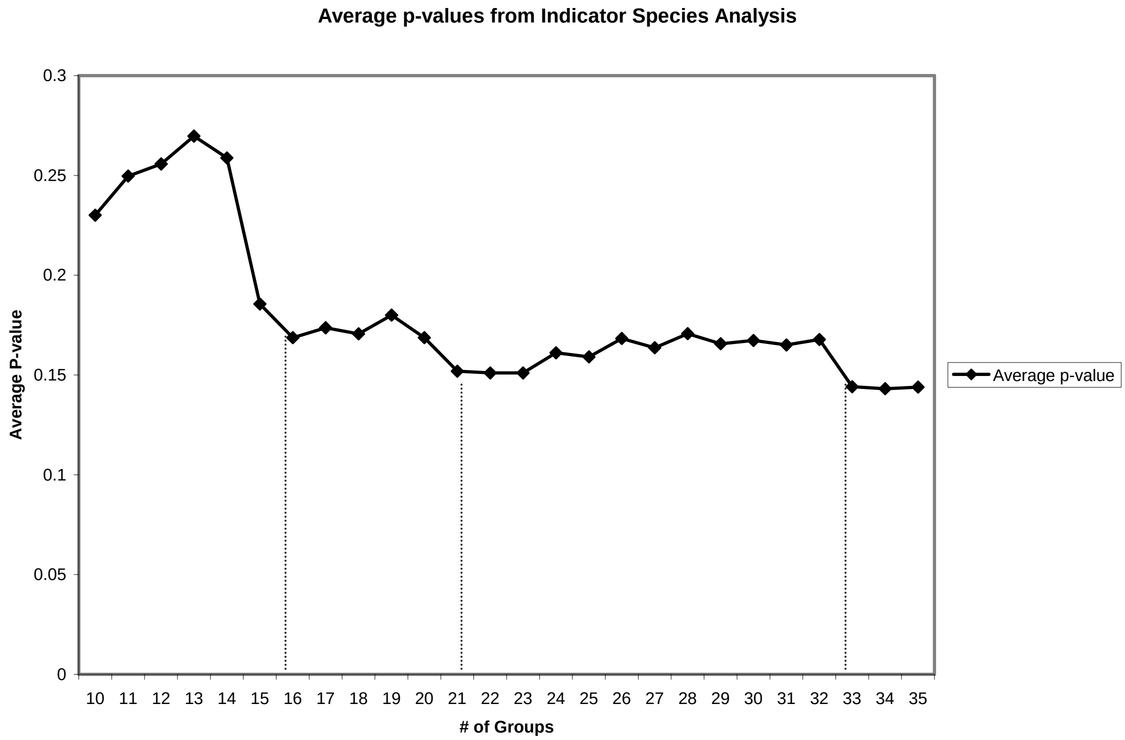

Figure 9. Average P-value from Indicator Species Analysis. The average p-values across all species for selected vegetation type grouping scenarios are plotted. Grouping scenarios involving 10 – 35 groups (vegetation types) are presented. The significance of the average p-value is only to serve as a measure of the quality of the groupings in comparison to each other. Low average p-values in relation to number of groups represent desirable grouping scenarios. Therefore grouping scenarios that represent a relatively large decrease in average p-value from scenarios to the left on the x-axis and relatively equal average p-values to scenarios to the right on the x-axis are most desirable. The best groupings identified through visual examination are identified by dashed vertical lines.

Vegetation Type Summary Statistics

Cover for each vegetation community type was tabulated and analyzed for the combined 5 study plot area (representing the entire study area) and for individual plots (representing reaches). Cover was also summarized for non-vegetative cover types open water and bare ground. For each transect, percent cover for a vegetation type was calculated as the sum of patch lengths of that type, divided by that transect's total length, and then multiplied by 100. For each plot and type, mean percent cover was estimated as the mean of the 21 transect values for percent cover. For the 5-plot area, mean percent cover was estimated as the mean of all 105 transect values for percent cover. The precision of these estimates was summarized with bootstrap-t 95% confidence intervals (Efron and Tibshirani 1993), as this method lacks the assumptions regarding uneven sample sizes, non-normality, and skewness of other methods. Negative lower confidence intervals were set to zero, since negative cover is not physically possible. For less prevalent community types, transect values for percent cover were often zero. When the sample included fewer than 5 unique values, confidence intervals were not applicable. The range of percent cover (minimum, maximum) was reported to provide secondary information about the distribution of cover values around the mean. The objective of the sampling design was to be able to make site-scale inferences. The design supports inference from a plot estimate is to the same 2 km study plot area, and inference from a 5-plot estimate is to the 5-plot area. Since the plots were not randomly located in the study area, extending inference to the entire Lower Owens River floodplain would require making a professional argument that the 5-plots are representative of the entire Lower Owens River floodplain. To the extent that the 5 plots are representative, 5-plot estimates provide estimates of Lower Owens River floodplain condition. The stratified approach, careful selection of representative plots, and large sample size enable managers to draw conclusions about the entire study area from the 5-plot results.

Canopy cover and groundcover estimates for each vegetation type were estimated at the 5-plot scale from data collected at transect subplots. Percent canopy (all species combined) and groundcover for a vegetation type was derived from the mean of percent canopy or cover values for all subplots of that type. Due to the randomization scheme, sample sizes were proportional to community type prevalence, resulting in unequal precision of estimates across community types. Precision was summarized with bootstrap-t 95% confidence intervals (Efron and Tibshirani 1993). Often sample sizes were low for these estimates (e.g. n=6) and their reliability should be viewed within this context.

Tests for differences between the dry reach (Plots 1 and 2) and the wet reaches (Plots 3,4,5) were made to investigate difference between completely dewatered reaches those that retain a minimum flow. Two-sided randomization tests (Manly 1991) were used to test for and estimate differences in mean cover percentage of each vegetation type between the dry reach (plots 1 and 2) and the wet reaches (plots 3, 4, and 5). All native dominated vegetation types were agglomerated into one group and another two-sided randomization test on mean native dominated cover between the dry and wet reaches was performed.

Diversity Measures

Species diversity within and between vegetation types was examined through several metrics. Utilizing the same transect data set used for the ordination analysis, PC-ORD was used to calculate a series of diversity measures utilizing both vegetation types as the unit and also for each species that occurred as a dominant species. Within each vegetation type, species richness (S), evenness as measured by Shannon's Equitability Index (E_H), and Shannon's Diversity Index (H′) were examined. Species richness was defined as the number of species that appeared in the ranked dominance scores within all of the samples within each vegetation type. Shannon's Diversity Index accounts for both abundance and evenness of the species present. The proportion of species *i* relative to the total number of species (p_i) was calculated, and then multiplied by the natural logarithm of this proportion ($\ln p_i$). The resulting product was summed across species, and multiplied by -1:

$$H' = -\sum_{i=1}^{S} p_i \ln p_i$$

Shannon's Equitability Index (E_H), often termed evenness, was calculated by dividing H′ by H_{MAX} [which I defined as ln(S)] and was calculated as such:

$$E_H = H' / H_{MAX}$$

Where E_H= Shannon's Equitability Index, H′= Shannon's Diversity Index, and H_{MAX} = ln(S) where S= species richness

Shannon's Equitability Index assumes a value between 0 and 1 with 1 being complete evenness.

Weighted Wetland Indicator Score

For many years, botanists have been qualitatively evaluating which species are reliably found in either wetland or upland sites, and the frequency with which they are found in each area (Michener 1983) To standardize the process, the U.S. Fish and Wildlife Service National Wetland Inventory compiles a master list (it is constantly re-evaluated and revised) of all wetland indicator species in the U.S. The U.S. Environmental Protection Agency, Soil Conservation Service, and U.S. Army Corps of Engineers have cooperated in this effort (Michener 1983). Each species on the master list has been evaluated by these agencies for wetland or upland site preference by their frequency of wetland occurrence. Species are classified from obligate wetlands (99% estimated probability of occurring in a wetland under natural conditions) to Obligate upland (99% estimated probability of occurring in non-wetlands under natural conditions). There are several facultative designations between these two spectrum extremes. Facultative wetland species prefer wetlands, facultative upland species prefer uplands, and facultative species are able to tolerate both wet and dry conditions (Michener 1983).

Stromberg (2001) used wetland indicator scores as a measure of biotic integrity. She devised a method by which weighted wetland indicator scores were calculated for each of her plots by multiplying assigned wetland weights by the relative abundance. Her method to calculate a weighted average wetland indicator score for each vegetation type was adapted to fit the data set. Vegetation type wetland indicator scores were calculated by multiplying a numerical representation (range 1-5) of established wetland designations (Table 2) by the average rank for each species within a vegetation type. These scores were then summed and divided by the average rank total for that vegetation type:

$$\text{VT WWI} = \frac{\sum (\text{MDscore}_{sp1} \times \text{WI}_{sp1}, \text{MDscore}_{sp2} \times \text{WI}_{sp2}, \ldots)}{\sum (\text{MDscore}_{sp1}, \text{MDscore}_{sp2}, \ldots)}$$

Where VT WWI= Vegetation Type Weighted Wetland Indicator Score, MDscore_{sp1}= mean dominance score for species 1, and WI_{sp1}= Wetland Indicator score for species 1

This produced a weighted wetland indicator score for each vegetation type based on species wetland indicator scores weighted by dominance within each vegetation type. This number represents the wetland designation most associated with that vegetation type. Reach WWI scores were calculated by multiplying each vegetation type's WWI score by its percent cover within each plot. Linear regression was run on the WWI scores for vegetation types against the diversity measures to examine if there was a linear relationship between diversity and the weighted wetland indicator scores.

Table 3. Weighted Wetland Indicator Values. In order to compute the weighted wetland indicator score for each vegetation type, a number was applied to each species. The number was determined by the species wetland indicator listed by the Plants National Database, based on a 1996 revision of Reed (1988).

Number	Code	Wetland Type	Comment
1	OBL	Obligate Wetland	Occurs almost always (estimated probability 99%) under natural conditions in wetlands.
2	FACW	Facultative Wetland	Usually occurs in wetlands (estimated probability 67%-99%), but occasionally found in non-wetlands.
3	FAC	Facultative	Equally likely to occur in wetlands or non-wetlands (estimated probability 34%-66%).
4	FACU	Facultative Upland	Usually occurs in non-wetlands (estimated probability 67%-99%), but occasionally found on wetlands (estimated probability 1%-33%).
5	UPL	Obligate Upland	Occurs in wetlands in another region, but occurs almost always (estimated probability 99%) under natural conditions in non-wetlands in the regions specified. If a species does not occur in wetlands in any region, it is not on the National List.
	NA	No agreement	The regional panel was not able to reach a unanimous decision on this species.
	NI	No indicator	Insufficient information was available to determine an indicator status.
	NO	No occurrence	The species does not occur in that region.
0.5	+	one-half point was subtracted from a score for any + designation	
0.5	-	one-half point was added to a score for any - designation	

Non-Metric Multi-Dimensional Scaling

To visualize differences in community composition between vegetation types, Non-Metric Multi-Dimensional Scaling (NMS) was selected from the array of ordination methods available (Kruskal 1964, Mather 1976). NMS is an iterative method that avoids the assumptions of linear relationships among variables (a weakness of other ordination methods). NMS seeks to minimize "stress," a measure of departure in montonicity in the dissimilarity of original and ordination space. This method is compatible with Sorrenson's distance measure, the distance measure used in the cluster analysis.

NMS was performed on the original transect data set (matrix of 1999 patches x 81 dominant species). Graphical examination of ordination results suggested the data set characteristics made the ordination unreliable and difficult to interpret (possible local minima). The original data set then was reduced to a new matrix of 22 vegetation types (determined by the cluster analysis) x 81 species (Figure 10). Mean species dominance scores were used to populate the new matrix. Outlier analysis revealed none of concern, and descriptive statistics suggested the problems with the original data set had been ameliorated by the data reduction. The resulting data set had 78.7% zeros, a beta diversity of 4.7, and the CV of totals for the rows was 64.5 and the columns was 61.5.

An associated environmental matrix consisting of 9 variables was included in the ordination. The variables included five presence/absence indicators (0-1), study plot number (indicating reach or geographic location), weighted wetland indicator score, and the three diversity measures (S, E, and H'). PC-ORD was set to run NMS using Sorenson's distance measure and the slow and thorough option from a random starting configuration. Forty runs with real data and 50 runs with randomized data were performed. The number of axes was assessed through relationship between stress and dimensionality and used the Monte Carlo randomization.

An ordination was run on individual species canopy cover estimates using mean canopy cover estimates to populate the main matrix. The associated environmental matrix was populated with 13 groundcover estimates. The main matrix was 80.6% zeros, had a beta diversity of 5.2, and the CV of totals for the rows was 61.2 and the columns was 270.7. The same distance measures, linkage methods and software settings were used as the ordination of transect data.

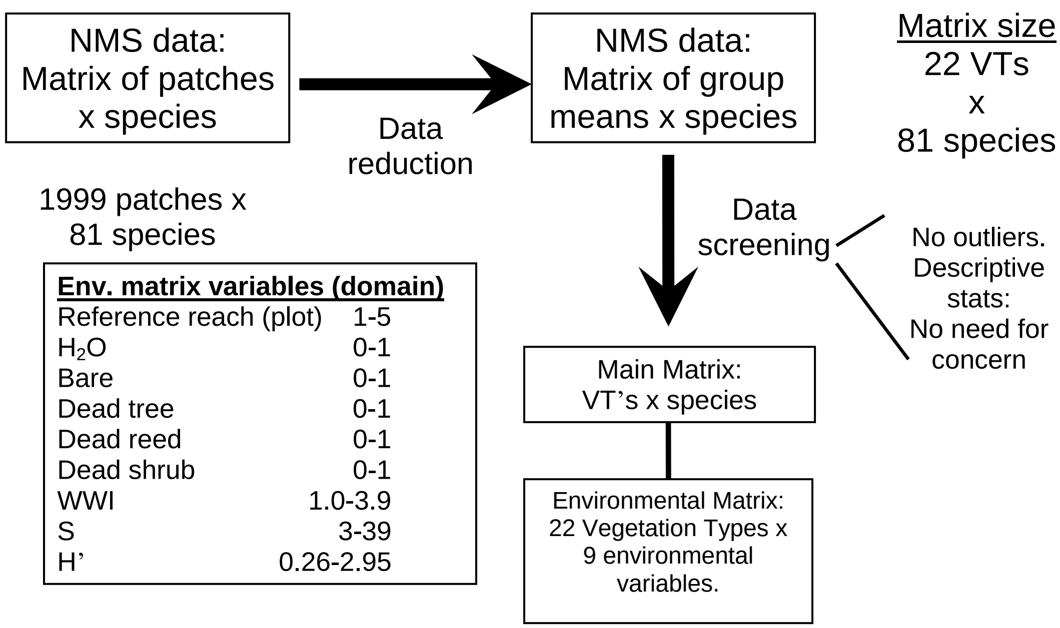

Figure 10.Ordination Analysis. This flow chart depicts the process of determining the appropriate matrices to utilize in ordination analysis. The final main matrix was composed of the 22 vegetation types (VT) and their mean dominance scores for each of the 81 species. The second, or environmental matrix, was composed of 9 variables: 5 means of presence-absence indicators, a mean reference reach number (study plot number), the vegetation type's weighted wetland indicator score (WWI), species diversity (S), and Shannon's Diversity Index (H'). A similar analysis was used to ordinate sub-plot data.

Results

Vegetation Types and Complexes

The hierarchical agglomerative cluster analysis and Indicator Species Analysis revealed 22 vegetation types in the five plot study area (Table 4). With the addition of 2 cover types (Bare ground and Open Water) 24 cover types were attributed to all transect data. Vegetation types were named for dominant species and physiognomy. These vegetation types are described in more detail by a vegetation type summary sheet containing descriptive data in Appendix C.

Table 4. Vegetation Types and Complexes. The 22 vegetation types delineated by this study fall within 6 vegetation complexes.

Willow/Wet Meadow Complex	**Saline Scrub Complex**
Goodding's Willow Woodland	Shadscale Scrub
Coyote Willow/Saltgrass Riparian Shrubland	Greasewood-Seepweed-Shadscale Scrub
Chairmaker's Bullrush-Saltgrass Wet Meadow	Greasewood-Saltbush Scrub
Sunflower-Licorice Wet Meadow	Greasewood-Russian Thistle Scrub
Wildrye-Saltgrass Meadow	Smotherweed-mixed shrubland
Baltic Rush-Saltgrass Wet Meadow	
	Saltbush/Saltgrass Scrub Complex
Emergent Wetland Complex	Saltbush-Saltgrass Scrub Meadow
Bull Rush-Cattail-Willow Wetland	Rabbitbrush-Saltbush-Saltgrass Scrub Meadow
Willow-Cattail-Rush Wetland	Seepweed-Saltbush/Saltgrass Scrub Meadow
	Alkali Sacaton-Saltgrass Meadow
Tamarisk Complex	Saltgrass Meadow
Tamarisk-Saltbush Woodland	
Saltbush-Russian Thistle Scrub	**Common Reed Complex**
Tamarisk Cuttings-Saltbush Scrub	Common Reed-Coyote Willow/Yerba Mansa

Despite sampling the river floodplain between historic terraces, vegetation types adapted to a wide range of environments were found. Xeric shrub vegetation types were dominated by shadscale (*Atriplex confertafolia*), saltbush (*Atriplex lentiformis*), and greasewood (*Sacrobatus vermiculatus*). More mesic shrublands were mainly comprised of rabbitbrush (C*hrysothamnus nauseosus*) and saltbush. Alkali meadows were dominated by alkali sacatone (*Sporobolus airoides*) and the ubiquitous saltgrass (*Distichlis spicata*). The common species in mesic meadows included Baltic rush (*Juncus* *balticus*), saltgrass, creeping wildrye (*Leymus triticoides*), Charmaker's bullrush (*Scirpus americanus*), and yerba mansa (*Anemopsis californica*). Marsh areas were dominated by bullrush or tules (*Sciprus acutus*) and cattail (*Typha latifolia*). Native riparian woodlands were composed mainly of the dominant native tree Goodding's willow (*Salix gooddingii*) with occasional cottonwoods (*Populis fremontii*) and the riparian shrub coyote willow (*Salix exigua*). The exotic tamarisk (*Tamarix ramosissima*), Russian thistle (*Salsola tragus*), and smotherweed (*Bassia spp.*) occur throughout the study area and dominate large sections the detwatered reach.

The second hierarchical agglomerative cluster analysis (Figure 11) identified six vegetation complexes, or collections of similar vegetation types. The two most general classes were Dry/Xeric and Wet/Mesic. The xeric complexes included Saline Scrub, Tamarisk, and Saltbush/Saltgrass Scrub. The mesic complexes were Willow-Wet Meadow, Common reed, and Emergent Wetland. The Willow/Wet Meadow and Saltbush/Saltgrass Scrub complexes had the most vegetation types (6), while Common Reed (1) and Emergent Wetland (2) had the fewest.

Five Plot Area Results

In 2001 and 2002, the Lower Owens River historic floodplain was predominantly shrub-dominated. Over half (52%) of the five-plot study area was covered by shrub dominated vegetation types. About 24% was covered by grasslands. The remaining quarter was composed of emergent wetland vegetation types (11%), woodlands (10%) and herbaceous vegetation types (1%). The remaining 2% was dominated by cover types devoid of vegetation (bare ground and open water).

Throughout the five plot study area, roughly three-quarters of the area was covered by vegetation types dominated by native vegetation (74%). Vegetation types dominated by exotic species covered 24% of the study area, while only 2% of the area was completely devoid of species.

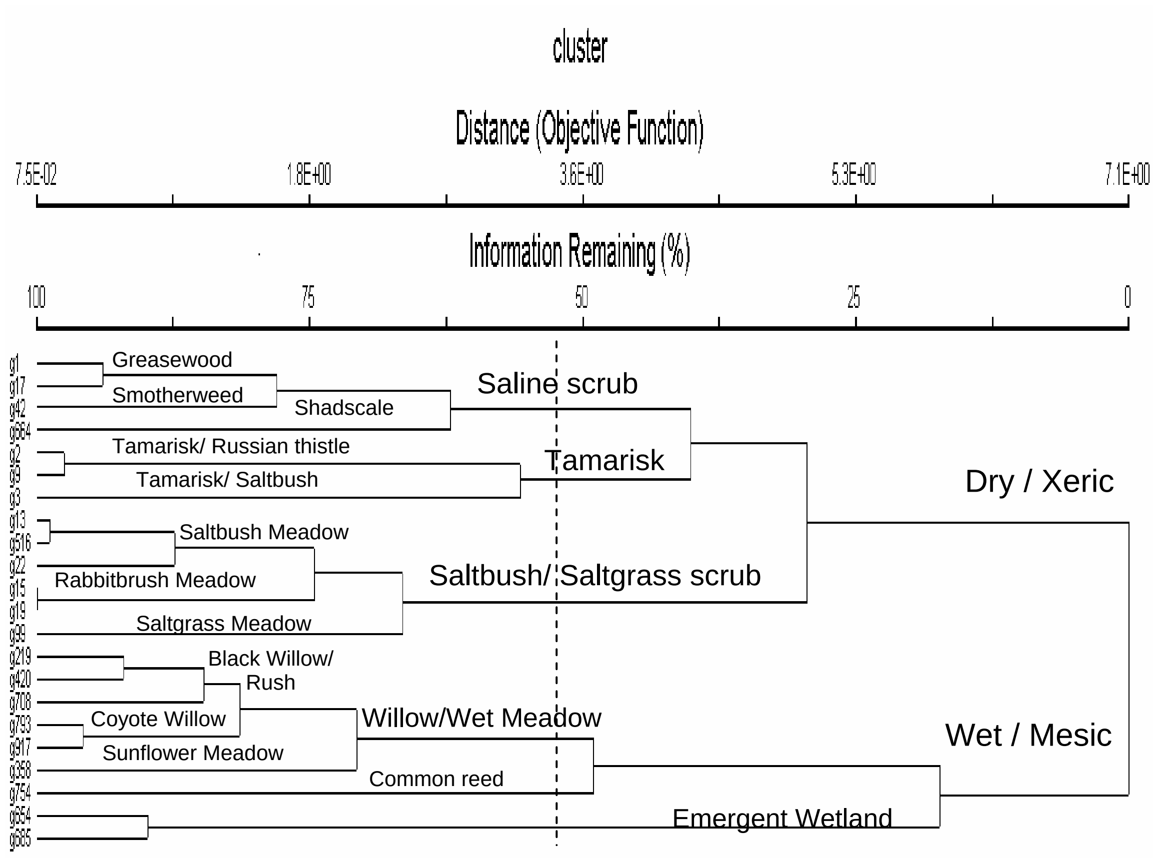

Figure 11. Cluster of Vegetation Types Dendrogram. The vegetation types delineated and described in this study appear on the left of the dendrogram, represented by a code number (this code may be found in Table 3). As the dendrogram is read left to right, the two closest groups in species space are merged first, the centoids are adjusted and then the closest of the new groups is merged and so on until eventually only two groups remain. These two most general groups are Dry/ Xeric and Wet/Mesic, and each contains three complexes. As the dendrogram is read left to right, information lost as the groups are merged. The amount of information remaining is shown on a percentage scale of Information remaining. The Distance (Objective Function=E) is the sum of the error sum of squares from each centroid to the items in that group. Labels represent an appropriate characterization for the agglomerated vegetation types represented by the line below the label. The Vegetation Complex level was determined by trimming the dendrogram at the dashed line with slightly more than 50% of the information remaining.

The most common vegetation type within the 5-plot study area was the Alakali Sacaton/Saltgrass Meadow type covered 11% (95% CI of 8.7-13.9% from a bootstrap-t) of the study area. This vegetation type appeared in every plot, but predominantly in plots 3-5 (wet reaches), with a mean plot position of 4.0 – meaning that the geographic center of this vegetation type's distribution was plot 4. Shrub dominated vegetation types containing Russian thistle were the second and third most common vegetation types, as

Saltbush/Russian Thistle Scrub covered 10% (95% CI of 6.9-13.1%) and Greasewood/ Russian Thistle Scrub covered 9% (95% CI of 6.6-11.5%) and were found predominantly in the first two plots (in the dry reach).

The most common mesic (wet) vegetation types (Table 5) were the Willow/Cattail-Rush Wetland covering 6% (95% CI of 4.5-8.5%) followed by the Goodding's Willow Woodland, the most common tree dominated vegetation type, covering 6% (95% CI of 4.4-7.5%). The three least common vegetation types were all covered less than 1% of the five plot area and included Sunflower-Licorice Wet Meadow (0.7%, 95% CI of 0.4-1.1%), Coyote Willow/Saltgrass Riparian Shrubland (0.8%. 95% CI of 0.4-1.6%), and Common Reed-Coyote Willow/Yerba Mansa (0.9%, 95% CI of 0.5-1.5%).

The mean patch length for all vegetation patches within the five plot area was 19.2 m. Most of the shrublands averaged over 20m per patch, including Greasewood-Saltbush (25.9 m) and Shadscale Scrub (23.7m). The vegetation type with the largest mean patch size was the Bullrush-Cattail-Willow Wetland (28.5 m). The other component of the emergent wetland or marsh complex, Willow/Cattail-Rush Wetland, also had a large mean patch size (24.2m). Two wet meadow vegetation types, the Sunflower-Licorice Wet Meadow (9.6m) and the Chairmaker's Bullrush-Saltgrass Wet Meadow (8.4m) had the smallest mean patch length.

Table 5. Vegetation Type Cover and Characteristics. Vegetation types are listed in order of mean cover of the study area (five 2k study plots). To obtain cover estimates for the entire 5-plot study area, all of the transects were used as experimental units (n=105). No vegetation types appeared on all transects (Min=0 for all types). Estimates include the maximum percent cover for any transect (Max) the mean cover for all transects (Mean) and the lower confidence limit (LCL) and the upper confidence limit (UCL) for the mean from a bootstrap-t distribution. Mean length is the mean transect distance covered by each patch of the given type. The weighted wetland indicator score (WWI), species diversity (S), Evenness (E), Shannon's Diversity Index (H').

Code	Vegetation Type	Max (%)	LCL (%)	Mean (%)	UCL (%)	Structure	Length (m)	WWI	S	E	H′
15	Alkali Sacaton/Saltgrass Meadow	62.3	8.7	11.1	13.9	grass	22.8	2.5	28	0.6	1.9
9	Saltbush/Russian Thistle Scrub	62.2	6.9	9.7	13.1	shrub	23.3	3.2	15	0.6	1.5
2	Greasewood/Russian Thistle Scrub	45.3	6.6	8.8	11.5	shrub	21.7	3.9	14	0.4	1.0
13	Saltbush/Saltgrass Scrub Meadow	55.9	6.3	8.3	11.2	shrub	22.6	2.6	11	0.5	1.2
17	Greasewood/Seepweed-Shadscale Scrub	25.6	5.1	6.4	7.8	shrub	23.2	3.2	15	0.7	1.9
654	Willow/Cattail-Rush Wetland	46.0	4.5	6.2	8.5	emergent	24.2	1.1	20	0.5	1.5
19	Rabbitbrush-Saltbush/Saltgrass Scrub Meadow	38.1	4.5	6.1	7.9	shrub	19.9	2.6	24	0.7	2.1
219	Goodding's Willow Woodland	34.2	4.4	5.7	7.5	tree	14.6	1.8	39	0.7	2.4
99	Saltgrass Meadow	36.8	3.8	5.3	7.5	grass	19.5	2.0	6	0.1	0.3
22	Tamarisk/Saltbush Woodland	41.9	3.4	4.7	6.6	tree	14.0	2.4	14	0.5	1.3
685	Bull Rush-Cattail-Willow Wetland	48.5	2.5	4.1	6.7	emergent	28.5	1.0	10	0.6	1.3
1	Greasewood-Saltbush Scrub	25.7	2.8	4.1	5.6	shrub	25.9	3.5	6	0.6	1.0
664	Shadscale Scrub	19.9	2.5	3.3	4.4	shrub	23.7	3.8	15	0.7	1.9
3	Tamarisk Cuttings-Saltbush Scrub	49.2	1.5	3.0	5.9	shrub	20.9	2.4	3	0.7	0.8
420	Baltic Rush-Saltgrass Wet Meadow	23.5	1.7	2.5	3.6	grass	14.4	1.6	30	0.7	2.5
516	Seepweed-Saltbush/Saltgrass Scrub Meadow	18.4	1.4	2.1	3.1	shrub	18.6	2.6	12	0.6	1.6
917	Wildrye-Saltgrass Meadow	23.7	1.3	2.0	3.1	grass	10.9	2.2	21	0.6	1.8
24	Barren Ground	13.4	1.2	1.7	2.3	None	9.0	N/A	N/A	N/A	N/A
42	Smotherweed-mixed shrubland	18.7	0.6	1.2	2.2	herbaceous	18.8	3.1	12	0.7	1.8
708	Chairmaker's Bullrush-Saltgrass Wet Meadow	14.8	0.7	1.2	1.9	emergent	8.4	1.4	21	0.6	1.9
754	Common Reed-Coyote Willow/Yerba Mansa	10.3	0.5	0.9	1.5	shrub	15.5	1.7	15	0.7	1.9
793	Coyote Willow/Saltgrass Riparian Shrubland	15.5	0.4	0.8	1.6	shrub	10.9	1.8	19	0.8	2.3
358	Sunflower-Licorice Wet Meadow	9.3	0.4	0.7	1.1	herbaceous	9.6	2.1	30	0.9	2.9
23	Open Water	4.7	0.1	0.2	0.5	None	12.6	N/A	N/A	N/A	N/A
	Totals			100.0			19.2	2.5			

Indicator Species Analysis

Beyond informing the delineation of vegetation types, the ISA identified species which were the best indicators of each vegetation type (Table 6). Indicator values are based on a ratio of frequency to fidelity, a score of 100 represents perfect indication; such a species always occurs in a vegetation type and is never present in other vegetation types. For this reason, more common species are often poor indicators. For example, saltgrass was present in all Saltgrass Meadow patches (100% frequency), was always dominant (mean dominance score=3.0), but was the lowest indicator (13) in Table 4 because it appeared in so many other vegetation types. This is true for other common species (e.g. *Atriplex lentiformis* and *Sarcobatus vermiculatus*). Common species have other drawbacks as indicator species. Greasewood was the top indictor species for two vegetation types, Greasewood/Saltbush Scrub (IV=31) and Greasewood/Seepweed-Shadscale Scrub (IV=30). However, as would be expected by the vegetation type name, saltbush is the second best indictor in of Greasewood-Saltbush Scrub (84% frequency, IV=9), while Seepweed (81% frequency, IV=27) was the second best indicator of the Greasewood/Seepweed-Shadscale Scrub type. Some diverse vegetation types lacked good indictor species. One of the most diverse vegetation types, Sunflower-Licorice Wet Meadow, had the lowest mean dominance score for its best indictor, sunflower (*Helianthus annuus*) at 1.2, was the only type whose best indicator was less then 95% of the patches sampled (46%), yet it had an indicator value of 24. This suggests that sunflower may be quite loyal to the vegetation type, but is not always present as one of the top three dominant species in its vegetation patch.

Table 6. Indicator Species Values by Vegetation Type. For each vegetation type, the species with the highest indicator value (IV, range: 1-100), the mean ranked dominance score (Mean Dom., range 0-3.0), and the frequency that species appeared in a plot classified as that vegetation type (%frequency), and the code assigned each vegetation type by PC-ORD is presented for reference.

Code	Vegetation Type	Best Indicator Species	Mean Dom.	% Frequency	IV
1	Greasewood-Saltbush Scrub	*Sarcobatus vermiculatus*	2.7	100	31
2	Greasewood/Russian Thistle Scrub	*Salsola tragus*	3.0	100	44
3	Tamarisk Cuttings-Saltbush Scrub	*Tamarisk* cuttings	3.0	100	97
9	Saltbush/Russian Thistle Scrub	*Salsola tragus*	3.0	99	43
13	Saltbush/Saltgrass Scrub Meadow	*Atriplex lentiformis*	3.0	99	15
15	Alkali Sacaton/Saltgrass Meadow	*Sporobolus airoides*	2.9	99	67
17	Greasewood/Seepweed-Shadscale Scrub	*Sarcobatus vermiculatus*	2.8	95	30
19	Rabbitbrush-Saltbush/Saltgrass Scrub Meadow	*Chrysothamnus nauseosus*	2.7	97	36
22	Tamarisk/Saltbush Woodland	*Tamarix ramosissima*	3.0	99	51
42	Smotherweed-mixed shrubland	*Bassia hyssopifolia*	3.0	100	88
99	Saltgrass Meadow	*Distichlis spicata*	3.0	100	13
219	Goodding's Willow Woodland	*Salix gooddingii*	2.9	95	51
358	Sunflower-Licorice Wet Meadow	*Helianthus annuus*	1.2	45	24
420	Baltic Rush-Saltgrass Wet Meadow	*Juncus balticus*	2.7	97	60
516	Seepweed-Saltbush/Saltgrass Scrub Meadow	*Suaeda moquinii*	3.0	100	47
654	Willow/Cattail-Rush Wetland	*Typha latifolia*	3.0	100	58
664	Shadscale Scrub	*Atriplex confertifolia*	2.8	95	60
685	Bull Rush-Cattail-Willow Wetland	*Scirpus acutus*	2.7	100	83
708	Chairmaker's Bullrush-Saltgrass Wet Meadow	*Scirpus americanus*	2.9	100	63
754	Common Reed-Coyote Willow/Yerba Mansa	*Phragmites australis*	3.0	100	87
793	Coyote Willow/Saltgrass Riparian Shrubland	*Salix exigua*	3.0	100	71
917	Wildrye-Saltgrass Meadow	*Leymus triticoides*	2.8	98	46

Crosswalk

As discussed in the introduction, any grouping of vegetation into communities, vegetation types, complexes, or any other classification depends on a number of factors including scale, methods, philosophy, and objectives. To help to place this study's vegetation types in to context, a crosswalk (Table 7) was devised to illustrate the relationship between the 22 vegetation types and two cover types identified by this study, and four other classification systems. These studies vary in methods, scale, and objectives. Two systems are state-wide and two are specific to the Owens Valley, as this study is. The National Diversity Data Base/Holland (1986) and California Native Plant Society (Sawyer and Keeler-Wolf 1995) classification systems were devised to classify all of the vegetation types in the state of California. The Greenbook (Inyo County and City of Los Angeles 1990) and Whitehorse Associates (2004) systems were designed specifically for the Owens Valley. The Greenbook system was devised to classify all Owens Valley Lands, with an emphasis on uplands in order to monitor vegetation change associated with groundwater pumping. The Whitehorse Associates system was designed to classify all Lower Owens River Project lands (which includes the riverine-riparian area, adjacent uplands, Blackrock Waterfowl Management Area, and the Delta Habitat Area) with an emphasis on the riparian area. The project area and objectives are very similar to this study; however, the Whitehorse Associates study was a mapping effort designed to operate on a smaller scale. Therefore it covered a larger area and had a larger minimum patch size.

Table 7. Crosswalk Between Selected Vegetation Classification Systems.

Whitehorse Associates (2004)	NDDB/ Holland (1986)	Greenbook (1990)	Sawyer and Keeler-Wolf (1995)	This Study
Water	None	Open water	None	Open Water
Reedgrass	Transmontane alkali marsh	Transmontane alkali marsh	Common reed series	Common Reed-Coyote Willow/Yerba Mansa
Marsh			Cattail series	Willow/Cattail-Rush Wetland
			Bullrush series	Bull Rush-Cattail-Willow Wetland
Wet Alkali meadow (rush/sedge)		Rush-sedge meadow*	Sedge series	Sunflower-Licorice Wet Meaadow
				Chairmaker's Bullrush-Saltgrass Wet Meadow
				Baltic Rush-Saltgrass Wet Meadow
Irrigated meadow	Irrigated agricultural land	Irrigated agricultural land		
Dry alkali meadow	Valley sacaton grasslands	Alkali meadow	Alkali sacaton series	Alkali Sacaton-Saltgrass Meadow
	Alkali meadow		Saltgrass sereies	Saltgrass Meadow
	Valley wildrye grasslands		Creeping ryegrass series	Wildrye-Saltgrass Meadow
Riparian Shrub (willow)	Modoc-Great Basin riparian scrub	Modoc-Great Basin riparian scrub	Narrowleaf willow series	Coyote Willow/Saltgrass Riparian Shrubland
Riparian Forest (willow)	Modoc-Great Basin cottonwood/willow riparian forest and Mojave riparian forest	Modoc-Great Basin cottonwood/willow riparian forest and Mojave riparian forest	Black willow series	Goodding's Willow Woodland
Riparian Forest (cottonwood)			Freemont Cottonwood series	
Alkali scrub/meadow	Desert saltbush scrub	Rabbitbrush meadow*	Rubber rabbitbrush series	Rabbitbrush-Saltbush/Saltgrass Scrub Meadow
		Nevada saltbush meadow*	Mixed saltbush series	Saltbush/Saltgrass Scrub Meadow
		Desert saltbush scrub		Seepweed-Saltbush/Saltgrass Scrub Meadow
Alkali scrub	Desert greasewood scrub or Desert sink scrub	Desert greasewood scrub or Desert sink scrub	Greasewood series	Greasewood-Saltbush Scrub
				Greasewood/Russian Thistle Scrub
				Greasewood/Seepweed-Shadscale Scrub
	Desert saltbush scrub	Nevada saltbush scrub*	Mixed saltbush series	Tamarisk Cuttings/Saltbush Scrub
				Saltbush/Russian Thistle Scrub
		Non-native vegetation and misc. lands*		Smotherweed-mixed shrubland
	Shadscale scrub	Shadscale scrub	Shadscale series	Shadscale Scrub
	Great Basin mixed scrub	Great Basin mixed scrub		
Tamarisk	Tamarisk scrub	Tamarisk scrub	Tamarisk series	Tamarisk/Saltbush-Russian Thistle
				Tamarisk/Saltbush Woodland
Barren	none	Barren lands	none	Barren Ground
Streambar				
structure		none		

Several vegetation classification systems exist for the study area. The vegetation types delineated in this study are shown in the right hand column. These types are placed within a hierarchical and contextual framework by cross walking these types to other existing vegetation classifications that vary in methods, scale, and objectives. The National Diversity Data Base/Holland (1986) and California Native Plant Society (Sawyer and Keeler-Wolf 1995) classification systems were devised to classify all of the vegetation types in the state of California. The Greenbook (Inyo County and City of Los Angeles 1990) and Whitehorse Associates (2004) systems were designed specifically for the Owens Valley. The Greenbook system was devised to classify all Owens Valley lands, with an emphasis on uplands in order to monitor vegetation change associated with groundwater pumping. The Whitehorse Associates system was designed to classify all Lower Owens River lands, with an emphasis on the riparian area. The project area and objectives are very similar to this study; however, the Whitehorse Associates study was a mapping effort designed to operate on a smaller scale.

Ground Cover and Canopy Cover

The Coyote Willow/Saltgrass Riparian Shrubland had the highest canopy cover (Table 8) of all vegetation types (113%), but had a wide 95% confidence interval (78-113%) due it is small sample size (n=7). Canopy cover values for six of the top seven vegetation types in terms of canopy cover were from the Willow/ Wet Meadow complex, including Goodding's Willow Woodland (93%, 95% CI of 78-110%), which had a more reliable sample size (n=43). The vegetation types with the lowest estimated canopy cover were invasive dominated and upland types. Greasewood/Russian Thistle scrub and Tamarisk Cuttings-Saltbush Scrub were the vegetation types most devoid of canopy cover (6% and 7% respectively) with the upland vegetation types Shadscale and Greasewood-Saltbush Scrub also under 20% canopy cover.

Ground cover followed a similar trend, as wet meadow types had small amounts of bare ground and higher vegetation cover than upland and exotic dominated vegetation types. Downed wood was infrequent across all vegetation types save one, as estimates of cover are very low with wide 95% confidence interval spreads. The exception to this trend was the eradicated tamarisk vegetation type (where tamarisk stands had been cut down and their stumps treated by active restoration management), roughly one-third of which were covered in downed wood (30%, 95% CI 9-48%). Litter was somewhat uniform across all vegetation types (~20-60%), except for the sparsely vegetated upland Shadscale Scrub type, which had a very low litter estimate (5%, 95% CI 2-13%) coupled with a high bare ground (90%, 95% CI 78-96%).

Table 8. Vegetation Type Canopy Cover and Ground Cover. Vegetation types are listed in order of estimated mean canopy cover, which is the sum of all species canopy cover within the 2m x 2m sub-plots, enabling cover in multiple structural levels to total more than 100%. These estimates have unequal sample sizes, due to the randomization scheme (n= 5-57). Selected ground cover estimates are provided for bare ground, downed wood, litter and vegetation. Groundcover for all sub-plots was classified into one of several additional rare categories not presented here, including water, cow manure, rock, trash, etc. Estimates (Mean) and the lower confidence limit (LCL) and the upper confidence limit (UCL) for the mean from a bootstrap-t distribution. Confidence limits that were unreliable due to variance and sample size were given NA and those over 100 for ground cover were set to 100, as it is impossible to have more than 100% ground cover.

code	Vegetation type	n	Canopy Cover			Bare ground			Downed wood			Litter			Vegetation		
			lcl	mean	ucl	lcl	mean	ucl	lcl	mean	ucl	lcl	mean	ucl	lcl	mean	ucl
793	Coyote Willow/Saltgrass Riparian Shrubland	7	78	113	184	2	13	33	0	9	96	24	45	53	9	33	47
917	Wildrye-Saltgrass Meadow	17	88	102	115	3	6	12	0	4	32	19	28	37	48	60	72
754	Common Reed-Coyote Willow/Yerba Mansa	6	55	99	241	NA	1	NA	NA	0	NA	48	65	100	NA	32	NA
358	Sunflower-Licorice Wet Meadow	7	25	95	172	NA	5	NA	NA	3	NA	8	36	71	0	25	39
219	Goodding's Willow Woodland	43	78	93	110	5	9	17	3	5	9	28	36	44	31	39	47
708	Chairmaker's Bullrush-Saltgrass Wet Meadow	8	57	87	128	1	10	25	NA	0	NA	25	45	67	23	45	70
420	Baltic Rush-Saltgrass Wet Meadow	21	59	84	109	2	6	32	NA	1	NA	20	31	44	32	48	62
19	Rabbitbrush-Saltbush/Saltgrass Scrub Meadow	35	57	71	85	13	18	26	2	4	10	34	43	53	23	31	40
99	Saltgrass Meadow	24	55	70	82	5	10	20	1	2	4	31	40	49	29	38	46
22	Tamarisk/Saltbush Woodland	35	53	67	78	4	7	18	3	6	19	51	60	68	17	24	32
654	Willow/Cattail-Rush Wetland	20	39	63	89	0	4	100	NA	2	NA	13	26	53	18	34	55
15	Alkalai Sacatone-Saltgrass Meadow	57	49	61	71	21	29	37	1	2	4	23	28	34	30	37	45
685	Bull Rush-Cattail-Willow Wetland	10	15	57	92	NA	1	NA	NA	5	NA	7	28	71	6	22	53
13	Saltbush/Saltgrass Scrub Meadow	42	39	50	64	11	18	29	2	4	13	38	47	57	18	27	37
516	Seepweed-Saltbush/Saltgrass Scrub Meadow	16	30	44	65	34	53	70	0	1	3	13	21	40	9	17	30
42	Smotherweed-mixed shrubland	5	0	37	421	NA	50	NA	NA	0	NA	8	31	100	0	18	100
17	Greasewood/Seepweed-Shadscale Scrub	24	21	30	50	47	64	75	NA	1	NA	11	17	30	7	13	31
9	Saltbush/Russian Thistle Scrub	43	18	25	35	25	35	46	2	4	16	37	47	57	6	11	20
1	Greasewood-Saltbush Scrub	17	9	17	39	39	58	73	0	4	69	19	33	51	3	5	8
664	Shadscale Scrub	13	6	12	28	78	90	96	NA	0	NA	2	5	13	2	4	14
3	Tamarisk Cuttings-Saltbush Scrub	16	0	7	91	9	24	48	15	30	52	27	40	57	1	7	61
2	Greasewood/Russian Thistle Scrub	31	4	6	10	62	75	82	0	2	30	11	19	32	3	4	5
24	Barren Ground	19	1	1	3	50	72	85	NA	1	NA	14	26	44	0	1	1
23	Open Water	0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

Diversity Measures

In general, the vegetation types with the highest diversity measures were mesic vegetation types, especially wet meadow types, for two of the three diversity measures examined (Tables 7 and 9). The dominant species richness (S) and Shannon Diversity Index (H') followed this trend. Though the wet meadow types scored high on evenness, the results were less similar for evenness scores than the other two metrics. The only native tree vegetation type identified in this study, the Goodding's Willow Woodland, was one of the most diverse vegetation types, including the highest richness (S=39, H'=2.44). The two wet meadow vegetation types, Sunflower-Licorice Wet Meadow (H'=2.95) and Baltic Rush-Saltgrass Wet Meadow (H'=2.49) types both had 30 different dominant species and the two highest Shannon's Index values. As would be expected, the lowest diversity index scores were found in the heavily impacted Tamarisk Cuttings-Saltbush (S=3, H'=0.76), as well as the homogenous Greasewood-saltbush (S=6, H'=1.00) the Saltgrass Meadow (S=6, H'=0.26) vegetation types.

The highest species evenness (E) was found in two wet meadow vegetation types, as Sunflower-Licorice Wet Meadow had the highest evenness (0.87) while Baltic Rush-Saltgrass Wet Meadow type had 0.73. These two vegetation types scored high on all of the diversity indexes examined. In contrast, the Coyote Willow/Saltgrass Riparian Shrubland type had exceptionally high evenness (0.77) in comparison with other diversity measures. The vegetation types with the lowest evenness were the Saltgrass Meadow (0.15) and the Greasewood/Russian Thistle Scrub (0.39)

The species that occurred in the most vegetation types were common shrubs (rabbitbrush and saltbush, S=17) and saltgrass (S=15). Tamarisk also occurred in more than half of the vegetation types (S=13).

Table 9. Vegetation Types with High Diversity Measures. Rankings (from highest to lowest) among all vegetation types are presented for selected wet meadow complex types. Diversity indices are presented for species richness (S), evenness (E), Shannon's Diversity Index (H'), as well as Canopy cover, and vegetation groundcover.

Vegetation Type	S	E	H'	Canopy Cover	Veg
Goodding's Willow Woodland	1	9	3	5	4
Sunflower-Licorice Wet Meadow	2	1	1	4	2
Baltic Rush-Saltgrass Wet Meadow	3	3	2	7	2
Coyote Willow/Saltgrass Riparian Shrubland	9	2	4	1	9

Weighted Wetland Indicator Score

Weighted wetland indicator (WWI) scores were used to describe the vegetation types' location on the wetland type spectrum as determined by their dominant species. The two marsh vegetation types, Bullrush-Cattail-Willow Wetland (1.0) and Willow-Cattail-Rush Wetland (1.1) weighted wetland indicator score determined that they were obligate wetlands, while the other emergent graminoid dominated type, Chairmaker's Bullrush-Saltgrass Wet Meadow, scored slightly higher (WWI=1.4) classifying it as an obligate wetland (-). The most diverse vegetation types fell predominantly in the facultative wetland category (FAC+ = 1.5 to FAC- = 2.5) with the three most diverse vegetation types WWI scores in the range of 1.4-2.1 (Table 5). The vegetation types that had the highest WWI scores were shrublands dominated by shadscale, Russian thistle, and greasewood.

Study plot weighted wetland indictor score were computed multiplying all of the weighted wetland indicator scores for each vegetation type by their percent cover in each plot. An overall WWI score for the five-plot area was also derived in a similar manner. The overall score, for all vegetation types across the 5 plot study area was 2.3 (FAC-). The plot scores (Figure 12) ranged between 2.0 (facultative wetland, plot 4) and 2.8 (Facultative +, plot 1). The native dominated vegetation types had a cumulative score of

2.2 (facultative wetland) compared with 2.9 (facultative) for vegetation types dominated by exotic species.

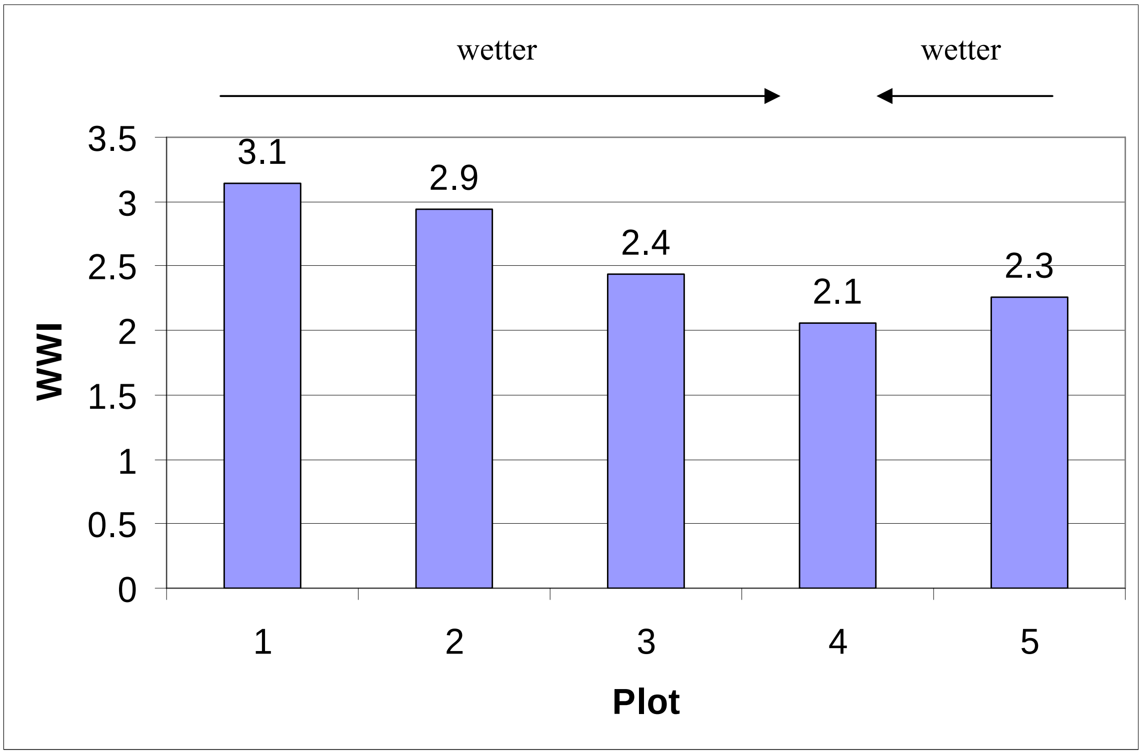

Figure 12.Weighted Wetland Indicator by Plot. Cumulative weighted wetland indicator scores by plot. Higher scores denote greater dominance by upland vegetation types, while lower scores are associated with dominance by wetland vegetation types. The range of values used to compute this metric ranged from 1 (Obligate Wetland) to 5(Obligate Upland).

Individual Study Plot Results

While each study plot was 2 km in length, valley bottom width, and hence transect length, varied from plot to plot. Transect data was collected for 2084 vegetation patches over 39,901 meters in the 5 different study plots. Transects were established to encompass the entire riparian area and the river valley between high terraces. Plots 1-3 had similar valley widths (321-330 m), while plots 4 and 5 had significantly larger valley widths (399 and 513 m) and therefore transect distances (Figure 13).

Vegetation type cover varied widely between plots. The most common vegetation types in plots 1 and 2 (both within the dry reach) were dominated by exotic vegetation predominantly Russian thistle and tamarisk (tables 10 and 11). In plot 3 (Table 12), plot 4 (Table 13) and Plot 5 (Table 14), native dominated vegetation types covered the largest area, specifically the Alakali Sacaton-Saltgrass Meadow. Each study plot is described in terms of these results below.

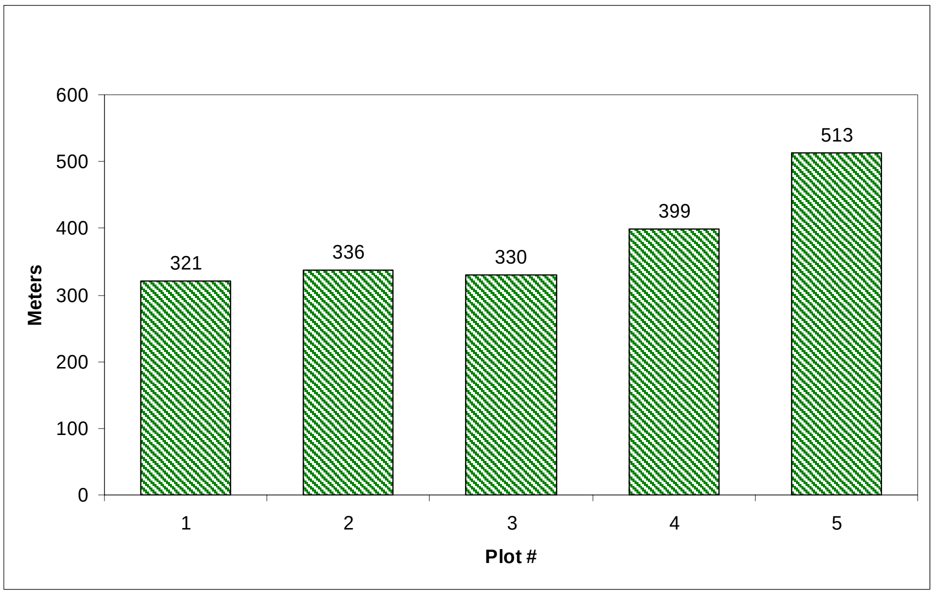

Figure 13. Mean Valley Bottom Width by Plot. The aggregate distance of all transects sampled within each plot is presented. Because transects were designed to encompass the entire river valley, total transect distance per plot is a measure of valley width. Distances should be viewed in relation to each other, not as raw values.

Plot 1

Roughly three-quarters of plot 1 was covered by vegetation types dominated by exotic species (73%). A large percentage of the plot was covered by two shrub communities that contain the exotic annual Russian thistle, which together cover approximately 50% of the plot. The Saltbush/Russian thistle Scrub vegetation type covered 28% (95% CI of 19.0-36.7%) of the plot, while the Greasewood/Russian thistle vegetation type covered a slightly smaller percentage of the plot, an estimated 23% (95% CI of 17.3-28.1%), and appeared on every transect (Min=5.1%). Tamarisk was widespread throughout this plot (as well as Plot 2), but at the time of the survey, an eradication program was underway. Six percent (95% CI of 3.3-10.8%) of the plot was covered by Tamarisk/Saltbush Woodland, while an additional 14% (95% CI of 6.3-24.8%) was covered by Tamarisk Cuttings-Saltbush Scrub, a vegetation type that is a result of tamarisk eradication efforts on Tamarisk/Saltbush communities.

The Alkali Sacaton-Saltgrass vegetation type was the most common community throughout the entire 5-plot area (Table 5). However, it covered only 3% (95% CI of 0.9-6.5%) of Plot 1. The Goodding's Willow Woodland vegetation type only appeared on a few transects, and likely coved less than 1% of the plot area (estimates 0.3% with no confidence interval due to small sample size). This plot contained the fewest different vegetation types of any plot, as only 13 of the 24 cover types (22 vegetation types and two cover classes) appeared in the plot. Plot 1 and plot 2 fall into the completely dewatered reach, which has suffered the most severe perturbations among the reaches.

Table 10. Cover of Vegetation Types in Plot 1. Transects were the experimental unit (n=21) for each plot. Estimates include the minimum percent covered by a vegetation type on a transect within the given plot (Min), the maximum percent cover for any transect (Max) the mean cover for all transects (Mean) and the lower confidence limit (LCL) and the upper confidence limit (UCL) for the mean from a bootstrap-t distribution.

Plot 1 (Reach 1)					
Vegetation Type	**Min (%)**	**Max (%)**	**LCL (%)**	**Mean (%)**	**UCL (%)**
Saltbush/Russian Thistle Scrub	0.0	62.2	19.0	27.8	36.7
Greasewood/Russian Thistle Scrub	5.1	45.3	17.3	22.6	28.1
Tamarisk Cuttings-Saltbush Scrub	0.0	49.2	6.3	14.3	24.8
Greasewood-Saltbush Scrub	0.0	25.7	5.7	9.4	13.8
Tamarisk/Saltbush Woodland	0.0	26.0	3.3	5.9	10.8
Rabbitbrush-Saltbush/Saltgrass Scrub Meadow	0.0	38.1	1.2	4.5	26.2
Saltbush/Saltgrass Scrub Meadow	0.0	30.0	1.8	4.3	11.1
Smotherweed-Mixed Shrubland	0.0	14.3	1.5	3.6	6.5
Alkali Sacaton-Saltgrass Meadow	0.0	16.8	0.9	2.5	6.4
Barren Ground	0.0	11.4	1.1	2.5	5.5
Greasewood/Seepweed-Shadscale Scrub	0.0	19.1	0.4	2.0	13.3
Goodding's Willow Woodland	0.0	3.6	N/A	0.3	N/A
Saltgrass Meadow	0.0	3.5	N/A	0.3	N/A
Saltbush/Saltgrass Scrub Meadow	N/A	N/A	N/A	N/A	N/A
Willow/Cattail-Rush Wetland	N/A	N/A	N/A	N/A	N/A
Bull Rush-Cattail-Willow Wetland	N/A	N/A	N/A	N/A	N/A
Greasewood-Saltbush Scrub	N/A	N/A	N/A	N/A	N/A
Shadscale Scrub	N/A	N/A	N/A	N/A	N/A
Baltic Rush-Saltgrass Wet Meadow	N/A	N/A	N/A	N/A	N/A
Wildrye-Saltgrass Meadow	N/A	N/A	N/A	N/A	N/A
Chairmaker's Bullrush-Saltgrass Wet Meadow	N/A	N/A	N/A	N/A	N/A
Common Reed-Coyote Willow/Yerba Mansa	N/A	N/A	N/A	N/A	N/A
Coyote Willow/Saltgrass Riparian Shrubland	N/A	N/A	N/A	N/A	N/A
Sunflower-Licorice Wet Meadow	N/A	N/A	N/A	N/A	N/A
Open Water	N/A	N/A	N/A	N/A	N/A

Note on Bootstrap-t confidence intervals: In general, bootstrap-t confidence limits are not symmetrical about the mean, as you would expect from more traditional methods. This is an attribute of the method that accounts for the skewness of the observed distribution. It accurately reflects that there is more uncertainty in the upper confidence interval than the bottom. For some communities an N/A appears in the confidence interval cells. This means hat there were less than 5 unique transect cover values for that vegetation type within that plot. The methods were not designed for such small sample sizes, therefore intervals were not reported for these estimates. Generally, this situation occurs only with communities that cover 1% of the study plot or less (Efron and Tibshirani 1993). An N/A in the min (%) column means that the vegetation type did not occur in the plot.

Plot 2

The vegetation composition of Plot 2 was similar to Plot 1. The same two shrub vegetation types were the most common; Greasewood/Russian Thistle (19% ,95% CI of 12.8-26.0%) and Saltbush-Russian Thistle Scrub (18% ,95% CI of 11.0-27.4%) covered roughly one-third of the plot. The tamarisk eradication efforts had only begun in this plot at the time of measurement. Consequently, the Tamarisk/Saltbush Woodland covered 16% (95% CI of 11.9-22.1%) of the plot and was the only vegetation type to appear on every transect (Min=2.8%) while the Tamarisk Cuttings-Saltbush Scrub was estimated to cover less than 1% of the plot. While exotic communities were less frequent than in Plot 1, they still covered approximately half of the plot (53%). This plot had more meadow communities than plot 1, including 17% (95% CI of 9.8-26.3%) cover of Saltbush/ Saltgrass Scrub Meadow. The Goodding's Willow Woodland vegetation type covered 5% (95% CI of 2.4-12.3%), an increase over Plot 1. Three more vegetation types appeared in Plot 2 (16) than Plot 1 (13), but significantly fewer than the other three plots (Tables 7-11).

Table 11. Cover of Vegetation Types in Plot 2. Transects were the experimental unit (n=21) for each plot. Estimates include the minimum percent covered by a vegetation type on a transect within the given plot (Min), the maximum percent cover for any transect (Max) the mean cover for all transects (Mean) and the lower confidence limit (LCL) and the upper confidence limit (UCL) for the mean from a bootstrap-t distribution.

Plot 2 (Reach 1)					
Vegetation Type	**Min (%)**	**Max (%)**	**LCL (%)**	**Mean (%)**	**UCL (%)**
Greasewood/Russian Thistle Scrub	0.0	44.3	12.8	18.7	26.0
Saltbush/Russian Thistle Scrub	0.0	56.2	11.0	18.2	27.4
Saltbush/Saltgrass Scrub Meadow	0.0	55.9	9.8	17.1	26.3
Tamarisk/Saltbush Woodland	2.8	41.9	11.9	16.2	22.1
Greasewood-Saltbush Scrub	0.0	25.7	4.1	7.2	12.3
Goodding's Willow Woodland	0.0	34.2	2.4	5.0	12.3
Rabbitbrush-Saltbush/Saltgrass Scrub Meadow	0.0	26.9	2.2	4.9	11.0
Barren Ground	0.0	13.4	2.6	4.1	6.0
Greasewood/Seepweed-Shadscale Scrub	0.0	20.4	1.2	3.5	9.3
Seepweed-Saltbush/Saltgrass Scrub Meadow	0.0	10.7	0.8	2.0	4.2
Tamarisk Cuttings-Saltbush Scrub	0.0	6.8	0.2	0.9	2.6
Alkali Sacaton-Saltgrass Meadow	0.0	5.9	0.1	0.8	3.5
Baltic Rush-Saltgrass Wet Meadow	0.0	4.7	0.2	0.6	2.2
Smotherweed-Mixed Shrubland	0.0	12.9	N/A	0.6	N/A
Saltgrass Meadow	0.0	3.6	N/A	0.2	N/A
Sunflower-Licorice Wet Meadow	0.0	3.5	N/A	0.2	N/A
Willow/Cattail-Rush Wetland	N/A	N/A	N/A	N/A	N/A
Bull Rush-Cattail-Willow Wetland	N/A	N/A	N/A	N/A	N/A
Shadscale Scrub	N/A	N/A	N/A	N/A	N/A
Wildrye-Saltgrass Meadow	N/A	N/A	N/A	N/A	N/A
Chairmaker's Bullrush-Saltgrass Wet Meadow	N/A	N/A	N/A	N/A	N/A
Common Reed-Coyote Willow/Yerba Mansa	N/A	N/A	N/A	N/A	N/A
Coyote Willow-Saltgrass Riparian Shrubland	N/A	N/A	N/A	N/A	N/A
Open Water	N/A	N/A	N/A	N/A	N/A

Note on Bootstrap-t confidence intervals: In general, bootstrap-t confidence limits are not symmetrical about the mean, as you would expect from more traditional methods. This is an attribute of the method that accounts for the skewness of the observed distribution. It accurately reflects that there is more uncertainty in the upper confidence interval than the bottom. For some communities an N/A appears in the confidence interval cells. This means hat there were less than 5 unique transect cover values for that vegetation type within that plot. The methods were not designed for such small sample sizes, therefore intervals were not reported for these estimates. Generally, this situation occurs only with communities that cover 1% of the study plot or less (Efron and Tibshirani 1993). An N/A in the min (%) column means that the vegetation type did not occur in the plot.

Plot 3

The composition of Plot 3 can be viewed as a transition between the reaches that have remained completely dewatered (plots 1 and 2) and the wetted reaches dominated by more native, wetland vegetation types (plots 4 and 5). Water enters the river from an irrigation return ditch (George's Return Ditch) a few miles above plot 3 (Figure 3). This has a profound effect on the vegetation type composition. This plot had the most diverse array of vegetation types off all plots, as 23 of the 24 cover types (22 vegetation types and two cover classes) appeared in the plot. The Tamarisk Cuttings-Saltbush Scrub, a vegetation type that is a result of tamarisk eradication efforts on Tamarisk-Saltbush patches, was the only vegetation type not to appear in the plot. Since this is an artificial vegetation type resulting from management actions, this plot (and therefore reach) best represents the range of conditions throughout the entire river channel. The most common vegetation type in all five plots, Alakali Sacaton-Saltgrass Meadow was the most common vegetation type in this plot, covering 18% (95% CI of 13.0-25.3%) and was the only vegetation type to appear on all transects (100% frequency) within the plot (Min=3.4%). Rabbitbrush-Saltbush/Saltgrass Scrub Meadow (15%, 95% CI of 10.0-20.3%) and Saltbush/Saltgrass Scrub Meadow (11%, 95% CI of 5.9-18.5%) were the second and third most common vegetation types in the plot. There was an increase in wetland vegetation types in this plot. The Gooding's Willow Woodland vegetation type (10%, 95% CI of 6.5-14.7%) and Willow/Cattail-Rush Wetland (9%, 95% CI of 6.1-13.4%) were estimated to cover a larger percentage of the plot than in plot 1 or 2. Nearly the entire plot was covered by native-dominated communities (93%).

Table 12. Cover of Vegetation Types in Plot 3. Transects were the experimental unit (n=21) for each plot. Estimates include the minimum percent covered by a vegetation type on a transect within the given plot (Min), the maximum percent cover for any transect (Max) the mean cover for all transects (Mean) and the lower confidence limit (LCL) and the upper confidence limit (UCL) for the mean from a bootstrap-t distribution.

Plot 3 (Reach 2)					
Vegetation Type	**Min (%)**	**Max (%)**	**LCL (%)**	**Mean (%)**	**UCL (%)**
Alkali Sacaton-Saltgrass Meadow	3.4	50.9	13.0	18.4	25.3
Rabbitbrush-Saltbush/Saltgrass Scrub Meadow	0.0	32.9	10.0	15.0	20.3
Saltbush/Saltgrass Scrub Meadow	0.0	42.4	5.9	10.8	18.5
Greasewood/Seepweed-Shadscale Scrub	0.0	25.6	6.8	9.9	14.0
Goodding's Willow Woodland	0.0	29.1	6.5	9.7	14.7
Willow/Cattail-Rush Wetland	0.0	31.2	6.1	9.3	13.4
Greasewood-Saltbush Scrub	0.0	16.7	1.7	3.7	6.9
Baltic Rush-Saltgrass Wet Meadow	0.0	23.5	1.2	3.7	9.4
Bull Rush-Cattail-Willow Wetland	0.0	22.7	1.0	3.4	10.2
Seepweed-Saltbush/Saltgrass Scrub Meadow	0.0	15.0	1.1	3.3	6.8
Shadscale Scrub	0.0	10.4	1.3	2.5	4.0
Greasewood/Russian Thistle Scrub	0.0	22.3	0.7	2.4	7.4
Saltbush/Russian Thistle Scrub	0.0	15.2	0.4	2.0	6.2
Chairmaker's Bullrush-Saltgrass Wet Meadow	0.0	14.8	0.5	1.7	5.1
Saltgrass Meadow	0.0	9.5	0.7	1.6	3.5
Smotherweed-Mixed Shrubland	0.0	18.7	N/A	1.0	N/A
Wildrye-Saltgrass Meadow	0.0	8.3	N/A	0.6	N/A
Sunflower-Licorice Wet Meaadow	0.0	6.6	N/A	0.3	N/A
Coyote Willow/Saltgrass Riparian Shrubland	0.0	2.4	N/A	0.2	N/A
Barren Ground	0.0	3.0	N/A	0.1	N/A
Tamarisk/Saltbush Woodland	0.0	1.9	N/A	0.1	N/A
Common Reed-Coyote Willow/Yerba Mansa	0.0	1.7	N/A	0.1	N/A
Open Water	0.0	1.6	N/A	0.1	N/A
Tamarisk Cuttings-Saltbush Scrub	N/A	N/A	N/A	N/A	N/A

Note on Bootstrap-t confidence intervals: In general, bootstrap-t confidence limits are not symmetrical about the mean, as you would expect from more traditional methods. This is an attribute of the method that accounts for the skewness of the observed distribution. It accurately reflects that there is more uncertainty in the upper confidence interval than the bottom. For some communities an N/A appears in the confidence interval cells. This means hat there were less than 5 unique transect cover values for that vegetation type within that plot. The methods were not designed for such small sample sizes, therefore intervals were not reported for these estimates. Generally, this situation occurs only with communities that cover 1% of the study plot or less (Efron and Tibshirani 1993). An N/A in the min (%) column means that the vegetation type did not occur in the plot.

Plot 4

Just as in Plot 3, the Alkali Sacaton-Saltgrass Meadow was the vegetation type with the greatest cover (19%, 95% CI of 13.0-28.4%). However, plot 4 was characterized by extensive bullrush-cattail wetlands. These wetlands, commonly known as tules, covered roughly one-third of the study area. The Willow/Cattail-Rush Wetland covered 16% (95% CI of 10.5-24.2%) and the Bull Rush-Cattail Willow Wetland covered 14% (95%

CI of 7.7-23.4%) of the plot area. Twenty-two of the 24 cover types were found in the plot, but no vegetation type appeared on every transect. As with Plots 3 and 5, the vast majority of Plot 4 was covered by native-dominated vegetation types (95%). The xeric vegetation type cover varied in this plot from the upstream plots, in that Greasewood-Seepweed-Shadscale Scrub (8%, 95% CI of 5.6-12.6%) and Shadescale Scrub (8%, 95% CI of 5.8-10.9%) were the shrublands with the highest estimated cover.

Table 13. Cover of Vegetation Types in Plot 4. Transects were the experimental unit (n=21) for each plot. Estimates include the minimum percent covered by a vegetation type on a transect within the given plot (Min), the maximum percent cover for any transect (Max) the mean cover for all transects (Mean) and the lower confidence limit (LCL) and the upper confidence limit (UCL) for the mean from a bootstrap-t distribution.

Plot 4 (Reach 4)					
Vegetation Type	**Min (%)**	**Max (%)**	**LCL (%)**	**Mean (%)**	**UCL (%)**
Alkali Sacaton-Saltgrass Meadow	0.0	62.3	13.0	19.0	28.4
Willow/Cattail-Rush Wetland	0.0	46.0	10.5	16.3	24.2
Bull Rush-Cattail-Willow Wetland	0.0	48.5	7.7	14.4	23.4
Greasewood/Seepweed-Shadscale Scrub	0.0	23.1	5.6	8.4	12.6
Shadscale Scrub	0.0	19.9	5.8	8.2	10.9
Goodding's Willow Woodland	0.0	29.3	2.7	5.7	11.3
Saltgrass Meadow	0.0	29.2	2.9	5.6	10.7
Baltic Rush-Saltgrass Wet Meadow	0.0	20.9	2.1	4.7	9.2
Chairmaker's Bullrush-Saltgrass Wet Meadow	0.0	11.2	1.5	2.8	4.9
Wildrye-Saltgrass Meadow	0.0	8.5	1.6	2.7	4.1
Common Reed-Coyote Willow/Yerba Mansa	0.0	10.3	1.1	2.4	4.8
Saltbush/Saltgrass Scrub Meadow	0.0	11.7	0.7	1.9	3.9
Seepweed-Saltbush/Saltgrass Scrub Meadow	0.0	14.5	0.7	1.8	5.0
Rabbitbrush-Saltbush/Saltgrass Scrub Meadow	0.0	9.4	0.5	1.3	3.4
Tamarisk/Saltbush Woodland	0.0	10.2	N/A	1.1	N/A
Barren Ground	0.0	4.2	0.3	0.8	1.7
Sunflower-Licorice Wet Meaadow	0.0	3.6	0.2	0.7	1.5
Smotherweed-Mixed Shrubland	0.0	10.7	N/A	0.7	N/A
Coyote Willow/Saltgrass Riparian Shrubland	0.0	4.9	0.1	0.6	4.8
Greasewood/Russian Thistle Scrub	0.0	9.6	N/A	0.5	N/A
Saltbush/Russian Thistle Scrub	0.0	7.8	N/A	0.4	N/A
Open Water	0.0	4.7	N/A	0.3	N/A
Tamarisk Cuttings-Saltbush Scrub	N/A	N/A	N/A	N/A	N/A
Greasewood-Saltbush Scrub	N/A	N/A	N/A	N/A	N/A

Note on Bootstrap-t confidence intervals: In general, bootstrap-t confidence limits are not symmetrical about the mean, as you would expect from more traditional methods. This is an attribute of the method that accounts for the skewness of the observed distribution. It accurately reflects that there is more uncertainty in the upper confidence interval than the bottom. For some communities an N/A appears in the confidence interval cells. This means hat there were less than 5 unique transect cover values for that vegetation type within that plot. The methods were not designed for such small sample sizes, therefore intervals were not reported for these estimates. Generally, this situation occurs only with communities that cover 1% of the study plot or less (Efron and Tibshirani 1993). An N/A in the min (%) column means that the vegetation type did not occur in the plot.

Plot 5

Of the 20 vegetation types that appeared in Plot 5, the Saltgrass Meadow vegetation type had the highest estimated cover (19%, 95% CI of 14.4-23.2%), followed closely by the Alkali Sacaton-Saltgrass Meadow (15%, 95% CI of 9.3-21.4%). The only vegetation type that occurred on every transect was the Gooding's Willow Woodland (Min=1.2%) (8%, 95% CI of 5.9-11.2%). Two vegetation types in the Willow-Wet Meadow complex had their highest coverage of any plot: Sunflower-Licorice Wet Meaadow (2%, 95% CI of 1.0-4.0 %) and Coyote Willow/Saltgrass Wet Meadow (3%, 95% CI of 1.4-6.2%). Xeric vegetation types with the highest cover were Greasewood/Seepweed-Shadscale Scrub (8%, 95% CI of 5.5-11.1%) and Shadscale Scrub (6%, 95% CI of 3.9-7.6%). Although two exotic-dominated vegetation types occurred in Plot 5 (Tamarisk/Saltbush Woodland and Smotherweed-Mixed Shrubland) they covered less than one percent of the plot combined.

Table 14. Cover of Vegetation Types in Plot 5. Transects were the experimental unit (n=21) for each plot. Estimates include the minimum percent covered by a vegetation type on a transect within the given plot (Min), the maximum percent cover for any transect (Max) the mean cover for all transects (Mean) and the lower confidence limit (LCL) and the upper confidence limit (UCL) for the mean from a bootstrap-t distribution.

Plot 5 (reach 5)					
Vegetation Type	**Min (%)**	**Max (%)**	**LCL (%)**	**Mean (%)**	**UCL (%)**
Saltgrass Meadow	0.0	36.8	14.4	19.0	23.2
Alkali Sacaton-Saltgrass Meadow	0.0	41.4	9.3	14.7	21.4
Greasewood/Seepweed-Shadscale Scrub	0.0	21.8	5.5	8.0	11.1
Goodding's Willow Woodland	1.2	23.7	5.9	7.9	11.2
Saltbush/Saltgrass Scrub Meadow	0.0	21.2	4.4	7.6	11.6
Wildrye-Saltgrass Meadow	0.0	23.7	3.9	6.6	11.1
Shadscale Scrub	0.0	13.4	3.9	5.9	7.6
Willow/Cattail-Rush Wetland	0.0	25.7	3.1	5.6	11.6
Rabbitbrush-Saltbush/Saltgrass Scrub Meadow	0.0	27.4	2.6	4.9	10.5
Seepweed-Saltbush/Saltgrass Scrub Meadow	0.0	18.4	1.6	3.4	7.1
Baltic Rush-Saltgrass Wet Meadow	0.0	9.8	2.0	3.3	4.9
Coyote Willow/Saltgrass Riparian Shrubland	0.0	15.5	1.4	3.1	6.2
Bull Rush-Cattail-Willow Wetland	0.0	14.6	1.5	2.8	5.4
Sunflower-Licorice Wet Meadow	0.0	9.3	1.0	2.1	4.0
Common Reed-Coyote Willow/Yerba Mansa	0.0	7.7	0.9	1.9	3.4
Chairmaker's Bullrush-Saltgrass Wet Meadow	0.0	6.3	0.6	1.3	2.4
Barren Ground	0.0	5.0	0.3	0.8	2.3
Open Water	0.0	4.2	0.1	0.6	2.7
Tamarisk/Saltbush Woodland	0.0	3.3	0.1	0.4	1.2
Smotherweed-Mixed Shrubland	0.0	2.4	N/A	0.1	N/A
Tamarisk Cuttings-Saltbush Scrub	N/A	N/A	N/A	N/A	N/A
Greasewood-Saltbush Scrub	N/A	N/A	N/A	N/A	N/A
Saltbush/Russian Thistle Scrub	N/A	N/A	N/A	N/A	N/A
Greasewood/Russian Thistle Scrub	N/A	N/A	N/A	N/A	N/A

Note on Bootstrap-t confidence intervals: In general, bootstrap-t confidence limits are not symmetrical about the mean, as you would expect from more traditional methods. This is an attribute of the method that accounts for the skewness of the observed distribution. It accurately reflects that there is more uncertainty in the upper confidence interval than the bottom. For some communities an N/A appears in the confidence interval cells. This means hat there were less than 5 unique transect cover values for that vegetation type within that plot. The methods were not designed for such small sample sizes, therefore intervals were not reported for these estimates. Generally, this situation occurs only with communities that cover 1% of the study plot or less (Efron and Tibshirani 1993). An N/A in the min (%) column means that the vegetation type did not occur in the plot.

Differences Between the Dry Reach and the Wet Reaches

There was a dramatic difference in vegetation composition between the reach without persistent surface water (plots 1 and 2) and the reaches with persistent surface water (plots 3-5). When vegetation type cover was summed within these two groups (wet and dry reaches) only two vegetation types did not have significant differences in mean percentage to the .05 level. The two vegetation types were Saltbush/Saltgrass Scrub Meadow and Alkali Sacaton-Saltgrass Meadow, two common vegetation types that were a constant presence in all plots. Greasewood-Saltbush Shrubland was the only native dominated vegetation type with a lower cover percentage in the wet reaches. When the native vegetation types were agglomerated and treated as one group, the dry reach had a mean estimated native dominant vegetation cover of 32% compared with a 96% cover of native dominated vegetation in the wet reaches (plots 3-5), an estimated 64% increase in cover over the dry reach (p=0 from a randomization test).

Table 15.Test for Differences in Vegetation Type Coverage between Wet and Dry Reaches. Test for difference between mean cover between plots in the dry reach (plots 1-2) and the wet reaches (plots 3-5) by cover type. Positive differences represent higher mean cover downstream. Statistical significance (p) is from a two-sided randomization test (Manly 1991) of the null hypothesis of no difference in mean cover.

Vegetation Type	Cover Change	p
Saltbush/Russian Thistle Scrub	-22.2	0
Greasewood/Russian Thistle Scrub	-19.7	0
Tamarisk/Saltbush Woodland	-10.5	0
Tamarisk Cuttings-Saltbush Scrub	-7.6	0
Greasewood-Saltbush Scrub	-7.1	0
Saltbush/Saltgrass Scrub Meadow	-3.9	0.097
Barren Ground	-2.7	0
Smotherweed-mixed shrubland	-1.5	0.027
Open water	0.3	0.045
Sunflower-Licorice Wet Meadow	1.0	0.005
Coyote Willow/Saltgrass Riparian Shrubland	1.3	0.011
Common Reed-Coyote Willow/Yerba Mansa	1.5	0.002
Seepweed-Saltbush/Saltgrass Scrub Meadow	1.8	0.022
Chairmaker's Bullrush-Saltgrass Wet Meadow	1.9	0
Rabbitbrush-Saltbush/Saltgrass Scrub Meadow	2.4	0.188
Wildrye-Saltgrass Meadow	3.3	0
Baltic Rush-Saltgrass Wet Meadow	3.6	0
Goodding's Willow Woodland	5.1	0
Shadscale Scrub	5.5	0
Greasewood/Seepweed-Shadscale Scrub	6.0	0
Bull Rush-Cattail-Willow Wetland	6.9	0.001
Saltgrass Meadow	8.5	0
Willow/Cattail-Rush Wetland	10.4	0
Alkali Sacaton-Saltgrass Meadow	15.7	0

Non-metric Multi-dimensional Scaling

The first Non-metric Multi-dimensional Scaling (NMS) analysis was performed on the mean species ranked dominance scores for the 22 vegetation types. The ordination revealed 3 axes, with the combined $r^2 = .85$ (Table 16). The final configuration had a minimum stress of 10.043, with a p-value from the Monte Carlo test of 0.0196 (40 runs on real data, 50 runs with randomized data). These results show no reason to doubt the validity of the ordination results.

Table 16.Transect Data Ordination Axis Coefficients of determination. R-squared values are presented for the final NMS ordination configuration and represent the correlations between ordination distances and distances in the original 81-dimensional species space.

Axis	Increment	Cumulative
1	0.25	0.25
2	0.34	0.59
3	0.26	0.85

The results of the NMS ordination are displayed in Figures 14 and 15 in which the ordinations were rotated for interpretation. In Figure 14, the only vegetation type not contained within its loop is the Shadscale Scrub type (code g664). It is grouped into the Saline Scrub complex, but is distant from the group in species space relative to the other types in the complex. Examination of the an ordination plotted with axis 2 and axis 3 (Figure 15) the Shadscale Scrub type revealed the Shadscale Scrub type to be the most heavily weighted on axis 3 (1.36 ordination score) and distant form other types, even the saline scrub complex, which scored between 0.35 to 0.76 on the third ordination axis.

The rotation of the ordination in Figure 14 enabled the variable for plot number (referenc in diagram) to be aligned from left to right. This means that vegetation types more frequently located in the upper reaches are located on the left side of the diagram, and those that are more frequently found in the lower reaches are found on the right side of the diagram. Vegetation types with more bare ground are located in reverse orientation; those on the left side of the diagram more frequently have bare ground (>5% cover) are located on the left side of the diagram. Vegetation types located at the bottom of the diagram more frequently contained open water (>5%) and snags (represented by the dtree label. Figure 14 was rotated to be aligned with the upper reaches at the top of the diagram and lower reaches at the bottom of the diagram. This was the environmental variable with the strongest correlation with axis 1 (represented by the longest line). The environmental variables BARE (bare ground), dtree (snags), and H2O (open water) represents the presence or absence of a given variable covering more than 5% of vegetation type's patch area.

In Figure 15, the diversity measures were not significantly correlated with the axes, but all of the other environmental variables were significant, with different correlations. Unlike Figure 13, the location of the Shadscale Scrub vegetation type in Figure 14 enabled it to be easily included in the vegetation complex loops.

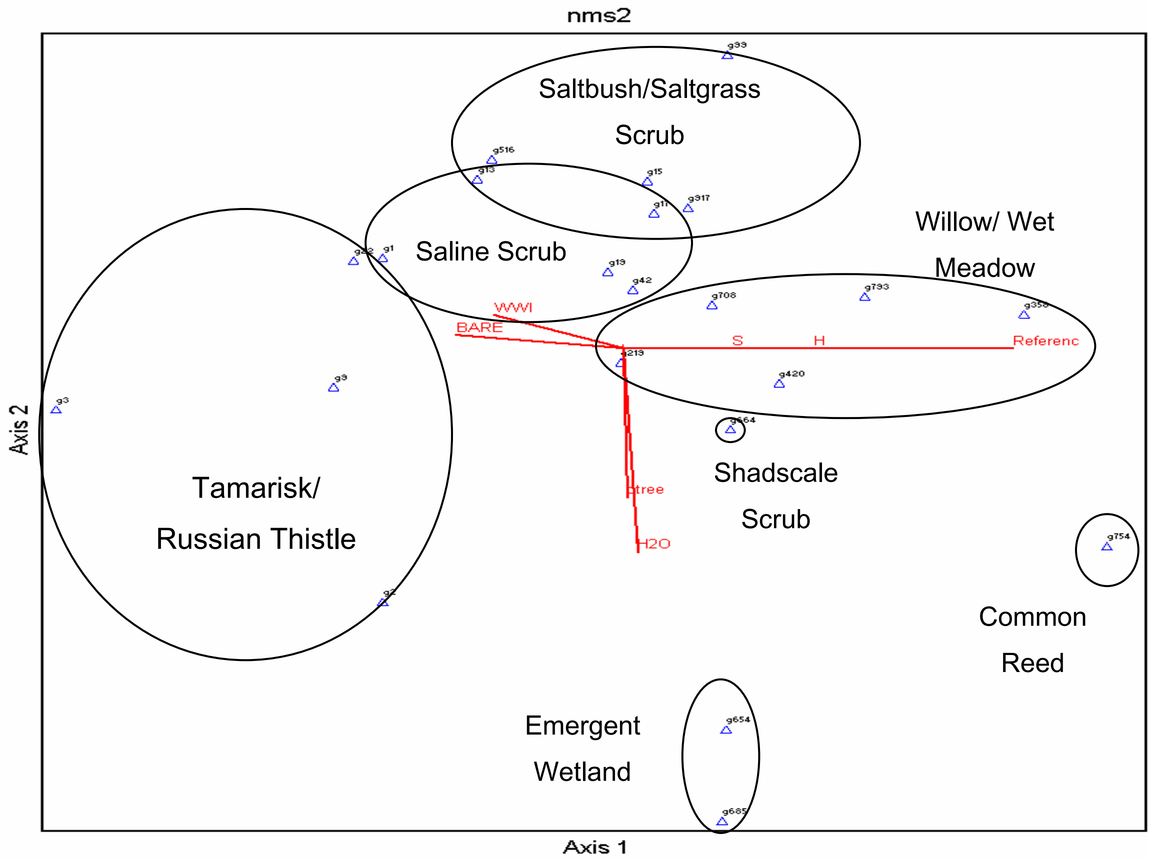

Figure 14. Transect Data Ordination Axis 1 and 2. The 22 vegetation types (triangles) which contain species (excluding barren ground and open water) are shown on Axis 1 and Axis 2 of the final ordination configuration. Vegetation types are labeled by their code listed in Table 5. A joint plot of environmental variables is overlaid onto the ordination diagram (red lines). BARE indicated the presence of bare ground, dtree represents the presence of snags, H2O the presence of open water, and Referenc represents the plot number, S represents species diversity, and H represents Shannon's Diversity Index. The direction and the length of the lines indicate the direction and the strength of the relationships of the variables with the ordination scores. Only the variables with significant relationships are presented. Other variables (e.g. WWI) had more significant correlations with the third ordination axis (Figure 15). Loops represent vegetation complexes defined by the cluster analysis diagramed in Figure 11.

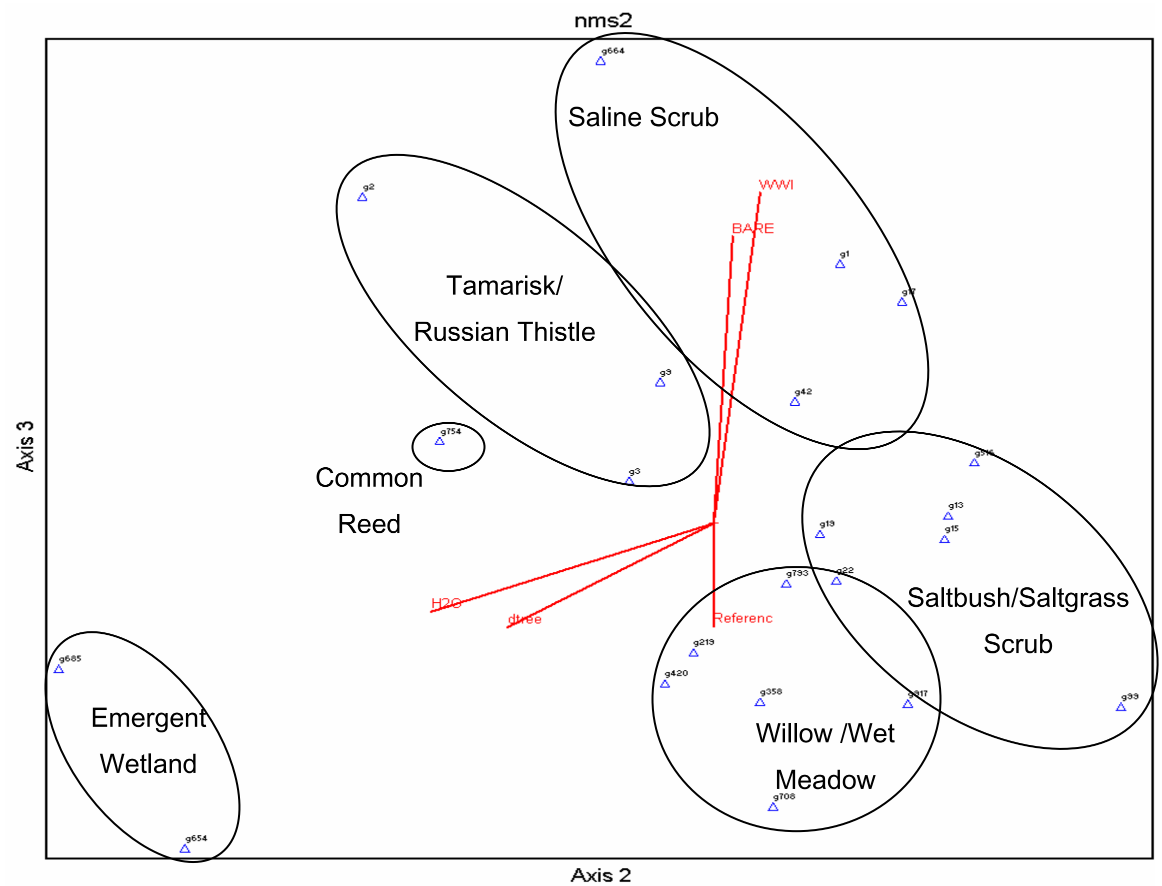

Figure 15. Transect Data Ordination Axis 2 and 3. The vegetation types (triangles) are shown on Axis 2 and Axis 3 of the final ordination configuration. Vegetation types are labeled by their code listed in Table 5. A joint plot of environmental variables is overlaid onto the ordination diagram (red lines). BARE indicated the presence of bare ground, dtree represents the presence of snags, H2O the presence of open water, and Referenc represents the plot number, WWI represents weighted wetland indicator score. The direction and the length of the lines indicate the direction and the strength of the relationships of the variables with the ordination scores. Only the variables with significant relationships are presented. Loops represent vegetation complexes defined by the cluster analysis (Figure 11).

The final configuration of the NMS ordination run on sub-plot data (canopy and ground cover) revealed two axis, with a combined r^2 = .70 (Table 14) and is graphically displayed in Figure 16. The diagram was rotated +40 degrees for interpretation. The rotation aligns the diagram so that bare ground decreases from left to right, and litter, water, and vegetation increase. The mean groundcover estimates with significant correlations with axes are overlaid on the diagram and vegetation complexes from Figure 10 are represented by loops. Because sub-plots were measured in patches classified as Barren Ground, these plots were included in the ordination.

Table 17. Canopy and Ground Cover Data Ordination Axis Coefficients of Determination. R-squared values are presented for the final NMS ordination configuration and represent the correlations between ordination distances and distances in the original 92-dimensional species space.

Axis	Increment	Cumulative
1	0.51	0.51
2	0.19	0.70

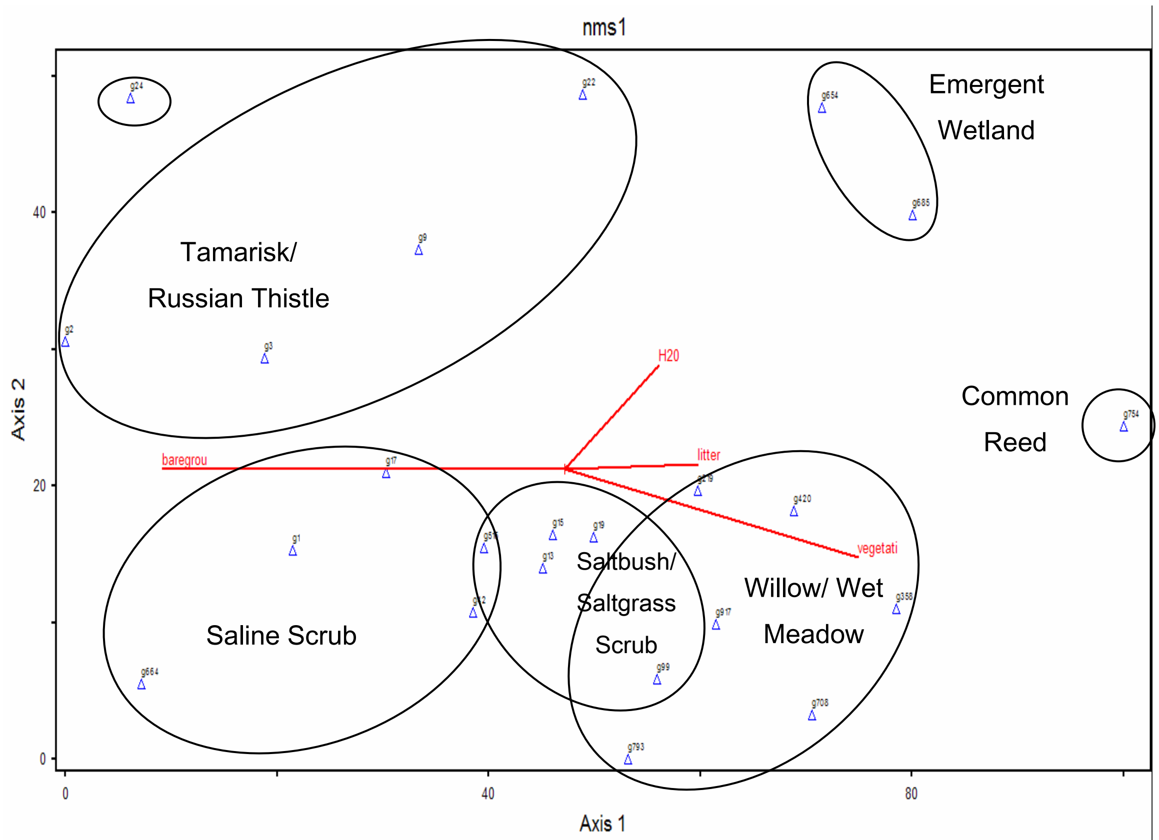

Figure 16. Canopy and Ground Cover Data Ordination Diagram. Diagram was rotated 40 degrees for interpretation enabling ground cover correlations with axis to be interpreted. The vegetation types (triangles) are shown on Axis 1 and Axis 2 of the final ordination configuration. Vegetation types are labeled by their code listed in Table 3. A joint plot of groundcover variable is overlaid onto the ordination diagram (red lines). Baregrou (bareground), H2O (water), litter, and vegetati (vegetation) were significantly correlated with axis 1. The direction and the length of the lines indicate the direction and the strength of the relationships of the variables with the ordination scores. Loops represent vegetation complexes defined by the cluster analysis diagramed in Figure 11.

Discussion

Differences between Vegetation Types and Plots

The Lower Owens River is a heavily impacted and invaded riparian system which has suffered long-term hydrologic alteration and degrading land uses. Historical descriptions of the vegetation of the study are vague. They qualitatively describe a grassland or a woodland system (Anon. 1886, Fremont 1849, Brewer 1930, Davidson 1976). This study described the current floodplain condition as shrub-dominated, as more than half of the study area was covered by shrub-dominated vegetation types. These shrub types have larger patch sizes (lower habitat heterogeneity), are common vegetation types found in the surrounding uplands, and are less diverse than the native Willow-Wet Meadow vegetation types.

The dry reach (plots 1-2) exhibited very different vegetation conditions than the wetted reaches (plots 3-5). The dry reach had fewer different vegetation types than the wet reaches, more exotic vegetation types, higher WWI scores (more xeric), and lower canopy cover estimates. All but two vegetation types (both Alkali Scrub-meadow types) had significant changes in cover between the wet and dry reaches (Table 12). The estimated 63.8% increase in cover of native-dominated vegetation types in the wet reaches over the dry reaches illustrates the impact that a small amount of persistent surface and shallow ground water can have on the persistence of native riparian systems.

Floristic gradients and relationships in species space were revealed by ordination analysis (joint plot in Figures 14-16). Since ordination scores were derived from species composition data, scores of sample units along the axis indicate sample unit positions along floristic gradients. If restoration actions change the conditions along these environmental gradients, then vegetation should shift along a predictable trajectory. The spatial relationship between vegetation types in the ordination diagram should reveal the direction of the trajectory. Figures 14 and 15 reveal that a shift in weighted wetland indicator (a likely result of rewatering) may shift patches classified into the

Saltbush/saltgrass complex and Saline Scrub complex to the Willow wet meadow complex, resulting in higher diversity (Figure 14), vegetation groundcover (Figure 16), and canopy cover (Table 8).

Joint plots also revealed that the open water and snags were most highly correlated with wetland types. The increased presence of snags in wetland areas may reflect the result of beaver dam flooding of riparian areas, drowning native cottonwoods and willows (Naiman et al. 1988). These tree communities are remnants of historic flow conditions, and are not easily replaced. Because native vegetation types increased in the wetted reaches, diversity measures were positively correlated with reach number, which increase downstream. Vegetation ground cover was most highly correlated with the Willow-Wet Meadow complex, whereas bare ground is more associated with the tamarisk and Saline Scrub complexes. These results further indicate that the Willow-Wet Meadow complex as a restoration target. Of course, the value of these communities can only be fully realized when placed within a diverse mosaic of other vegetation types.

The Goodding’s Willow Woodland vegetation type was found at the center of nearly every ordination axis in each of the ordinations performed. This keystone species to the ecosystem suggests that it shares the most species with other vegetation types. It also suggests that *Salix gooddingii* is a species capable of existing in many different habitats within the study area. It also illustrates it capacity to persist when hydrological conditions change, possibly because roots were able to maintain contact with the water table.

Wetland Indicators and Biotic Integrity

Weighted wetland indictor scores are a measure of biotic integrity (Stromberg 2001), and are a tool for evaluating how disturbance affects the vegetation, processes, and function of riparian areas (Coles-Ritchie et al. 2007). Coles-Ritchie et al. (2007) utilized a wetland index for riparian communities based on the Winward (2000) methods and calculated the their wetland index using wetland indicator score classes (range 1-100) and species relative importance (a combination of canopy cover and relative frequency). Others have used the percentage of classes (Toledo and Kauffman 2001, Chapin et al. 2002). This study adapted both the methods of Winward (2000) for sampling and the weighted average indicator score utilized by Stromberg (2001) based on a range of 1-5 (Table 3).

For low gradient steams like the Lower Owens, functioning riparian areas typically have a high proportion of hydric and wetland species (Coles-Ritchie et al. 2007). Loss of connectivity between stream and the floodplain can lead to a reduction in moisture availability to plants, which can lead to a shift to facultative or up-land species adjacent to the stream (Toledo and Kauffman 2001). This study demonstrates its utility, as heavily impacted, dewatered plots had higher WWI scores (3.1-2.9 - facultative) than the plots with abundant surface water and similar geomorphic settings dominated by native species (2.1-2.4 facultative wetland -). These conditions represent a lack of connectivity between the stream and the floodplain, especially in the dry reaches. As restoration efforts (re-watering) progress, a shift in weighted wetland indictor scores for vegetation types, study plots and reaches would be indicative of a shift toward species more commonly found in wetlands, which will indicate greater connectivity between the stream's hydrology (surface and groundwater) and the floodplain (Coles-Ritchie et al. 2007).

Diversity

The Owens's river is somewhat species poor compared to other California river systems (Roberts et al. 1977, Brothers 1984). This lack of diversity is likely reflective of the land use history, change in disturbance regime, and the dominance of exotic species. Species turnover has been observed to be quite low in the system (Brothers 1984). However, this study illustrates there are major differences between the wet and dry reaches of the river. This suggest that dewatering has resulted in decreases in biodiversity, as historically species rich (relative to the system) mosaics of native vegetation patches have likely been reduced and replaced by less diverse non-native vegetation types. Diversity measures in the more severely dewater reach were significantly lower than those in the wetter reaches, where native plants were able to maintain a link to the water table.

There was a clear difference in species diversity measures between both reaches and vegetation complexes. In general, the invaded vegetation types found in the most de-watered reaches were the least diverse (Table 5). However, the native dominated Saltgrass Meadow vegetation type had the lowest H' of any type (0.3) and was found throughout the study area, including the lower (wetter) reaches. The vegetation types with the highest diversity measures were within the Willow-Wet Meadow vegetation complex (Tables 5 and 15) and were more likely to be found in found in the wetter reaches (Table 15). These diverse vegetation types also exhibited high canopy cover and vegetation groundcover estimates. Despite their high diversity measures, these types occurred in the smallest patches (8.4-14.6m, Table 5). These types generally occurred on longitudinally oriented landforms near the stream bank and in old meanders or oxbows (Figure 5). In contrast, the shrub dominated and wetland types had the largest patch sizes (Table 5).

The rewetting of the river channel will likely increase native diversity, particularly in the upper reaches, for a number of reasons. These include increases in soil moisture and root access to the water table in a large portion of the historical floodplain. The change in hydrology should create new habitats on existing fluvial landforms increasing riparian habitat area and heterogeniety. However, when WWI was plotted against different diversity measures, there was no correlation. Regression analysis showed no significant linear relationship between WWI and any of the diversity measures. This may be because the marsh and saltgrass types had low to medium diversity scores, and these types have relatively low WWIs (more mesic). Therefore the creation of marsh habitats will not create the vegetation types with the highest diversity measures. Rewatering will likely result in increases in wetland and native vegetation types, as conditions in the dry reach will likely move towards those found in the wet reaches. The conversion of existing dewatered lands to marsh vegetation types will increase native diversity from the existing heavily impacted and invaded state. Although the tule and cattail vegetation types exhibited low plant species diversity, they do provide other important ecosystem functions, including fisheries and wildlife habitat. However, the creation of large homogenous marshlands, especially those associated with beaver dams, may have unintended negative effects on existing native trees as they may be subject to mortality from prolonged inundation. These lands will provide important wetland habitat for many species, but may not accomplish project goals of increasing native plant diversity.

In order to maximize plant species biodiversity, conditions for the establishment of the Willow/Wet Meadow complex must be created. These communities, especially the riparian tree species, rely heavily on the natural flow regime. The periodic flooding of the floodplain opens up patches for colonization, exposes suitable substrates for germination, and creates the proper hydrologic conditions for establishment and native riparian tree survival (Stromberg and Patten 1992, Auble and Scott 1998, Merigliano 1998, Rood et al. 1998, Shafroth et al. 1998, Rood et al. 1999, Rood and Mahoney 2000, Sher et al. 2000). The periodic disturbance of wet meadow vegetation patches may increase diversity (intermediate disturbance hypothesis) as changing conditions may enable rare species within these diverse patches to expand their populations. The relationship between diversity and weighted wetland indicator found in this study may support existing theory relating disturbance to diversity.

Classification of Vegetation Types

Each vegetation classification system has its own methods, objectives, and range of applicability. The classification system presented in this study is specific to this study area and the spatial and temporal objectives of the project. The vegetation classification also reflects the physical and biological setting, as well as the area's land use and water use history. The vegetation types described in this study fit within a hierarchical framework of complexes of vegetation types (Figure 11), but crosswalk well to other classifications within the river system and state (Table 7).

In a review of riparian classification systems in the west, Alpert and Kagan (1998) concluded that the utility of vegetation types for inventory and management rests on three main properties: limited number, easy detection, and correlation with other biological and physical features. Classification systems can also cause confusion if they are not easily cross-walked to other systems or put in a regional context. For example, a study comparing 14 riparian stream sites in 2 states, (Coles-Ritchie et al. 2007) found that many different classifications using numerous names regardless of similarity or differences between vegetation types made comparisons between stream sites difficult. The classification used in this study was derrived with this in mind. The desired level of detail was balanced with the desire to limit the number of vegetation types, resulting in a manageable number of vegetation types. Indicator species analysis identified dominant species that were the best indictors of each vegetation type, enabling managers performing other classifications to quickly identify vegetation types and to crosswalk them to other systems. This enables workers in other fields with little experience in vegetation science to quickly identify vegetation types and then crosswalk them to the appropriate scale for their application. The vegetation types were cross-walked to local, regional and state-wide classification systems. The WWI scores and differences between the dry and wet reaches illustrated the correlation of the vegetation types with environmental gradients.

Many riparian vegetation studies have classified a patch as one specific vegetation type, and then they lay out a plot and sample that community (Sawyer and Keeler-Wolf 1995). This project had a different study design, in that it recognized a relatively homogenous patch, but rather than automatically classifying it, the patch characteristics (dominant species) were recorded, and the classification was done according to the data structure. In other words, each patch was grouped together with other patches which had similar species scores. This removed some the observer bias found in other classification methods in which each patch is classified as a predetermined vegetation type in the field.

Riparian vegetation sampling often occurs in large plots designed to be placed within the interior of riparian patches. If plots are located in the center of a large stand, then only the interior information is being measured and the edge effects are excluded from the data structure. This may be desirable in some contexts, but if a question of interest is how closely related stands are to each other, sampling the entire stand provides a more complete picture of the floodplain vegetation and the relationships between vegetation patches and types. In fact, riparian patches often are gradations from one community into another, and by ignoring these gradual ecotones, information is lost. Of course, ecotones can be difficult to identify and there will always be some debate between scientists as to what constitutes vegetation patches, stands, communities, and complexes.

The vegetation of this study area has been mapped and classified on several scales. Holland (1996) classified the entire state of California, with a 100 ha minimum patch size. The Greenbook (Inyo county and City of Los Angeles 1990) mapped the entire Owens valley in an effort to track vegetation change through time, specifically in uplands. Whitehorse Associates (2004) mapped the entire Lower Owens River project area based on aerial imagery interpretation, geomorphic, and hydrologic characteristics. All of these studies have larger grain sizes (smaller scale) and different goals than this study. The objectives of this study included the delineation and definition of vegetation on a much finer grain size (larger scale) in order to detect subtle changes over a shorter period of time in order to inform adaptive management decisions.

The vegetation types defined by this study roughly equate to the Sawyer and Keeler-Wolf (1995) or California Native Plant Society (CNPS) series level (Table 7). However, it is likely that some CNPS series that rarely occurred within the study area were lumped together during the cluster analysis. For example, *Spartina gracilis* has its own series in the CNPS system but *S. gracilis* dominated patches were patches were lumped into one of the Baltic Rush-Saltgrass Wet Meadow and Sunflower-Licorice Wet Meadow vegetation types. There were only a handful of *S. gracilis* patches and they shared many common species with the other wet meadow series, which were combined into the wet meadow types identified in this study. Wet meadow vegetation types were the most species diverse in the study area, and could have been split out into more vegetation types if a finer scale had been selected. Though less diverse, the dry alkali meadow types were split into three types roughly equivalent to series or types identified in statewide classification efforts, but not in efforts with other goals and scales within the basin (Table 7). Identifying these dry meadow vegetation types individually was important to project goals because there was a large difference in diversity between Alkali Sacotone-Salgrass Meadow (H'=1.9) and Wildrye-Saltgrass Meadow (H'=1.8) and the Saltgrass Meadow vegetation type (H'=0.3).

Unless designed to locate and inventory rare species, vegetation sampling often describes dominant species but fail to accurately record rare species (Abella and Covington 2004), as was the case with this study. Dominants are often found in a patch with many rare species. Many of these species are functionally equivalent, but may become dominant following a disturbance event. Following a disturbance, the rare or minor species may fill the gap opened by the reduction of the dominant species population (Walker et al. 1999). This may be true with the wet meadow vegetation types, as they were among most dominant species diverse.

Although overstory species are generally used to classify vegetation (Sawyer and Keeler-Wolf 1995), understory species have been shown to be reliable indicators of hydrologic and geomorphic conditions (Abella and Covington 2004). The classification method utilized in this study included species ranked in six structural levels enabling understory species to determine vegetation groupings. Many classification systems (especially mapping techniques) use the dominant overstory species as the primary indicator of vegetation type. Structure was weighted in this data set, as dominant species were ranked within each structural level. If only one species occurred in any structural level (and covered the minimum 5% of the patch), it was recorded as dominant.

The results of the indicator species analysis clearly show that many of the indicator species were understory species (Table 6). The most widespread tree species in the study area (*Salix gooddingii)* appears in many different vegetation types (10), as its presence in a patch did not automatically designate that patch into the Willow-Wet Meadow vegetation type. *S. gooddingii* was found in a range of habitats from high to low terraces, along canals, old meanders as well as the floodplain and the streambank. With the hydrologic conditions changing through time, native willows have persisted. Consequently, *S. gooddingii* appeared as a dominant species within its structural layer in 30% of Willow-Cattail-Rush Wetland, 24% of Bull Rush-Cattail-Willow Wetland, and 15% of Baltic Rush-Saltgrass Wet Meadow types (Appendix C).

The riparian tree dominated vegetation type Goodding's Willow Woodland included both willow and cottonwood (*Populus fremontii*), among others. Many vegetation classifications based on dominant species in the highest structural level would have broken the cottonwood dominated patches into their own vegetation type. Cottonwoods and willows were frequently found in the same patches (all but one patch). Splitting the native tree communities between cottonwood and willow dominated would have required an extreme deviation from the objective clustering method used to classify data. Despite high diversity measures and close species relationships with other vegetation types, the tree willow vegetation type was identified by cluster analysis in each of the different grouping scenarios examined. Given the objective method employed in this study it did not make sense to deviate from the method despite the ecological importance of these species. Other classifications have also grouped these trees together (Holland 1986, Whitehorse Associates 2002).

The decision where to trim the cluster analysis dendrogram (Appendix B) involved balancing statistical measures with project objectives and biological significance. The ideal number of vegetation types must be large enough to meet monitoring objectives (e.g. at the appropriate scale within project hierarchy) but small enough to be manageable in the field and in analysis. The desired scale for the project limited the statistical investigation to 15 – 35 vegetation types. Indicator species analysis indicated that 16, 21, 29, and 33 groups were the best groupings of patches (Figures 7 and 8). Although 29 and 33 exhibited strong statistical evidence of very distinct vegetation types, these scenarios produced a number of vegetation types that would be more complex to manage and recognize in the field. The 16 and 21 group scenarios lumped native wet meadow vegetation types together with the exotic *Bassia* dominated vegetation type. The 22 group scenario fit project objectives by identifying native and exotic vegetation types at the appropriate scale, while exhibiting strong quantitative evidence of their existence.

As with all vegetation sampling, the temporal aspect of the sampling could have affected the dominance scores of some species. For example, the lower reaches (Plots 4 and 5) were sampled later in the field season, when the annual *Helianthus annuus* was in full bloom. The Sunflower-Licorice Wet Meadow was one of the most diverse communities (Table 3), and *H. annuus* may be the most dominant due to the sample timing. For this reason, future monitoring should follow the same sampling protocols and timing.

Chapter 4. Management Implications

Invasive Species

Tamarisk, Russian thistle, and smotherweed were all dominant species and indicator species for vegetation types in the highly modified landscape of the study area. These species alter ecosystems in undesirable ways, frequently homogenizing flora and fauna, reducing diversity and negatively impacting populations of native species (MacNally et al. 2004). The results of this study support this idea, as vegetation types dominated by exotic species had decreased diversity, canopy cover, and vegetation groundcover.

Understanding how native plant assemblages respond to invasions of non-native species will aid managers in constructing successful restoration and management strategies (Rejmanek 2000, Zavaleta et al. 2001, Sax et al. 2002). A recent study (Herms and Hiebert 2006) found that tamarisk restoration sites increased in canopy cover, but remained below control sites following restoration actions. They suggest that recovery from tamarisk invasion will take many years and sites may never completely recover to a natural state. Therefore it is likely that areas that have been converted from tamarisk-saltbush vegetation type to tamarisk cuttings vegetation type by eradication efforts will likely be slow to transition to vegetation types dominated by native riparian species. For this reason, restoration of the heavily invaded riverine-riparian system of the Lower Owens must viewed over a long time frame. However, Herms and Hiebert (2006) also found Mojave tamarisk restoration sites responded more rapidly to restoration actions compared to Chihuahuan and Colorado Plateau systems. Since the Lower Owens is on the boarder between the Great Basin and Mojave ecoregions (The Nature Conservancy 2001), tamarisk eradication efforts may be more successful than in other southwestern riparian ecosystems.

The study results suggest that many of the invaded, disturbed lands will be slow to recover to native-dominated vegetation types. Aside from the tamarisk resprouting and recruitment from seed banks, the lands dominated by *Salsola tragus* may shift dominance to a wetter invasive, *Bassia* or *Sueda* communities. Conversely, the introduction of more water to the system will raise water tables and shift many landform to a vegetation types with lower WWI scores (more mesic) vegetation types, increasing native species and communities. However, since the eradicated tamarisk areas are highly disturbed sites, those vegetation types adapted to disturbance will be most likely to colonize these areas. Many riparian species are well adapted to disturbance, but the altered flow regime, history of poor land use and severe habitat degradation will likely enable exotic species to persist on these sites far into the future.

Because the sampling dates coincided with tamarisk eradication efforts, the baseline data can be used to better understand future conditions. Intact tamarisk stands were measured, as well as tamarisk stands that had been treated by cutting and herbicide application to stumps. This provided a representation of invaded stands before restoration and immediately following restoration. The likely trajectory of change for these stands can be seen by examining the differences in measurements for these vegetation types. For example, the mean canopy cover in tamarisk patches was 67% and only 7% in treated tamarisk patches, along with increased in bare ground and downed wood and decreases in vegetation groundcover (Table 8).

The consequences of efforts to eradicate dominant exotic invaders will likely result in a short-term reduction in overall foliar cover, structure, and stream shading. These efforts will likely result in a long-term reduction in tamarisk cover, but managers should not view eradication effort as a solitary effort. It must be coupled with other restoration actions, such as proper flow management, continued weed management and eradication efforts, including the management of the slash created by tamarisk eradication and land use modifications such a grazing management that reduce impacts on native riparian species. The future trajectory of these patches remains uncertain (Figure 17).

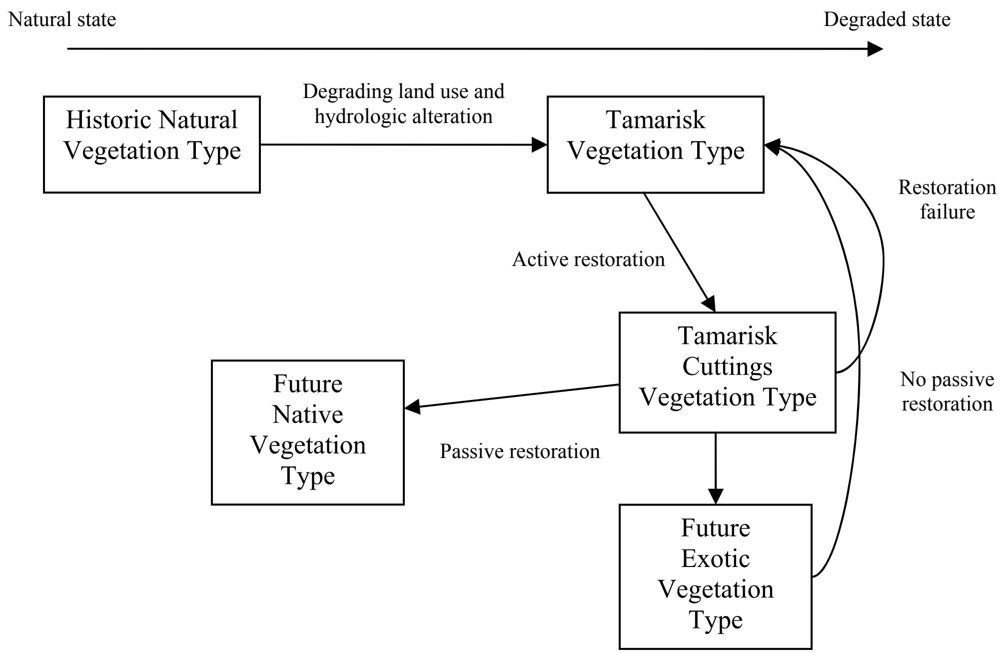

Figure 17. Conceptual diagram of history and future of tamarisk eradication sites. Tamarisk dominated sites existed in an unknown natural historic state. Over 80 years of land use and hydrologic alteration resulted in invaded, degraded state. Active restoration action was taken to eradicate tamarisk, resulting in a further degraded and less diverse. Passive restoration actions, including changes in the hydrologic regime and grazing management are necessary and will influence the future trajectory of these sites. However, the future vegetation of these sites is difficult to predict.

Domestic Livestock Grazing

The effects of cattle grazing were not a focus of this investigation, however, grazing and its effects on riparian function, its influence on past, current, and future vegetation condition cannot be ignored. There is little information on past grazing pressure and pasture condition, making specific correlations about the effects of grazing on current conditions difficult. However, excessive livestock grazing has been shown to have deleterious effects on riparian areas (Belsky et al. 1999). Cessation of grazing has been shown to decrease soil compaction and increase infiltration (Bohn and Buckhouse 1985, Wheeeler et al. 2002) up to 3 times in wet meadows and 11 times in dry meadows (Kauffman et al. 2004), species composition (Leege et al. 1981, Dobkin et al. 1998), and increases in woody vegetation (Shultz and Leininger 1990, Green and Kauffman 1995, Case and Kauffman 1997, Brookshire et al. 2002).

The study design will inform managers about the effects of grazing management strategies, as two of the plots are located half inside one grazing lease and half in another grazing lease. This design will inform managers about the effects of different grazing management strategies on ecosystem response to restoration actions.

The evidence in the literature clearly shows that exclusion of cattle from riparian areas brings about more rapid restoration progress. In a comparison between grazed sites and sites with livestock exclosures, sites where livestock were excluded had higher wetland index values (Toledo and Kauffman 2001, Coles-Ritchie 2007). These results are consistent with other studies that have observed changes with livestock exclusion (Beschta and Platts 1986, NRC 2002). Cattle spend a disproportionate amount of time in riparian areas in semi-arid regions because they find water, high quality forage, and cooler temperatures (Kauffman and Krueger 1984, Fleischner 1994). Fencing riparian area can be costly, and complete exclusion of cattle from most systems is currently not politically or economically feasible. In the Lower Owens, continuing sustainable land use, including grazing, are explicit goals of the project. Construction of exclosures and implementation of a progressive grazing strategies will aid restoration efforts, but scientists and managers should consider the added grazing pressure possibly put on unfenced areas, as cattle will continue to seek the shade and forage quality of the riparian zone. When viewed from a watershed or ecosystem perspective, the exclusion of cattle may have significant site-specific benefits, but the reduction cattle head or total Animal Unit Months (the amount of forage required for one animal unit, which is fully grown cow and calf) in the watershed could have a more significant positive effect on riparian restoration efforts.

Conclusions

The transects established and measured in this study extended laterally from historic terrace to historic terrace. Restoration will predominantly occur within the inset channel, with saturation and flooding of low elevation geomorphic surfaces. Some surfaces will remain perched above the water table, and will have little response to hydrologic restoration actions; other surfaces far from the channel will benefit from higher water tables and shift towards more mesic vegetation types. Water table increases from the increased flow will likely result in the flooding of old meanders creating off-channel increases in wetland and wet meadow habitats. This increase in the water table a loss of established willow trees, as those established in or near the channel may be flooded by the increased flows. Managers and interested parties must be ready to accept the dynamic reaction of the system to restoration actions.

In their review of Ecosystem restoration in the western riparian systems, Kauffman et al. (1997) developed a conceptual model of ecosystem state response to perturbations. This model has been adapted to the Lower Owens River (Figure18). The system was not *resistant* to the changes in water and land use in the study area, as it has clearly moved outside its natural dynamic state. The lower reaches, where they were somewhat buffered from the hydrological disturbance with the connection to the water table, appear to be somewhat *resistant*, shifting to a less disturbed and stable state, dominated by native species. The dry reach, lacking the groundwater buffer, was shifted to an invaded dominated state, with low cover of native vegetation.

The capacity of the lower reaches to resist invasion by tamarisk and Russian thistle illustrates the resiliency of riparian systems. If a small amount of water had been kept in the channel between the intake and the intersection of the earthquake fault, some of the native communities could have been preserved, at least in part, and therefore buffered the system from invasive species invasion. The results illustrate the need for environmental flow to consider riparian vegetation along with fisheries and other ecosystem components.

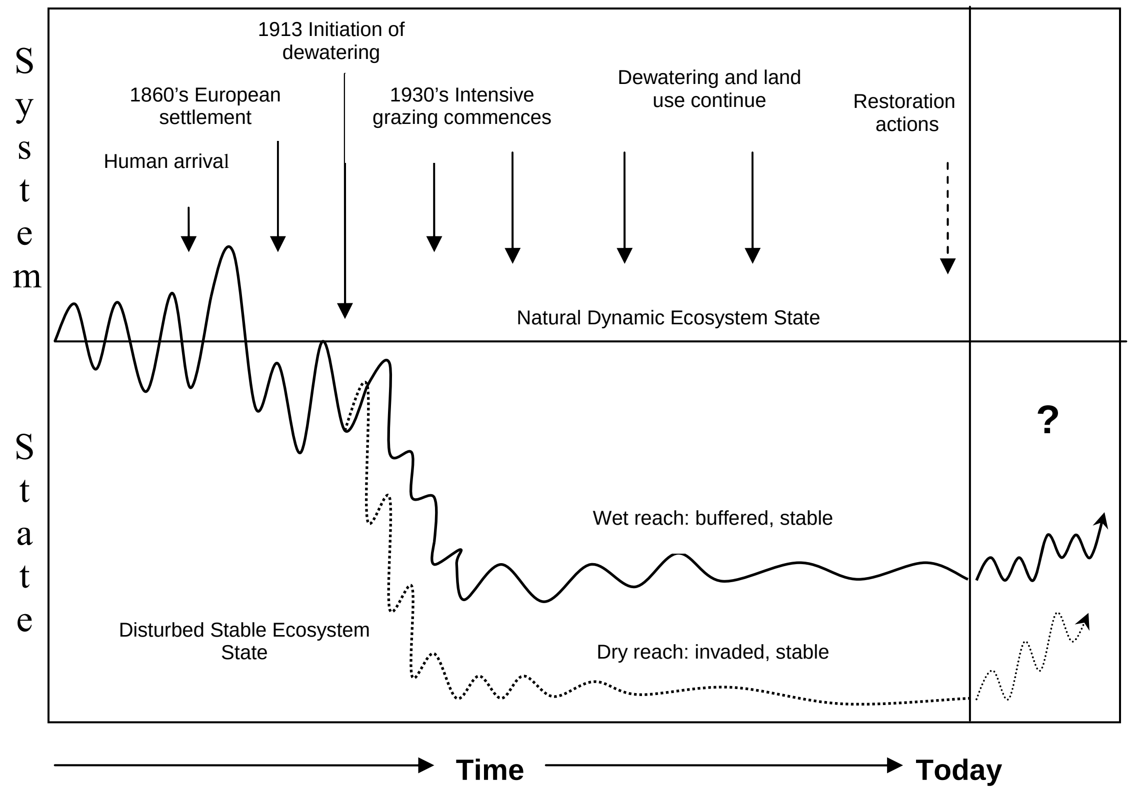

Figure 18. Conceptual Diagram of Ecosystem State. An conceptual representation the effects of land use and hydrologic alterations on past, present and future ecosystem state of the Lower Owens River. Adapted to fit the system from a generalized diagram presented in Kauffman et al. 1997.

With the introduction of a 1.1 m^3/sec (40 cfs) base flow for restoration, the dry reaches can be expected to move towards the condition of the wet reaches, as their ecological trajectory will be changed. The changes in hydrology will result in permanent baseflow and a spring pulse flow timed for riparian seed dispersal. This will move the hydrologic regime closer to a natural hydrologic regime, but will remain highly modified. The literature suggests that a flow regime that captures the most important elements of the natural flow regime will be most effective in accomplishing restoration goals.

If the system responds to tamarisk eradication efforts as many others in the western U.S. that have suffered tamarisk invasions, the shift to native dominated communities will be slow (Harms and Hiebert 2006). However, the dry reaches, following an extensive tamarisk eradication program, will have a relatively unimpeded flow. This will contrast with the wet reaches, which have channels choked with tules and cattails, beaver dams, and accumulated organic sediments. These conditions may allow the dry reaches to move on a steeper trajectory towards a functioning riverine environment, while the wet reaches may remain entrenched in their established ecosystem state. The same surface and ground water that buffered the wet reaches from invasion, may impede system recovery due to the resiliency of the established vegetation and accumulated sediments. However, over time, the small base flow within a larger historical channel will likely become choked with vegetation. Higher pulse flows may be needed to maintain a “riverine environment.” Change in the lower reaches may be slow. With a low gradient and high roughness, flow will be slow in the lower reaches, exhibiting characteristics of a spring or seep fed wetland system, rather than the dynamic lotic system associated with riverine systems. However, the slow velocity, high roughness, and increased flow will inundate new landforms, increasing riparian and wetland habitat significantly.

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Appendices

Appendix A: Data Sheets

Transect: Line-Intercept

Ref. plot:	Sampled by:	Date:	

Tran. #	C#	length (m)	C.T./ dom. species	Notes:

Notes:

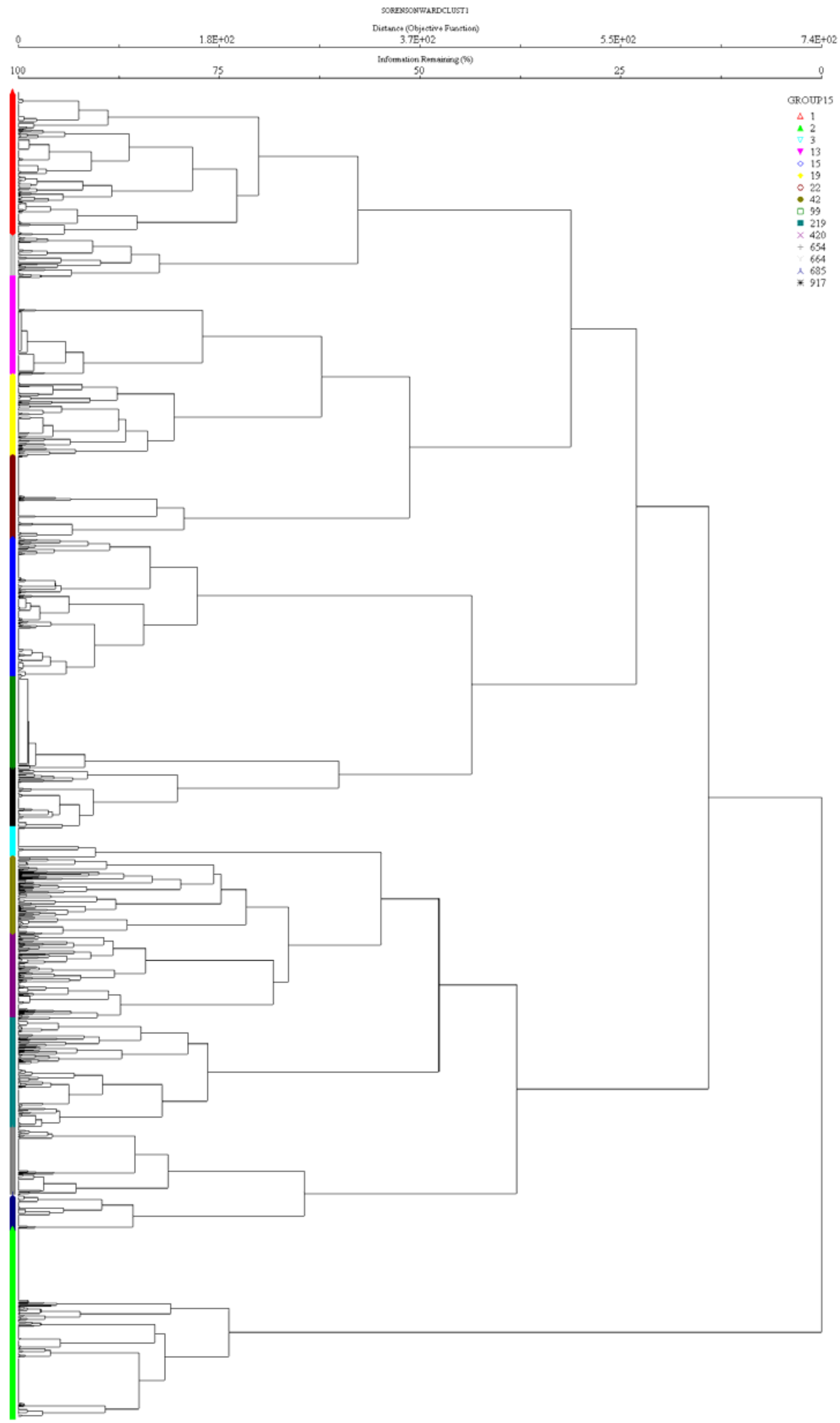
Transect: Subplots

Reference plot:	Sampled by:	Date:

Transect #					
Community #					
Dist. From fencepost					
Community type/dom spec					
Canopy cover (%)					
Ground cover (%)					
bare ground					
vegtation					
litter					
rock					
downed wood					
cow pie					
other (record below					

notes:

Appendix B: Cluster Dendrogram



Appendix C: Vegetation Type Summary Sheets

A summary sheet for each of the 22 vegetation types delineated by this study is found below. The data contained within these sheets is described in the body of the text and its tables and figures. The information pertaining to each vegetation type, along with a representative picture, is presented here for easy reference.

Vegetation Type: Greasewood – Saltbush Scrub

Community Characteristics:						
Plot	1	2	3	4	5	Total
Cover %	10.3	7.5	3.5	0	0	3.3
Mean plot pos.:						1.8
Ave. patch length (m):						26
WWI score:						(FACU-)3.5
Dominant sp. origin:						native
Community complex:						saline scrub
Species abundance:						
# of dominant species in transects:						6
Total species in subplots						10

			n=56	**Groundcover**	n=17
Most Common Dominant Species	**Dom. score**	**%Freq**	**IV**	**Cover type**	**%**
Sarcobatus vermiculatus	2.7	100	31	bareground	58
Atriplex lentiformis	2.0	84	9	litter	33
Chrysothamnus nauseosus	0.2	21	1	vegetation	5
Tamarix ramosissima	0.1	4	0	downed wood	4
unknown forb	0.1	2	1	cow manure	<1
Ephedra nevadensis	0	2	0	dead shrub	<1

Cover percentage and diversity measures:

Max (%)	**LCL (%)**	**Mean (%)**	**UCL (%)**	**Structure**	**S**	**E**	**H′**
19.9	2.5	3.3	4.4	shrub	15	0.7	1.9

Canopy Cover:

n	**lcl**	**mean**	**ucl**
17	9	17	39

Crosswalk:

Whitehorse Associates (2004)	**NDDB/ Holland (1986)**	**Greenbook (1990)**	**Sawyer and Keeler-Wolf (1995)**
Alkali scrub	Desert greasewood scrub or Desert sink scrub	Desert greasewood scrub or Desert sink scrub	Greasewood series

Vegetation Type: Tamarisk Cuttings/-Saltbush Scrub

Community Characteristics:

Plot	1	2	3	4	5	Total
Cover %	21.8	18.0	2.3	0.5	0	3.0
Mean plot pos.:						1.5
Ave. patch length (m):						22
WWI score:						(FACU) 3.9
Dominant sp. Origin:						exotic
Community complex:						tamarisk
Species abundance:						
# of dominant species in transects:						14
Total species in subplots						12

			n=44	**Groundcover**	N=16
Most Common Dominant Species	**Dom. score**	**%Freq**	**IV**	**Cover type**	**%**
tamarisk cuttings	3.0	100	97	litter	40
Atriplex lentiformis	0.8	27	1	downed wood	30
Salsola tragus	0.3	11	1	bare ground	24
				vegetation	7

Cover percentage and diversity measures:

Max (%)	**LCL (%)**	**Mean (%)**	**UCL (%)**	**Structure**	**S**	**E**	**H′**
49.2	1.5	3.0	5.9	shrub	3	0.7	0.8

Canopy Cover:

n	**lcl**	**mean**	**ucl**
16	0	7	91

Crosswalk:

Whitehorse Associates (2004)	**NDDB/ Holland (1986)**	**Greenbook (1990)**	**Sawyer and Keeler-Wolf (1995)**
Alkali scrub	Desert saltbush scrub	Nevada saltbush scrub*	Mixed saltbush series

Vegetation Type: Greasewood/ Russian Thistle Scrub

Community Characteristics:						
Plot	1	2	3	4	5	Total
Cover %	21.8	18.0	2.3	0.5	0	8.8
Mean plot pos.:						1.5
Ave. patch length (m):						22
WWI score:						(FACU) 3.9
Dominant sp. Origin:						exotic
Community complex:						tamarisk
Species abundance:						
# of dominant species in transects:						14
Total species in subplots						12

		n=138		**Groundcover**	N=31
Most Common Dominant Species	**Dom. score**	**%Freq**	**IV**	**Cover type**	**%**
Salsola tragus	3.0	100	44	bare ground	74
Sarcobatus vermiculatus	0.4	13	1	litter	19
Bassia hysssopifolia	0.1	6	0	vegetation	4
Atriplex lentiformis	0.1	5	0	cow manure	2
Atriplex confertifolia	0.1	4	0	downed wood	1
Chrysothamnus nauseosus	0	2	0		
Malva neglecta	0	2	0		

Cover percentage and diversity measures:

Max (%)	**LCL (%)**	**Mean (%)**	**UCL (%)**	**Structure**	**S**	**E**	**H′**
45.3	6.6	8.8	11.5	shrub	14	0.4	1.0

Canopy Cover:

n	**lcl**	**mean**	**ucl**
31	4	6	10

Crosswalk:

Whitehorse Associates (2004)	**NDDB/ Holland (1986)**	**Greenbook (1990)**	**Sawyer and Keeler-Wolf (1995)**
Alkali scrub	Desert greasewood scrub or Desert sink scrub	Desert greasewood scrub or Desert sink scrub	Greasewood series

Vegetation Type: Saltbush/ Russian Thistle Scrub

Community Characteristics:

Plot	1	2	3	4	5	Total
Cover %	28.8	18.1	2.2	0.3	0	9.7
Mean plot pos.:						1.5
Ave. patch length (m):						23
WWI score:						(FAC) 3.2
Dominant sp. Origin:						exotic
Community complex:						tamarisk
Species abundance:						
# of dominant species in transects:						15
Total species in subplots						10

			n=146	Groundcover	N=43
Most Common Dominant Species	Dom. score	%Freq	IV	Cover type	%
Salsola tragus	3.0	99	43	litter	47
				bare ground	35
Atriplex lentiformis	2.4	82	10	vegetation	11
Tamarix ramosissima	0.8	26	4	downed wood	4
Chrysothamnus nauseosus	0.3	14	1		
Distichlis spicata	0.3	11	0	rock	1
Atriplex pusilla	0.2	8	5	cow manure	1
				dead shrub	1
				water	<1

Cover percentage and diversity measures:

Max (%)	LCL (%)	Mean (%)	UCL (%)	Structure	S	E	H′
62.2	6.9	9.7	13.1	shrub	15	0.6	1.5

Canopy Cover:

n	lcl	mean	ucl
43	18	25	35

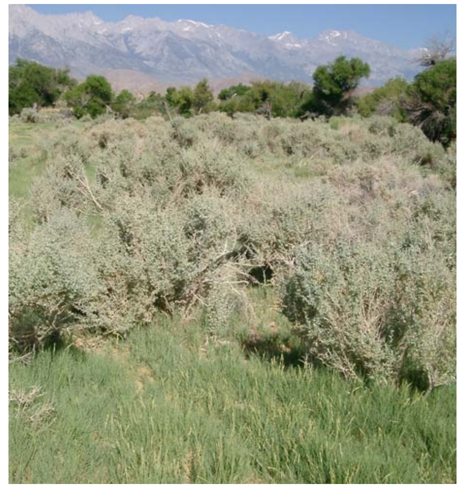
Crosswalk:

Whitehorse Associates (2004)	NDDB/ Holland (1986)	Greenbook (1990)	Sawyer and Keeler-Wolf (1995)
Alkali scrub	Desert saltbush scrub	Nevada saltbush scrub*	Mixed saltbush series

Vegetation Type: Saltbush/ Saltgrass Scrub Meadow

Community Characteristics:

Plot	1	2	3	4	5	Total
Cover %	3.7	17.5	11.5	2.0	7.9	8.3
Mean plot pos.:						3.2
Ave. patch length (m):						23
WWI score:						(FAC+)2.6
Dominant sp. Origin:						native
Community complex:	Saltbush/ saltgrass scrub					
Species abundance:						
# of dominant species in transects:						11
Total species in subplots						12



			n=146
Most Common Dominant Species	**Dom. score**	**%Freq**	**IV**
Atriplex lentiformis	3.0	99	15
Distichlis spicata	2.0	66	6
Chrysothamnus nauseosus	0.4	21	1
Phragmites australis	0.1	3	0
Sarcobatus vermiculatus	0.1	3	0
tamarisk cuttings	0.0	1	0
Suaeda moquinii	0.0	1	0
Sporobolus airoides	0.0	1	0

Groundcover	n=42
Cover type	**%**
litter	49
vegetation	27
bare ground	18
downed wood	4
cow manure	1
dead shrub	<1

Cover percentage and diversity measures:

Max (%)	**LCL (%)**	**Mean (%)**	**UCL (%)**	**Structure**	**S**	**E**	**H′**
55.9	6.3	8.3	11.2	shrub	11	0.5	1.2

Canopy Cover:

n	**lcl**	**mean**	**ucl**
42	39	50	64

Crosswalk:

Whitehorse Associates (2004)	**NDDB/ Holland (1986)**	**Greenbook (1990)**	**Sawyer and Keeler-Wolf (1995)**
Alkali scrub/meadow	Desert saltbush scrub	Nevada saltbush meadow*	Mixed saltbush series

Vegetation Type: Alkalai Sacatone/ Saltgrass Meadow

Community Characteristics:

Plot	1	2	3	4	5	Total
Cover %	2.8	0.8	18.3	19.6	15.5	11.1
Mean plot pos.:						4
Ave. patch length (m):						23
WWI score:						(FAC+)2.5
Dominant sp. Origin:						native
Community complex:			Saltbush/ saltgrass scrub			
Species abundance:						
# of dominant species in transects:						28
Total species in subplots						23

			n=212	Groundcover	n=57
Most Common Dominant Species	Dom. score	%Freq	IV	Cover type	%
Sporobolus airoides	2.9	100	67	vegetation	38
Distichlis spicata	2.5	84	9	litter	29
Chrysothamnus nauseosus	1.4	51	10	bare ground	29
Atriplex lentiformis	1.3	53	3	downed wood	2
Suaeda moquinii	0.3	13	1	cow manure	1
Juncus balticus	0.2	10	1	dead grass	1
Glycyrrhiza lepidota	0.2	10	1	dead shrub	1

Cover percentage and diversity measures:

Max (%)	**LCL (%)**	**Mean (%)**	**UCL (%)**	**Structure**	**S**	**E**	**H′**
62.3	8.7	11.1	13.9	grass	28	0.6	1.9

Canopy Cover:

n	**lcl**	**mean**	**ucl**
57	49	61	71

Crosswalk:

Whitehorse Associates (2004)	**NDDB/ Holland (1986)**	**Greenbook (1990)**	**Sawyer and Keeler-Wolf (1995)**
Dry alkali meadow	Valley sacaton grasslands	Alkali meadow	Alkali sacaton series

Vegetation Type: Greasewood-Seepweed-Shadscale Scrub

Community Characteristics:

Plot	1	2	3	4	5	Total
Cover %	2.0	3.5	9.6	8.3	7.7	6.4
Mean plot pos.:						3.8
Ave. patch length (m):						22
WWI score:					(FAC)	3.2
Dominant sp. Origin:						native
Community complex:						Saline scrub
Species abundance:						
# of dominant species in transects:						15
Total species in subplots						13

Most Common Dominant Species	Dom. score	%Freq	IV (n=111)	Groundcover: Cover type	% (n=24)
Sarcobatus vermiculatus	2.8	96	30	bare ground	67
Suaeda moquinii	2.2	81	27	litter	18
Atriplex confertifolia	1.3	49	14	vegetation	13
Distichlis spicata	1.2	39	2	downed wood	1
Sporobolus airoides	0.8	26	5	dead shrub	1
Atriplex lentiformis	0.8	34	1	cow pie	1
Chrysothamnus nauseosus	0.3	14	1		

Cover percentage and diversity measures:

Max (%)	LCL (%)	Mean (%)	UCL (%)	Structure	S	E	H′
25.6	5.1	6.4	7.8	shrub	15	0.7	1.9

Canopy Cover:

n	lcl	mean	ucl
24	21	30	50

Crosswalk:

Whitehorse Associates (2004)	NDDB/ Holland (1986)	Greenbook (1990)	Sawyer and Keeler-Wolf (1995)
Alkali scrub	Desert greasewood scrub or Desert sink scrub	Desert greasewood scrub or Desert sink scrub	Greasewood series

Vegetation Type: Rabbitbrush- Saltbush/ Saltgrass Scrub Meadow

Community Characteristics:

Plot	1	2	3	4	5	Total
Cover %	5.8	4.7	16.4	1.2	4.9	6.1
Mean plot pos.:						3.3
Ave. patch length (m):						20
WWI score:						(FAC+) 2.6
Dominant sp. Origin:						native
Community complex:						Saltbush/ saltgrass scrub
Species abundance:						
# of dominant species in transects:						24
Total species in subplots						17

			n=123	**Groundcover**	n=35
Most Common Dominant Species	**Dom. score**	**%Freq**	**IV**	**Cover type**	**%**
Chrysothamnus nauseosus	2.7	98	36	litter	44
Atriplex lentiformis	1.6	75	6	vegetation	32
Distichlis spicata	1.4	47	3	bare ground	19
Suaeda moquinii	0.4	13	1	downed wood	4
Glycyrrhiza lepidota	0.4	12	1	cow pie	1
Juncus balticus	0.3	12	1	dead shrub	1
Anemopsis californica	0.3	11	1		

Cover percentage and diversity measures:

Max (%)	**LCL (%)**	**Mean (%)**	**UCL (%)**	**Structure**	**S**	**E**	**H′**
38.1	4.5	6.1	7.9	shrub	24	0.7	2.1

Canopy Cover:

n	**lcl**	**mean**	**ucl**
35	57	71	85

Crosswalk:

Whitehorse Associates (2004)	**NDDB/ Holland (1986)**	**Greenbook (1990)**	**Sawyer and Keeler-Wolf (1995)**
Alkali scrub/meadow	Desert saltbush scrub	Rabbitbrush meadow*	Rubber rabbitbrush series

Vegetation Type: Tamarisk / Saltbush Woodland

Community Characteristics:

Plot	1	2	3	4	5	Total
Cover %	6.1	16.5	0.1	1.2	0.3	4.7
Mean plot pos.:						1.9
Ave. patch length (m):						22
WWI score:						(FAC+)2.4
Dominant sp. Origin:						exotic
Community complex:						tamarisk
Species abundance:						
# of dominant species in transects:						14
Total species in subplots						10

Most common Dominant Species	Dom. score	%Freq	IV (n=123)	Groundcover Cover type (n=35)	%
Tamarix ramosissima	3.0	99	51	litter	61
Atriplex lentiformis	2.0	69	7	vegetation	25
Distichlis spicata	0.8	26	1	bare ground	7
Chrysothamnus nauseosus	0.1	5	0	downed wood	6
Elaeagnus angustifolia	0.1	2	1	cow manure	1
Malva neglecta	0	2	0		
Anemopsis californica	0	2	0		

Cover percentage and diversity measures:

Max (%)	LCL (%)	Mean (%)	UCL (%)	Structure	S	E	H′
41.9	3.4	4.7	6.6	tree	14	0.5	1.3

Canopy Cover:

n	lcl	mean	ucl
35	53	67	78

Crosswalk:

Whitehorse Associates (2004)	NDDB/ Holland (1986)	Greenbook (1990)	Sawyer and Keeler-Wolf (1995)
Tamarisk	Tamarisk scrub	Tamarisk scrub	Tamarisk series

Vegetation Type: Smotherweed-Mixed Shrubland

Community Characteristics:						
Plot	1	2	3	4	5	Total
Cover %	3.2	0.6	0.7	0.7	0.1	1.2
Mean plot pos.:						2.2
Ave. patch length (m):						19
WWI score:						(FAC+)3.1
Dominant sp. Origin:						exotic
Community complex:						Saline scrub
Species abundance:						
# of dominant species in transects:						12
Total species in subplots:						9

			n=20	**Groundcover**	n=5
Most Common Dominant Species	**Dom. score**	**%Freq**	**IV**	**Cover type**	**%**
Bassia hyssopifolia	3.0	100	88	bare ground	50
Sarcobatus vermiculatus	1.1	35	4	litter	31
Distichlis spicata	1.1	35	2	vegetation	18
Atriplex lentiformis	1.0	40	2	downed wood	<1
Leymus triticoides	0.4	15	1	cow manure	<1
Salsola tragus	0.2	10	0		
Salix gooddingii	0.2	5	0		

Cover percentage and diversity measures:

Max (%)	**LCL (%)**	**Mean (%)**	**UCL (%)**	**Structure**	**S**	**E**	**H′**
18.7	0.6	1.2	2.2	herbaceous	12	0.7	1.8

Canopy Cover:

n	**lcl**	**mean**	**ucl**
5	0	37	421

Crosswalk:

Whitehorse Associates (2004)	**NDDB/ Holland (1986)**	**Greenbook (1990)**	**Sawyer and Keeler-Wolf (1995)**
Alkali scrub	Desert saltbush scrub	Non-native vegetation and misc. lands*	Mixed saltbush series

Vegetation Type: Saltgrass Meadow

Community Characteristics:

Plot	1	2	3	4	5	Total
Cover %	0.2	0.2	1.5	5.7	19.2	5.3
Mean plot pos.:						4.6
Ave. patch length (m):						20
WWI score:						(FACW) 2.0
Dominant sp. Origin:						native
Community complex:						Saltbush/ saltgrass scrub
Species abundance:						
# of dominant species in transects:						6
Total species in subplots						14

			n=137	**Groundcover**	n=24
Most common Dominant Species	**Dom. score**	**%Freq**	**IV**	**Cover type**	**%**
Distichlis spicata	3.0	100	13	litter	41
Anemopsis californica	0.1	4	0	vegetation	41
Lolium sp.	0	1	0	bare ground	10
Ambrosia acanthicarpa	0	1	0	road	4
Atriplex pusilla	0	1	0	cow manure	2
Juncus balticus	0	1	0	downed wood	2
				ant hill	<1

Cover percentage and diversity measures:

Max (%)	**LCL (%)**	**Mean (%)**	**UCL (%)**	**Structure**	**S**	**E**	**H′**
36.8	3.8	5.3	7.5	grass	6	0.1	0.3

Canopy Cover:

n	**lcl**	**mean**	**ucl**
24	55	70	82

Crosswalk:

Whitehorse Associates (2004)	**NDDB/ Holland (1986)**	**Greenbook (1990)**	**Sawyer and Keeler-Wolf (1995)**
Dry alkali meadow	Alkali meadow	Alkali meadow	Saltgrass sereies

Vegetation Type: Goodding's Willow Woodland

Community Characteristics:

Plot	1	2	3	4	5	Total
Cover %	0.4	4.9	10.0	5.6	7.8	5.7
Mean plot pos.:						3.8
Ave. patch length (m):						15
WWI score:						(FACW+) 1.8
Dominant sp. Origin:						native
Community complex:						Willow wet meadow
Species abundance:						
# of dominant species in transects:						39
Total species in subplots						32

Most common Dominant Species	Dom. score	%Freq	n=162 IV	Groundcover Cover type	%
Salix gooddingii	2.9	96	51	vegetation	42
Distichlis spicata	1.7	58	4	litter	40
Atriplex lentiformis	0.9	31	1	bare ground	9
Leymus triticoides	0.8	29	4	downed wood	6
Scirpus americanus	0.5	20	2	dead shrub	1
Tamarix ramosissima	0.5	24	2	water	1
Anemopsis californica	0.5	17	2	cow manure	1
				rock	<1
				dead tree	<1

Cover percentage and diversity measures:

Max (%)	LCL (%)	Mean (%)	UCL (%)	Structure	S	E	H′
34.2	4.4	5.7	7.5	tree	39	0.7	2.4

Canopy Cover:

n	lcl	mean	ucl
43	78	93	110

Crosswalk:

Whitehorse Associates (2004)	NDDB/ Holland (1986)	Greenbook (1990)	Sawyer and Keeler-Wolf (1995)
Riparian Forest (willow)	Modoc-Great Basin cottonwood/willow riparian forest and Mojave riparian forest	Modoc-Great Basin cottonwood/willow riparian forest and Mojave riparian forest	Black willow series

Vegetation Type: Sunflower-Licorice Wet Meadow

Community Characteristics:

Plot	1	2	3	4	5	Total
Cover %	0	0.2	0.3	0.7	2.3	0.7
Mean plot pos.:						4.6
Ave. patch length (m):						10
WWI score:						(FACW) 2.1
Dominant sp. Origin:						native
Community complex:						Willow wet meadow
Species abundance:						
# of dominant species in transects:						30
Total species in subplots						19

			n=33	Groundcover	n=7
Most Common dominant Species	**Dom. score**	**%Freq**	**IV**	**Cover type**	**%**
Helianthus annuus	1.2	46	24	litter	50
Glycyrrhiza lepidota	0.7	30	7	vegetation	34
Distichlis spicata	0.7	27	1	bare ground	7
Rosa woodsii	0.5	15	7	downed wood	4
Xanthium strumarium	0.5	21	10	water	4
Anemopsis californica	0.4	15	1	cow manure	1
Malva neglecta	0.4	15	10		
Leymus triticoides	0.4	18	1		

Cover percentage and diversity measures:

Max (%)	LCL (%)	Mean (%)	UCL (%)	Structure	S	E	H′
9.3	0.4	0.7	1.1	herbaceous	30	0.9	2.9

Canopy Cover:

n	lcl	mean	ucl
7	25	95	172

Crosswalk:

Whitehorse Associates (2004)	NDDB/ Holland (1986)	Greenbook (1990)	Sawyer and Keeler-Wolf (1995)
Wet Alkali meadow (rush/sedge)	Transmontane alkali marsh	Rush-sedge meadow*	Sedge series

Vegetation Type: Baltic Rush – Saltgrass Wet Meadow

Community Characteristics:

Plot	1	2	3	4	5	Total
Cover %	0	0.6	3.5	4.8	3.5	2.5
Mean plot pos.:						4.2
Ave. patch length (m):						15
WWI score:						(FACW+) 1.6
Dominant sp. Origin:						native
Community complex:						Willow wet meadow
Species abundance:						
# of dominant species in transects:						30
Total species in subplots						41

Most Common Dominant Species	Dom. score	%Freq	IV (n=74)	Groundcover: Cover type	%
Juncus balticus	2.7	97	60	vegetation	46
Distichlis spicata	1.3	60	3	litter	36
Anemopsis californica	0.7	35	5	water	9
Salix gooddingii	0.4	15	1	bare ground	6
Tamarix ramosissima	0.4	14	1	downed wood	2
Atriplex lentiformis	0.4	14	0	cow manure	1
Glycyrrhiza lepidota	0.3	15	2		
Helianthus annuus	0.3	14	2		

Cover percentage and diversity measures:

Max (%)	LCL (%)	Mean (%)	UCL (%)	Structure	S	E	H′
23.5	1.7	2.5	3.6	grass	30	0.7	2.5

Canopy Cover:

n	lcl	mean	ucl
21	59	84	109

Crosswalk:

Whitehorse Associates (2004)	NDDB/ Holland (1986)	Greenbook (1990)	Sawyer and Keeler-Wolf (1995)
Wet Alkali meadow (rush/sedge)	Transmontane alkali marsh	Rush-sedge meadow*	Sedge series

Vegetation Type: Seepweed-Saltbush/ Saltgrass Scrub Meadow

Community Characteristics:

Plot	1	2	3	4	5	Total
Cover %	0	2.1	3.9	1.8	3.5	2.1
Mean plot pos.:						3.7
Ave. patch length (m):						19
WWI score:						(FAC+) 2.6
Dominant sp. Origin:						native
Community complex:		Saltbush/ saltgrass scrub				
Species abundance:						
# of dominant species in transects:						12
Total species in subplots:						15

Most Common Dominant Species	Dom. score	%Freq	n=51 IV	Groundcover Cover type	%
Suaeda moquinii	3	100	47	bare ground	57
Atriplex lentiformis	1.9	65	6	litter	23
Distichlis spicata	1.8	61	5	vegetation	19
Atriplex confertifolia	0.3	10	1	downed wood	1
Sarcobatus vermiculatus	0.2	10	0	cow manure	1
Chrysothamnus nauseosus	0.1	6	0	human trash	<1
Stephanomeria pauciflora	0.1	4	2		

Cover percentage and diversity measures:

Max (%)	LCL (%)	Mean (%)	UCL (%)	Structure	S	E	H′
18.4	1.4	2.1	3.1	shrub	12	0.6	1.6

Canopy Cover:

n	lcl	mean	ucl
16	30	44	65

Crosswalk:

Whitehorse Associates (2004)	NDDB/ Holland (1986)	Greenbook (1990)	Sawyer and Keeler-Wolf (1995)
Alkali scrub/meadow	Desert saltbush scrub	Nevada saltbush meadow*	Mixed saltbush series

Vegetation Type: Willow/ Cattail – Rush Wetland

Community Characteristics:

Plot	1	2	3	4	5	Total
Cover %	0.0	0.0	7.9	16.6	4.9	6.2
Mean plot pos.:						4.2
Ave. patch length (m):						24
WWI score:						(OBL) 1.1
Dominant sp. Origin:						native
Community complex:						Emergent wetland
Species abundance:						
# of dominant species in transects:						20
Total species in subplots						15

			n=102	**Groundcover**	n=20
Most Common Dominant Species	**Dom. score**	**%Freq**	**IV**	**Cover type**	**%**
Typha latifolia	3.0	100	58	vegetation	44
Salix gooddingii	0.9	30	5	litter	31
Scirpus americanus	0.6	26	3	water	18
Lemna sp.	0.1	4	3	bare ground	5
Juncus balticus	0.1	4	0	downed wood	2
Tamarix ramosissima	0.1	4	0	dead tree	<1
Scirpus acutus	0.1	3	0		

Cover percentage and diversity measures:

Max (%)	**LCL (%)**	**Mean (%)**	**UCL (%)**	**Structure**	**S**	**E**	**H′**
46.0	4.5	6.2	8.5	emergent	20	0.5	1.5

Canopy Cover:

n	**lcl**	**mean**	**ucl**
20	39	63	89

Crosswalk:

Whitehorse Associates (2004)	**NDDB/ Holland (1986)**	**Greenbook (1990)**	**Sawyer and Keeler-Wolf (1995)**
Marsh	Transmontane alkali marsh	Transmontane alkali marsh	Cattail series

Vegetation Type: Shadscale Scrub

Community Characteristics:

Plot	1	2	3	4	5	Total
Cover %	0.0	0.0	2.6	8.2	6.0	3.3
Mean plot pos.:						4.2
Ave. patch length (m):						24
WWI score:						(UPL)3.8
Dominant sp. Origin:						native
Community complex:						Saline scrub
Species abundance:						
# of dominant species in transects:						15
Total species in subplots:						11

			n=64	**Groundcover**	n=13
Most Common Dominant Species	**Dom. score**	**%Freq**	**IV**	**Cover type**	**%**
Atriplex confertifolia	2.8	95	60	bare ground	91
Sarcobatus vermiculatus	1.2	45	6	litter	5
Psorothamnus polydenius	1.0	41	37	vegetation	4
Chrysothamnus nauseosus	0.6	25	2	dead shrub	<1
Atriplex canescens	0.4	17	13	downed wood	<1
Salsola tragus	0.2	8	0	cow manure	<1
Suaeda moquinii	0.2	9	0		

Cover percentage and diversity measures:

Max (%)	LCL (%)	Mean (%)	UCL (%)	Structure	S	E	H′
19.9	2.5	3.3	4.4	shrub	15	0.7	1.9

Canopy Cover:

n	lcl	mean	ucl
13	6	12	28

Crosswalk:

Whitehorse Associates (2004)	NDDB/ Holland (1986)	Greenbook (1990)	Sawyer and Keeler-Wolf (1995)
Alkali scrub	Shadscale scrub	Shadscale scrub	Shadscale series

Vegetation Type: Bull Rush- Cattail-Willow Wetland

Community Characteristics:

Plot	1	2	3	4	5	Total
Cover %	0.0	0.0	2.0	12.3	2.6	4.1
Mean plot pos.:						4.3
Ave. patch length (m):						22
WWI score:						(OBL) 1.0
Dominant sp. Origin:						native
Community complex:						Emergent wetland
Species abundance:						
# of dominant species in transects:						10
Total species in subplots						7

			n=51
Most Common Dominant Species	**Dom. score**	**%Freq**	**IV**
Scirpus acutus	2.7	100	83
Typha latifolia	1.4	55	15
Salix gooddingii	0.7	24	3
Salix laevigata	0.1	4	1
Atriplex lentiformis	0.1	2	0
Polygonum hydropiperoides	0.1	4	2
Lemna sp.	0.1	2	1

Groundcover	n=10
Cover type	**%**
water	38
litter	31
vegetation	25
downed wood	5
bare ground	1
cow manure	<1

Cover percentage and diversity measures:

Max (%)	LCL (%)	Mean (%)	UCL (%)	Structure	S	E	H′
48.5	2.5	4.1	6.7	emergent	10	0.6	1.3

Canopy Cover:

n	lcl	mean	ucl
10	15	57	92

Crosswalk:

Whitehorse Associates (2004)	NDDB/ Holland (1986)	Greenbook (1990)	Sawyer and Keeler-Wolf (1995)
Marsh	Transmontane alkali marsh	Transmontane alkali marsh	Bullrush series

Vegetation Type: Chairmaker's Bullrush/Saltgrass Wet Meadow

Community Characteristics:

Plot	1	2	3	4	5	Total
Cover %	0.0	0.0	1.1	2.9	1.3	1.2
Mean plot pos.:						4.1
Ave. patch length (m):						8
WWI score:						(OBL-) 1.4
Dominant sp. Origin:						native
Community complex:						Willow wet meadow
Species abundance:						
# of dominant species in transects:						21
Total species in subplots						19

Most Common Dominant Species	Dom. score	%Freq	IV (n=54)
Scirpus americanus	2.9	100	63
Distichlis spicata	1.2	48	3
Anemopsis californica	0.9	33	6
Juncus balticus	0.4	15	1
Tamarix ramosissima	0.2	7	0
Polypogon monspeliensis	0.1	6	2
Xanthium strumarium	0.1	6	1

Groundcover n=8

Cover type	%
vegetation	45
litter	45
bare ground	10
cow manure	1

Cover percentage and diversity measures:

Max (%)	LCL (%)	Mean (%)	UCL (%)	Structure	S	E	H′
14.8	0.7	1.2	1.9	emergent	21	0.6	1.9

Canopy Cover:

n	lcl	mean	ucl
8	57	87	128

Crosswalk:

Whitehorse Associates (2004)	NDDB/ Holland (1986)	Greenbook (1990)	Sawyer and Keeler-Wolf (1995)
Wet Alkali meadow (rush/sedge)	Transmontane alkali marsh	Rush-sedge meadow*	Sedge series

Vegetation Type: Common Reed/ Yerba Mansa

Community Characteristics:

Plot	1	2	3	4	5	Total
Cover %	0.0	0.0	0.1	2.4	1.9	0.9

Mean plot pos.:	4.5
Ave. patch length (m):	16
WWI score:	(FACW+) 1.7
Dominant sp. Origin:	native
Community complex:	Common Reed
Species abundance:	
# of dominant species in transects:	15
Total species in subplots	12

			n=27	**Groundcover**	n=6
Most Common Dominant Species	**Dom. score**	**%Freq**	**IV**	**Cover type**	**%**
Phragmites australis	3.0	100	87	litter	65
Anemopsis californica	1.4	48	13	vegetation	32
Salix exigua	1.0	33	8	water	2
Apocynum cannabinum	0.3	15	15	bare ground	1
Chrysothamnus nauseosus	0.3	15	1	cow manure	<1
Typha latifolia	0.3	11	1		
Helianthus annuus	0.2	11	1		

Cover percentage and diversity measures:

Max (%)	**LCL (%)**	**Mean (%)**	**UCL (%)**	**Structure**	**S**	**E**	**H′**
10.3	0.5	0.9	1.5	shrub	15	0.7	1.9

Canopy Cover:

n	**lcl**	**mean**	**ucl**
6	55	99	241

Crosswalk:

Whitehorse Associates (2004)	**NDDB/ Holland (1986)**	**Greenbook (1990)**	**Sawyer and Keeler-Wolf (1995)**
Reedgrass	Transmontane alkali marsh	Transmontane alkali marsh	Common reed series

Vegetation Type: Coyote Willow/ Saltgrass Riparian Shrubland

Community Characteristics:

Plot	1	2	3	4	5	Total
Cover %	0.0	0.0	0.2	0.7	3.0	0.8

Mean plot pos.: 1.5
Ave. patch length (m): 11
WWI score: (FAC+)1.8
Dominant sp. Origin: native
Community complex: Willow wet meadow
Species abundance:
# of dominant species in transects: 19
Total species in subplots: 18

			n=36	Groundcover	n=7
Most Common Dominant Species	**Dom. score**	**%Freq**	**IV**	**Cover type**	**%**
Salix exigua	3	100	71	litter	45
Distichlis spicata	1.2	42	2	vegetation	33
Leymus triticoides	1.1	36	6	bare ground	13
Glycyrrhiza lepidota	0.6	22	4	downed wood	9
Atriplex lentiformis	0.5	31	1	cow manure	<1
Anemopsis californica	0.5	19	2		
Chrysothamnus nauseosus	0.3	17	1		

Cover percentage and diversity measures:

Max (%)	LCL (%)	Mean (%)	UCL (%)	Structure	S	E	H′
15.5	0.4	0.8	1.6	shrub	19	0.8	15.5

Canopy Cover:

n	lcl	mean	ucl
7	78	113	184

Crosswalk:

Whitehorse Associates (2004)	NDDB/ Holland (1986)	Greenbook (1990)	Sawyer and Keeler-Wolf (1995)
Riparian Shrub (willow)	Modoc-Great Basin riparian scrub	Modoc-Great Basin riparian scrub	Narrowleaf willow series

Vegetation Type: Wildrye/ Saltgrass Meadow

Community Characteristics:

Plot	1	2	3	4	5	Total
Cover %	0.0	0.0	0.6	2.8	6.4	2.0
Mean plot pos.:						1.5
Ave. patch length (m):						11
WWI score:						(FAW-) 2.2
Dominant sp. Origin:						native
Community complex:						Willow wet meadow
Species abundance:						
# of dominant species in transects:						21
Total species in subplots:						23

			n=89	Groundcover	
Most Common Dominant Species	Dom. score	%Freq	IV	Cover type	%
Leymus triticoides	2.8	99	46	vegetation	60
Distichlis spicata	2.3	78	8	litter	28
Glycyrrhiza lepidota	0.6	26	5	bare ground	6
Atriplex lentiformis	0.5	18	0	downed wood	4
Juncus balticus	0.3	12	1	dead shrub	1
Scirpus ameicanus	0.2	9	0	cow manure	1
Anemopsis californica	0.2	9	0		

Cover percentage and diversity measures:

Max (%)	LCL (%)	Mean (%)	UCL (%)	Structure	S	E	H′
23.7	1.3	2.0	3.1	grass	21	0.6	1.8

Canopy Cover:

n	lcl	mean	ucl
7	78	113	184

Crosswalk:

Whitehorse Associates (2004)	NDDB/ Holland (1986)	Greenbook (1990)	Sawyer and Keeler-Wolf (1995)
Dry alkali meadow	Valley wildrye grasslands	Alkali meadow	Creeping ryegrass series