RECLAMATION

Managing Water in the West

Technical Memorandum No. 86-68220-09-11

Comparison of Terrestrial Invertebrates Associated with Las Vegas Wash Exotic Vegetation and Planted Native Vegetation Sites

U.S. Department of the Interior
Bureau of Reclamation
Denver, Colorado

September 2009

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ABSTRACT

Butterflies identified by sight and invertebrates collected with sticky-traps were sampled at exotic vegetation sites and sites that had been cleared and then replanted with native vegetation along the Las Vegas Wash in Nevada. A measure of environmental variables, the qualitative "habitat" model, riparian rank, differed significantly between site types. Butterfly species richness and abundance also differed significantly (higher at native sites) between the site types, while there were no significant differences in sticky-trap arthropod metrics, despite lower mean values at exotic vegetation sites. Within each type of sites, there was a gradient of riparian qualities. Perhaps for this reason, sticky-trap arthropod richness was correlated with butterfly species richness and abundance. Multivariate analysis suggested that environmental variables such as forb and graminoid richness were important in structuring butterfly assemblages in the environment. Although butterfly species richness was increased at native vegetation riparian sites, there were few riparian obligate butterflies detected and it is suggested that isolation of Las Vegas Wash from other functioning riparian areas may inhibit enhancement of the "natural" riparian butterfly assemblage. Results demonstrate the importance of directly assessing communities rather than depending upon measures of habitat suitability. There is likely no short-cut to monitoring wildlife value of restoration sites and data from this study suggests that programs need to include both measures of environmental variables and wildlife to discern restoration success. Although financial constraints of most restoration projects might argue for simple measures of habitat suitability and against the inclusion of wildlife monitoring, the information-rich characteristics associated with wildlife monitoring indicate that these data should be collected at least from time to time over the course of a project.

INTRODUCTION

Riparian areas are among the most diverse environments in the western United States (Allan and Flecker, 1993). Perhaps because of the natural disturbance and connectivity of these environments, these systems are prone to invasion by exotic plants which can result in negative impacts to the riparian environment (Hood and Naiman, 2000). With increased destruction of riparian areas there has been a burgeoning interest in their restoration and a growing interest in using restoration methods to ameliorate environmental concerns associated with invasive species (e.g., Palmer et al., 2005).

One of the concerns with riparian restoration is whether restored environments result in positive changes in wildlife diversity and how this diversity varies with habitat patch type. Because of large expenditures associated with restoration of riparian areas it is important that revamping of these environments does indeed result in increased wildlife values. Thus it is important that wildlife responses are analyzed at these sites. Monitoring restoration areas can also be important in detecting the unexpected (positive and negative) consequences associated with intervention.

Of special importance to restoration is the response of insects to these new ecosystems. Insects play a vital role in transfer of plant nutrients and energy to higher trophic levels, can be ecological indicators of ecosystem structure and function, and may be the focus of recovery efforts in and of themselves. Vertebrate species, including those that are endangered or threatened, may also select riparian areas based on insect prey abundance (e.g., Whitaker et al., 2000).

Butterflies have great value as indicator organisms and are important in describing ecosystem "health". They often require resources found only in intact ecosystems, such as flowers for nectar, specific caterpillar food plants, and bare, moist soil areas for obtaining water and salts (e.g., Nelson and Andersen, 1999). Butterflies contribute to terrestrial ecosystem processes such as pollination and, because they feed on plant material, play a role in transfer of plant materials to higher trophic levels (Tallamy, 2004). Butterflies have been used as indicators for landscape conservation (Brown Jr. and Freitas, 2000), logging impacts (Cleary, 2004), to study wetland types (Sawchick et al., 2005), and as indicators in restoration monitoring (Lomov et al., 2006). Butterfly species can be threatened by increased weed abundance (New and Sands, 2002) and corresponding loss of habitat. It has been suggested that butterflies may also serve as surrogates for monitoring other terrestrial insects (Thomas, 2005) (but see Fleishman and Murphy, 2009), although there are few studies that have specifically examined this hypothesis. The value of butterflies as ecological indicators might be increased if this was the case.

A major effort to create/restore riparian environments in the Las Vegas Wash (Wash) in Nevada has been underway since 2000. The Wash serves as the major surface water outlet for the Las Vegas Valley. Population growth and increased water usage over the past five decades have dramatically increased water flow through the Wash and into Lake Mead on the Colorado River. As an example, the mean annual flow in the Wash at its mouth at Lake Mead doubled between 1990 and 2005. These increased daily flows, together with storm flows, caused erosion that led to an incised channel and disappearance of wetlands. Stabilization of the channel bed has been taking place through constructed weirs, in conjunction with bank protection and revegetation. Revegetation with native plant species included structural dominants Fremont cottonwood (*Populus fremontii*) and willow (*Salix* spp.). In many cases vegetated sites were placed in areas where the terrain surface had been lowered and concrete structures had been placed in the channel to stabilize the riverine environment. The effect was to create a hydologically functioning floodplain which provided the opportunity for occasional flooding of a portion of the terrestrial environment. Historically the Wash was an intermittent stream that likely contained very little mesic riparian woody vegetation (e.g., Stave, 2001) and therefore the aim of "restoration" in this case is not directed to a pre-existing condition but rather towards what might be expected in a perennial stream in the region.

The purpose of this study was to compare invertebrates at revegetated native vegetation sites with sites that had not been revegetated. Sticky-traps were used to sample the broad, non-specific invertebrate community while the more limited butterfly community was sampled by sight and sweep netting along the Wash. A variety of environmental variables were also measured as was the environmental (habitat) metric "riparian rank" (e.g., Stein et al., 2000). Most of the riparian environment, until recently, was dominated by the exotic invasive tamarisk (*Tamarix ramosissima*). The Southern Nevada Water Authority (SNWA) has been replacing large portions of this plant with native woody vegetation such as Fremont cottonwood, willow (including Gooding's willow (*Salix goodingii*)), and Seep-willow (*Baccharis salicifolia*); and herbaceous plants like Alkali heliotrope (*Heliotropium curassavicum*). One of the basic tenets of riparian restoration is to determine whether the ecological condition has been improved (Palmer et al., 2005) as native vegetation is established. In this study, goals were to compare two types of sites, one of planted native vegetation and the other of mainly exotic plants, and to compare associated invertebrate taxa (butterflies and sticky-trap invertebrates). This study also examined whether there was correlation between butterfly assemblages and sticky-trap arthropods and documented environmental variables associated with the two types of study environments.

One of the assumptions of this study was that higher taxa richness and abundance were desirable traits and that a positive response to improved conditions would be demonstrated through increases in richness and/or abundance.

METHODS

Study area--Research took place along the Wash just east of Las Vegas, Nevada. This Wash is a perennial stream that is largely fed by wastewater treatment plants that process water from communities in the surrounding area. SNWA has been charged with stabilizing the existing riverine environment in the Wash and has reduced the extensive head cutting that has occurred through construction of multiple erosion control structures in the channel, lining channel sections with riprap, and planting of native plants. The general goal for wildlife in the Wash is to enhance native biodiversity by providing the appropriate environmental conditions. Sites selected for study in 2008 were characterized by either of two riparian types: exotic vegetation sites were dominated, based on species-specific cover, by tamarisk and Common reed (exotic invasive haplotype of *Phragmites australis*), while native vegetation sites had been cleared of exotics and then planted with native vegetation. Sites were numbered from downstream to upstream and identified as exotic (E) or native (N) types (Figure 1). Five of each site type were selected from GIS maps from which 1 hectare areas were plotted (50 to 200-m each side depending upon site geography) and used as sampling units. One side of each plot typically bordered the Wash and therefore incorporated flowing water as an edge. The site N-2 was an island in the middle of the Wash and therefore was surrounded by water. Categorization of sites was not meant to imply that there was not some overlap in vegetation between site types. For example N-2, while containing extensive native woody vegetation, also had a large amount of Common reed as understory. Other exotic vegetation sites like E-5 also had trace amounts of native vegetation such as sandbar willow (*Salix exigua*). Some additional sites that were sampled in 2006 and 2007 (2-ha in size) were utilized in the multivariate analysis of butterfly assemblages along the Wash. These sites were also located in areas that were categorized as containing either native or exotic vegetation.

Butterfly assemblages—Individual butterflies were counted and identified by sight during timed searches (1.5 hrs) to provide data on both species presence and abundance. Most butterflies were identified immediately by sight. Sweep nets were used for verification or identification of species difficult to identify. Inclement weather (temperatures below 17^{o}C and wind speeds > a light breeze (6.4 km/hr) on the Beaufort wind force scale) were avoided. Three sessions (April, June, and September) corresponding to different species flight periods were sampled. Site sampling was confined to 1-ha areas that were resampled during each successive session. Sites from 2006 and 2007 were sampled in a similar manner except that the first session in 2006 occurred in March. These additional sites were only used in ordination analysis. Butterfly data were combined from all three seasons to create a single sample for each site in a given year.

Sticky-trap arthropods—Sticky-traps were used to sample other (mostly aerial) invertebrates in the habitat patches. A diagonal transect was established at each site with trapping stations for invertebrates placed towards the beginning, middle, and end of each transect. The beginning and end stations were placed 23.5 m from corners of the 1-ha plot. At each station a yellow single-sided tanglefoot (sticky) trap (The Tanglefoot® Company; 25.4 X 7.6 cm= 193 cm^2 surface area) was placed at a height of 1-m. Traps were folded, with the sticky side facing out, at the top of a 1-m long plastic pipe so that the vertical trap surface area was visible for 360^{o}. Traps were set for 23 $\pm$ 2 hrs at each site during each seasonal visit. When sticky trap cards were removed they were placed in ziplock bags containing a portion of Histo-Clear™ II (National Diagnostics). This is a citrus oil solvent used to remove sticky material to aid in recovery of invertebrates from traps (e.g., Miller et al., 1993). In the laboratory, traps were again soaked in Histo-Clear™ in an enamel pan and invertebrates removed under 10X magnification, identified to order, and placed in vials containing 70% propanol for later weighing. Samples were dried at 105^{o}C for 48 hrs, and then weighed for determination of dry mass. Identification of the type of arthropods present on traps occurred at the order level. For data analysis, collections from sites during different seasons were treated as a single sample (e.g., trap data from three different stations from three different time periods to make 9 traps combined for a single site).

Site characteristics--Estimates of invertebrate habitat quality were measured using floral (nectar) counts along with cumulative estimates of herbaceous/graminoid richness, and qualitative measures of the type of the riparian environment. During butterfly surveys, the numbers of flowers or inflorescences considered nectar sources were estimated. Although not a direct measure of nectar, Holl (1995) reports a linear relationship between nectar amount and number of inflorescences, and suggests little information gain from sugar quantification. Sampling took place within a 4-meter diameter circle at disjunct locations every 15-20 minutes during a survey (n=10 samples during each session). To estimate herbaceous richness at each site, a running-count of forb and graminoid richness was conducted, which resulted in a mean total number of cumulative taxa (pseudo-species in some cases) found in all circles for each session.

Other environmental variables--A riparian systems model (Stein et al., 2000) was used to rank riparian condition ("habitat" model). This qualitative model (riparian rank) includes spatial and structural diversity of native woody plants, contiguity of dominant vegetation, invasive vegetation, hydrology, topographic complexity, characteristics of flood-prone areas, and biogeochemical processing. These criteria consider the interaction between geology, hydrology, and organic and inorganic inputs to the system. Each criterion is scored between 0 and 1.0 and scores are added so that the “best” rank is an 8.

Three measurements of soil moisture (% saturation relative to field capacity; Kelway soil moisture tester Model HB-2) took place through the middle portion of the plot. Theoretically this is a significant parameter because moist soils and seeps have been recognized as important to butterflies for puddling (Murphy and Wilcox, 1986). Wind speed (km/hr) and air-temperature (^{o}C) were also collected at the start of each sampling occasion because they can affect butterfly detectability along with presence of butterfly species in certain areas (e.g., Andersen and Nelson, 1997). Relative humidity (RH) measurements were also taken at each site with a hand-held meter. Light meters were used to measure lux levels in the plots and these measurements were compared to light levels in open areas and then used to calculate % shade. Measurements were taken during each sampling session. Averages of environmental variables from the three sampling sessions were used in data analyses.

Data analysis—Invertebrate metrics (taxa richness and abundance) from Exotic and Native vegetation sites were compared using two-sample *t*-tests. Although there were multiple sites in each of the categories, they were not strict replicates and thus inferences from these data may be weaker than that achieved with a true experimental approach (e.g., Block et al., 2001). In large part, this reflects the difficulty of achieving true experimental rigor at the scale of hectares. This scale, however, is important because it is characteristic of many exotic vegetation control/restoration projects. Small-scale experiments (e.g., 10 m^2) at which many restoration ecology studies take place may allow for replication but may be poor at predicting actual restoration effects (Osenberg et al., 2006).

Stepwise multiple regression (SMR) (forward selection) was used to determine which variables were important ($P \leq 0.05$) in influencing butterfly metrics at Las Vegas Wash riparian sites. Data used in the analysis included measures of butterfly habitat quality and habitat type. If needed, values were transformed prior to analysis to increase normality. Habitat type was coded with dummy variables. The relationship between sticky-trap invertebrate richness and biomass and butterfly species richness and abundance was examined using correlation analyses.

Constrained ordination techniques (CANOCO 4.5) were used to examine gradients in butterfly assemblages (species and abundance) (pooled from the three sampling sessions for each year) and to identify environmental variables (mean values from three sessions each year) most closely associated with butterfly species distributions in the ordination. Initial analyses of butterfly data using detrended correspondence analysis (DCA) revealed that the data set had a relatively short gradient length (less than 3), suggesting that analysis using unimodal models was inappropriate. Therefore redundancy analysis (RDA) was used to explore relationships between assemblages (log transformed, infrequent species contributing $\leq$ 0.1% deleted) and environmental variables (ter Braak and Verdonschot, 1995). Environmental variables were normalized, if needed, with arcsin-squareroot transformations for percent data and ln (X+1) for numeric data. If environmental variables were highly correlated ($r \geq 0.6$) only a single variable was selected for use in RDA to avoid problems with multicollinearity. Forward selection of environmental variables and Monte Carlo permutations were used to determine whether variables exerted a significant ($P \leq 0.05$) effect on butterfly distributions.

RESULTS

Site characteristics—Sites planted with native vegetation tended to have higher forb and graminoid richness, riparian rank, higher wind speeds, higher soil moisture, and lower levels of shade (e.g., Table 1) in 2008. Only forb and graminoid richness and riparian rank were significantly different between the two types of sites (two-sample *t*-test, $P<0.03$) (Figure 2). Riparian rank contains as part of the assessment a qualitative measure of the structure of native woody vegetation. This was the main difference between site types in this evaluation. Although there was no statistical difference in floret (nectar) density between site types, there was a qualitative difference in nectar types (Figure 3) with tamarisk nectar most abundant at Exotic vegetation sites and willow the most common nectar source at Native vegetation sites. Native vegetation sites also had a greater variety of nectar sources including Seep-willow and Alkali heliotrope. Of the butterflies that were seen nectaring, 41% were observed on heliotrope, 21% on seep-willow, and 17% on tamarisk suggesting that there may have been differences in use of nectar sources.

Butterflies—Twenty-eight butterfly species were identified (Table 2) during the 2006-2008 studies. Common and scientific names are presented in Table 2. There were significant differences in butterfly species richness (two-sample *t*-test, $P=0.0074$) and abundance (ln transformed) (two-sample *t*-test, $P=0.0263$) between types of sites (2008 data only, Figure 4). Butterfly metrics were higher at native vegetation sites (Figure 4).

Forb and graminoid richness was an important predictor of butterfly species richness and abundance in the SMR models (Table 3). Temperature, soil moisture, and % shade were also important in predicting species richness. Other measured variables were not significant in either model.

Results of the RDA from 2006-2008 Wash butterfly assemblages had eigenvalues of 0.552 and 0.097 for the first two axes and explained 64.9% of the species data variation and 89.1% of the species-environment relation. All canonical axes were significant ($P=0.001$). The initial model was tested with all of the variables except soil moisture, which was highly correlated with forb and graminoid richness ($r=0.65$, $P=0.0046$) and therefore omitted. A significant effect of forb and graminoid richness, riparian rank, temperature, RH, and wind speed on species composition of the assemblages was exhibited by the RDA of the species data ($P \leq 0.05$) (Figure 5). The absence of % shade in the final model may be because it was highly negatively correlated with wind speed ($r=-0.6726$, $P=0.0031$) and therefore somewhat redundant in the RDA model. Shade was, in fact, highly negatively correlated with butterfly species richness (r=-0.6974, P=0.0250) and was also significant in the SMR model.

Riparian rank and forb and graminoid richness were associated largely with Axis I, while temperature was coupled with Axis II (Figure 5, Table 4). The other significant variables (Table 4) were mostly correlated with Axis III (wind speed) or Axis IV (RH) which explained only a small portion of species-environment relationships. Temperature was likely associated with sampling between years because sampling in 2006 started in March rather than April. Sites sampled in 2006 tended to be high on Axis II, probably as a result of cooler mean temperatures associated with March sampling.

Butterfly species richness was highly correlated with both riparian rank (r=0.8298, P<0.001) and forb and graminoid richness (r=0.7150, P=0.0013). Other variables significant in the RDA model were not correlated with species richness.

Sites tended to cluster in two areas with Exotic sites to the left along Axis I in the diagram (Figure 5) and Native sites to the right. There was also a small third Native group towards the bottom of Axis II. These three sites (N-2, N-4, and N-5) were where the single Wash riparian woody vegetation obligate (Mourning cloak) was detected. Highest abundances of most butterfly species were contained on the right side of the diagram suggesting major associations with Native vegetation sites. Most species, however, were found at both types of sites (Table 2). This is demonstrated in Figure 6 with the Yuma skipper, the most abundant butterfly along the Wash (53% of Wash butterflies were Yuma skippers in 2008), and demonstrates the high abundance at Native sites and limited presence at Exotic sites. The Yuma skipper has southwestern arid environment affinities in the US, and is also restricted to locations which contain its caterpillar host plant, Common reed of which there are native and non-native strains. This plant is especially common along Las Vegas Wash. The Common reed present at the sampling sites is a non-native genotype and this butterfly has apparently adapted to this new resource.

With the exception of the Mourning cloak, riparian-obligate butterflies that use native woody vegetation as caterpillars were not detected in the Wash.

Sticky-traps—Despite average values that were consistently higher at native vegetation sites, there was no significant difference (P>0.1) in sticky-trap richness (Exotic=6.8000 $\pm$ 0.5831, Native= 8.0000 $\pm$ 0.4472), abundance (Exotic=132.80 $\pm$ 22.486, Native=184.20$\pm$ 35.861), or biomass between site types. Weights averaged 0.1648 $\pm$ 0.0449g per trap at Exotic vegetation sites and 0.1771 $\pm$ 0.0464g per trap at Native vegetation sites. Overall, collections were dominated by dipterans at both types of sites (Exotic 66.3%, Native 61.5%) (Figure 7, Table 5).

Correlation between butterfly and sticky-trap metrics—Sticky-trap invertebrate richness was correlated with both butterfly abundance (r=0.6334, P=0.0493) and species richness (r=0.7339, P=0.0157). Neither sticky-trap invertebrate abundance nor biomass were correlated with any butterfly metric (P>0.19).

DISCUSSION

Butterfly response to riparian enhancement--Riparian enhancement efforts appeared to benefit butterfly assemblages along the Las Vegas Wash. Both species richness and abundance were significantly higher at sites restored with native vegetation compared to sites still dominated by exotic vegetation. Forb and graminoid richness was also higher at native vegetation sites and was identified as important in structuring Wash butterfly assemblages. Other studies have also associated herbaceous plant species richness with higher quality butterfly communities (Fleishman et al., 2005; Nelson and Wydoski, 2008). Plant richness, however, was associated with other variables such as soil moisture and % shade that could ultimately prove to be important drivers in the system. Hawkins and Porter (2003) found that plant and butterfly diversity were correlated in a California study, but considered it likely that plants and butterflies were responding to similar environmental factors rather than plant richness directly influencing butterfly diversity. Specific elements of plant communities, however, play a role in organizing butterfly communities, where between-taxa-congruence may be more complicated than can be determined with just simple measures of richness (e.g., Su et al., 2004). There may, in fact, be relationships between taxon groups despite the absence of correlations between richness measures. Burghardt et al. (2008) observed this sort of pattern in a study comparing native and non-native vegetation in suburban environments where, despite containing equivalent plant diversity, the native vegetation yards supported significantly more caterpillars and caterpillar species, demonstrating the inability of simple diversity measures to characterize the environment. Similarly, forb and graminoid measures in the Wash, because of associations with other environmental variables, likely represent more than just a richness value. There may be differences in nectar sources linked to forb and graminoid richness that may impact butterfly communities as suggested by observations indicating the importance of heliotrope as a nectar source in the Wash environment. Dennis (2004) has pointed to the importance of vegetation structure for butterfly assemblages because of its use for mate location and thermoregulation. Information suggests that there are subtle links between vegetation structure and butterfly assemblages, increasing the difficulty to characterize desirable restoration environments.

It appears that the native riparian butterfly community typically associated with woody vegetation in western riparian areas (e.g., Nelson, 2007, Nelson and Wydoski, 2008) is largely absent from the Wash. Colonization may be a major constraint to recovery of invertebrate communities, and some studies suggest that it may take decades for colonization of some invertebrates to occur at restored sites (Langford et al., 2009). This could be the case with the Wash. It is only recently that sediment control structures have been placed in the Wash and the elapsed time may be insufficient for terrestrial invertebrates to take full advantage of new environments. There may also be historical barriers to the presence of riparian obligates. Before the turn of the 20th century, the Las Vegas Wash was ephemeral for most of its length, except for a small wetland area and several springs (Stave, 2001), suggesting an absence of a diverse riparian butterfly community. A nearby source for riparian-obligates, such as the Viceroy (*Limenitis archippus*) (Nelson, 2003), may not exist, and may not allow for use of created riparian areas by certain butterflies. This and other riparian butterflies such as the Fatal metalmark

(*Calephelis nemesis*) are found in the species list for Clark County (www.butterfliesandmoths.org), within which the Wash is contained, and habitat requirements for these species appear to be met by tamarisk control and native vegetation plantings along Las Vegas Wash. If Wash management goals consider butterfly assemblages to be important, it may be necessary to introduce some species to maximize butterfly diversity.

Sticky-trap invertebrates--Despite a lack of significant differences between site types in sticky-trap invertebrates, the tendency for lower abundance and biomass values at exotic vegetation sites suggests ecologically important differences may exist. Even minor reductions in invertebrate biomass resulting from invasions of exotic vegetation are critical when wildlife are close to marginal food levels for survival (Skagen et al., 1998). The lack of significant differences in taxa richness between site types may be the result of the level of taxonomic identification which occurred. It is possible that identification to family or genus would have resulted in the detection of differences between site types.

It may also be the case that differences in structure between habitat types mitigated for sticky-trap invertebrate abundance in Exotic vegetation environments and against abundance in Native vegetation. In some cases, Native vegetation sites were more open environments, as evidenced by lower % shade and higher wind speed. This may limit the numbers of relatively small invertebrates susceptible to capture in sticky-traps. Exotic vegetation in the Wash is dense and shaded and the corresponding climate amelioration in this hostile environment may perhaps retain small invertebrates that might be captured with sticky-traps. Wind speed has been found to be related to capture rates of flying insects (Whitaker et al., 2000) and the higher winds at Native vegetation sites may have removed smaller invertebrates from those areas.

In the literature, correlation of butterfly assemblages with other invertebrates appears to be variable, with studies reporting both the presence and absence of associations. While Vessby et al. (2002) found a positive correlation between bumblebee diversity and grassland butterflies in a study in Sweden, Davis et al. (2008) found just the opposite correlation in an Iowa study. In a study of groups that are even more closely related phylogenetically, Ricketts et al. (2002) found no correlation between butterfly and moth diversity in subalpine environments. In the Wash, there was a positive correlation between butterfly species richness/abundance, and sticky-trap richness. Sticky-traps may be more useful in detecting presence/absence of taxa than in estimating numbers present in an environment (e.g., Hoelmer and Simmons, 2008) and the correlation of butterfly richness and butterfly abundance with sticky-trap richness, but not with sticky-trap abundance could be a result of this incongruity. The small numbers of easily identified butterfly species along with documented natural history requirements and correlation of information with other disparate taxa (sticky-trap invertebrates) suggests that butterflies are an informative and practical indicator group in the Wash.

Monitoring at the Wash-- In this study, butterfly metrics and measurements of butterfly habitat, such as riparian rank, differed significantly between sites with different vegetation types. At first glance this would suggest that a habitat measurement approach might be successfully used for monitoring restoration at the Wash and thus avoid the effort and expense of direct measurement of invertebrate communities. Others (Ricketts et. al., 2002) have made similar recommendations, especially in the area of conservation, that habitat measurements impart enough information to judge the benefits and presumably presence of invertebrate communities or that measurements of abiotic variables would provide information relevant to the environmental status of a site (Fleishman and Murphy, 2009). Others (Kondolf et al., 2000), however, argue that information from environmental models should be treated with caution and that these models are “not a substitute for biological understanding”. The assumption with the habitat-based approach is that a variety of habitats are created or improved which leads to maximum biodiversity of indicator groups. Defining important elements in an environment for use in a habitat model, however, may be difficult and predicting the response of a community to created habitats is likely to be ill-defined. It is unlikely, for instance, that habitat measurements would allow for discernment of the near absence of riparian-obligate butterflies in the Wash. Data from the Wash instead indicates that direct measurement of invertebrate communities is important in describing the wildlife status at planting/restoration projects and that there would be major insufficiencies if habitat was measured exclusively. The habitat approach to monitoring restoration success is also likely inappropriate because of important but subtle elements that will probably not be measured. The evidence that nectar and types of nectar plants are important to butterfly assemblages is information that would not be collected with a habitat metric such as riparian rank. It should also be recognized that if the ultimate measure of success is an increase in value to wildlife, that wildlife values should be measured directly. The best approach (e.g., Dennis, 2004) for monitoring indicators of environmental change is probably similar to the one taken in this study where there is simultaneous collection of information on vegetation structure, environmental resources, abiotic variables, and biotic assemblages. Habitat metrics would be a part of the measured components.

Restoration recommendations developed from invertebrate monitoring-- Although solely monitoring butterfly assemblages can provide some information on other invertebrate groups, the discrete study of sticky-trap invertebrates provided additional and ecologically important information. For example, study of this group was important in realizing what could be important information for additional modifications for revegetation of riparian environments. To date Wash plantings are often aligned with and in close proximity (tens of meters) to the narrow channel and do not extend for any great distance away from the waterway. It may increase the value of these environments if some plantings were extended (50-100 meters) back away from the channel. In order to increase the spatial extent of riparian vegetation (woody or herbaceous), it might be necessary to increase the interaction between floodplain and the wetted channel through construction of backwater environments. This sort of construction and planting scheme might increase abundance of invertebrates in the environment and provide additional resources for insectivorous vertebrates. Observations suggest that a relatively small amount of this sort of environment has a disproportionately positive impact on butterfly richness and abundance. If this were the case, then differences in overall invertebrate abundance might be observed between the two types of environments. The challenge is finding a planting scheme that is beneficial to a wide variety of invertebrates since the dense woody vegetation that might be useful in retaining sticky-trap invertebrates could have negative effects on butterfly communities.

The Wash example may be useful in setting goals for other restoration projects where habitat for butterfly assemblages is important. The importance of forb and graminoid richness, or its surrogates such as soil moisture, suggests considerations for restoration projects as does the presence of a variety of nectar resources. Additionally, source butterfly material for colonization of restored environments should be recognized as an important factor to development of a fully realized community.

CONCLUSIONS

1. Butterfly species richness and abundance were significantly higher at enhanced native vegetation sites compared to exotic vegetation sites.

2. Sticky-trap invertebrate metrics did not differ statistically between site types; however, richness values were correlated with butterfly richness/abundance.

3. Environmental variables that differed between site types included forb and graminoid richness and the habitat measure, riparian rank.

4. Multivariate and stepwise multiple regression analyses suggested that several environmental variables were important in structuring butterfly communities and these included forb and graminoid richness, air temperature, soil moisture, % shade, wind speed, RH, and riparian rank. While statistical differences in floret (nectar) density were not detected between site types, there was a qualitative difference in nectar types, with a greater variety of nectar sources available at Native vegetation sites.

5. Despite enhanced woody riparian vegetation at native vegetation sites, the butterfly community was limited as far as species that would use this vegetation as caterpillar host plants. Only direct measurement of wildlife (butterfly) use of an area would discern this limitation, suggesting inadequacies in measures of habitat suitability such as riparian rank.

Acknowledgements

I wish to thank the Southern Nevada Water Authority for requesting that Bureau of Reclamation funds identified for Las Vegas Wash Coordination Committee programs (Public Law 106-54,1 Section 529) be allocated to support this study. A portion of the funding was also provided by the Bureau of Reclamation S&T program. I would also like to thank Jason Eckberg, Debbie Van Dooremolen, and Seth Shanahan for help in defining study sites and for field assistance and Pam Adams in obtaining project funds**.** Jason Eckberg also developed Figure 1. Rick Wydoski’s assistance in butterfly monitoring was critical to study success. Special thanks to Doug Andersen and Seth Shanahan for thoroughly reviewing an earlier draft of the manuscript.

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Table 1. Mean environmental variables associated with Las Vegas Wash riparian sites. Sites designated with an “E” are those associated with exotic vegetation while those with an “N” contained native woody vegetation.

Site	Forb & graminoid richness	Nectar/flower density (#/m^2)	Percent shade	RH	Riparian rank	Soil moisture (% saturation)	Temperature (^oC)	Wind speed (km/hr)
E-1	1.0	112	67.4	21	4.4	30.0	27.6	1.6
E-2	1.2	394	65.4	17	4.4	11.4	28.7	0.4
E-3	0.7	41	39.1	4	5.1	1.1	34.7	2.0
E-4	0.7	168	63.8	21	5.8	3.3	29.5	0.5
E-5	2.7	116	60.0	27	5.9	26.7	31.1	0.7
N-1	8.5	73	32.6	12	6.6	36.4	32.6	1.3
N-2	5.2	38	76.0	34	5.6	87.8	30.4	1.1
N-3	2.8	204	19.7	24	5.9	9.6	28.6	1.9
N-4	3.8	38	45.2	8	6.1	16.1	35.9	4.1
N-5	4.8	604	32.3	21	6.4	62.5	32.5	2.7

Table 2. Butterfly species found at Las Vegas Wash during sampling from 2006-2008.

Common name	Scientific name	Presence (+) Absence (-) Exotic	Native
Black swallowtail	*Papilio polyxenes*	-	+
Checkered white	*Pontia protodice*	+	+
Cabbage white	*Pieris rapae*	+	+
Orange sulphur	*Colias eurytheme*	+	+
Southern dogface	*Colias cesonia*	-	+
Sleepy orange	*Eurema nicippe*	+	+
Western pygmy blue	*Brephidium exile*	+	+
Acmon blue	*Plebejus acmon*	+	+
Reakirt's blue	*Hemiargus isola*	+	+
Ceraunus blue	*Hemiargus ceraunus*	+	+
Marine blue	*Leptotes marina*	+	+
Grey hairstreak	*Strymon melinus*	+	+
Mormon metalmark	*Apodemia mormo*	+	-
Mourning cloak	*Nymphalis antiopa*	-	+
California tortoiseshell	*Nymphalis californica*	+	+
Red admiral	*Vanessa atalanta*	+	+
Painted lady	*Vanessa cardui*	+	+
Buckeye	*Junonia coenia*	-	+
Snout butterfly	*Libytheana carinenta*	-	+
Monarch	*Danaus plexippus*	+	+
Queen	*Danaus gilippus*	+	+
Funeral duskywing	*Erynnis funeralis*	-	+
Saltbush sootywing	*Hesperopsis alpheus*	-	+
Fiery skipper	*Hylephila phyleus*	+	+
Yuma skipper	*Ochlodes yuma*	+	+
Eufala skipper	*Lerodea eufala*	-	+
Small checkered-skipper	*Pyrgus scriptura*	+	+
Common checkered-skipper	*Pyrgus communis*	-	+

Table 3. Results of stepwise multiple regression for butterfly species richness and abundance. Significant variables were forb and graminoid richness, temperature, soil moisture, and % shade for species richness and forb and graminoid richness for butterfly abundance.

Variable	Species richness				Abundance			
	Coefficient	Standard Error	T	P	Coefficient	Standard error	T	P
Constant	21.4	1.42	14.97	<0.001	29.5	28.5	1.03	0.33
Forb & Graminoid Richness	1.2	0.07	15.19	<0.001	27.8	7.2	3.84	0.005
Temperature	-0.3	0.04	-7.56	<0.001	--	--	--	--
Soil moisture	-1.4	0.48	-2.97	0.031	--	--	--	--
% shade	-0.1	0.01	-8.23	<0.001	--	--	--	--
R squared	0.99				0.65			

Table 4. Weighted correlation matrix showing relationship between species axes and significant environmental variables. Highest correlations associated with a given variable are shown in **bold**.

Variable	Axis			
	1	2	3	4
Riparian rank	**0.6725**	-0.4328	-0.0663	-0.1080
Forb & graminoid richness	**0.8252**	-0.2868	0.1363	0.1502
Temperature	-0.0943	**-0.7265**	-0.0331	-0.3560
RH	0.0819	-0.0237	-0.3024	**0.6684**
Wind speed	0.2416	0.2259	**0.7178**	0.0638

Table 5. Orders of invertebrates collected from sticky traps at Exotic and Native vegetation sites during the study.

Taxon	Overall Abundance	
	Exotic	Native
Arachnida	7	11
Orthoptera	1	2
Embioptera	1	0
Thysanoptera	29	138
Hemiptera	0	4
Homoptera	73	106
Neuroptera	0	1
Trichoptera	0	8
Lepidoptera	4	13
Coleoptera	59	22
Hymenoptera	50	50
Diptera	440	567

Figure 1. Las Vegas Wash study sites. Sites are labeled as "N" for native vegetation sites and "E" for exotic vegetation sites. Direction of water flow is from left to right.

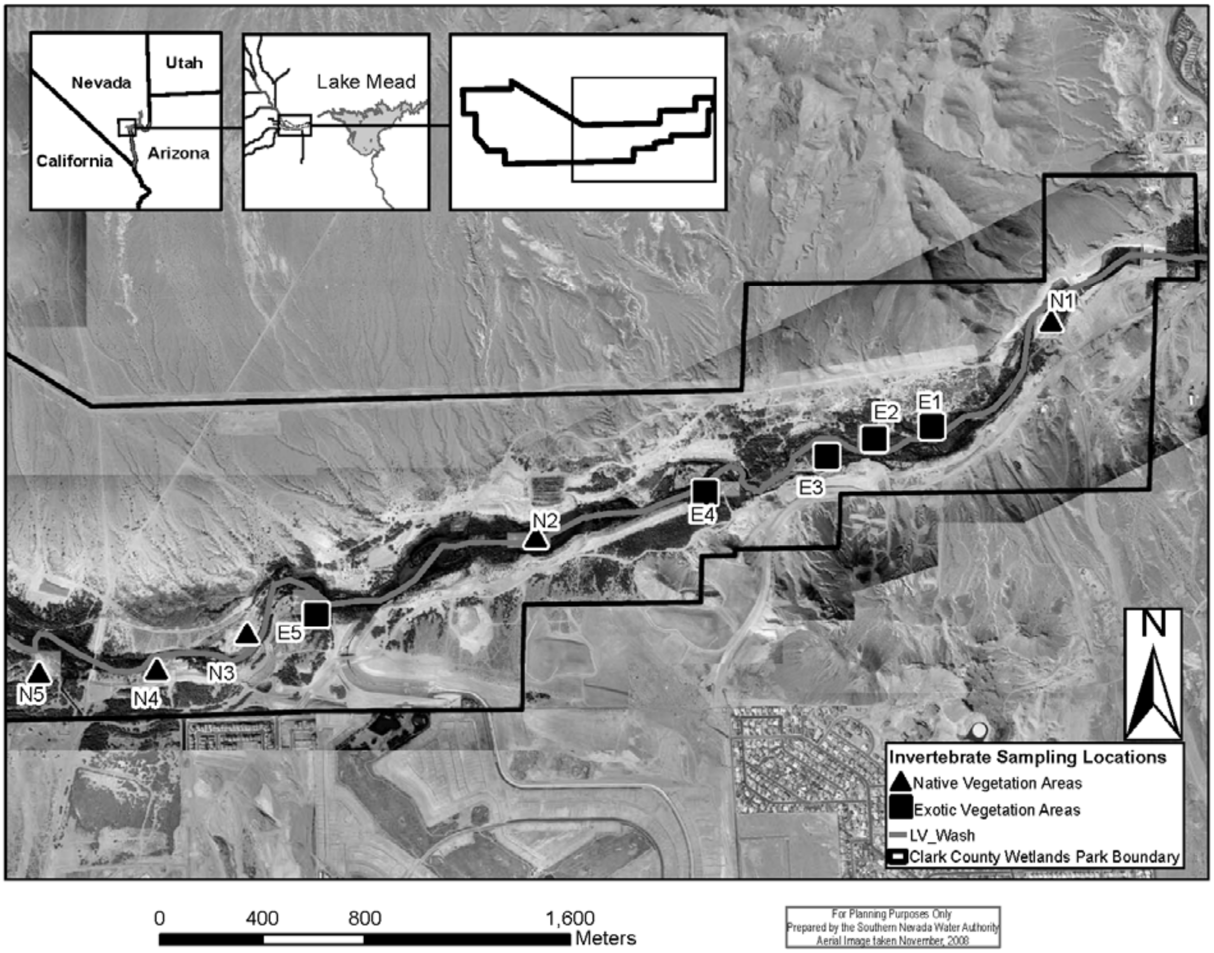
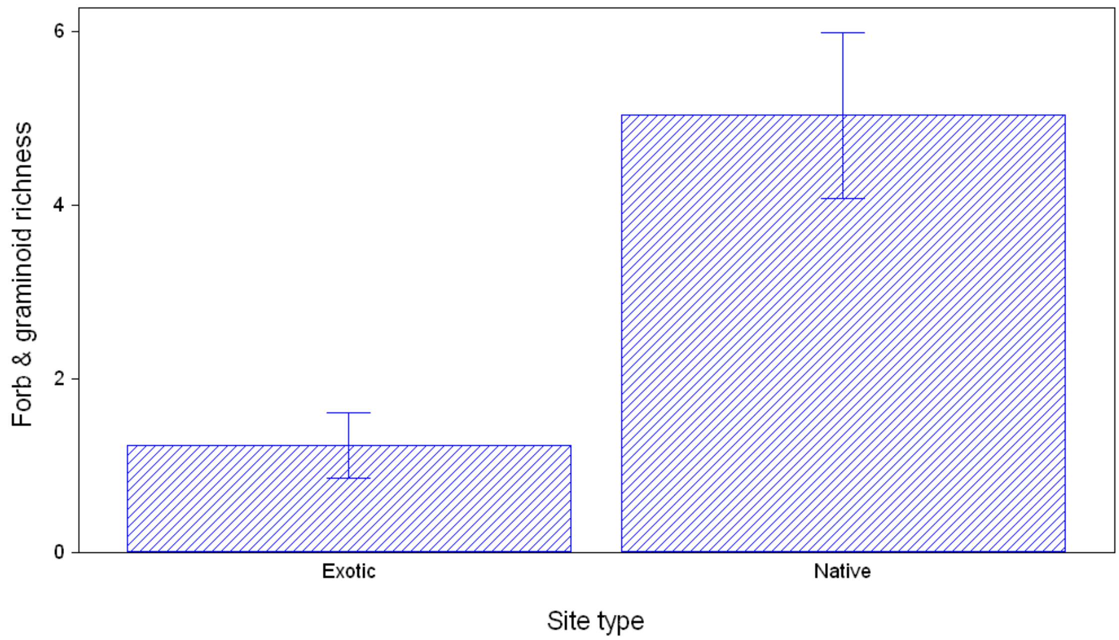


Figure 2. Mean forb & graminoid richness (a) and riparian rank (b) at Exotic and Native vegetation sites. Values were significantly different ($P<0.05$) between site type. Variance is presented as standard error.

a



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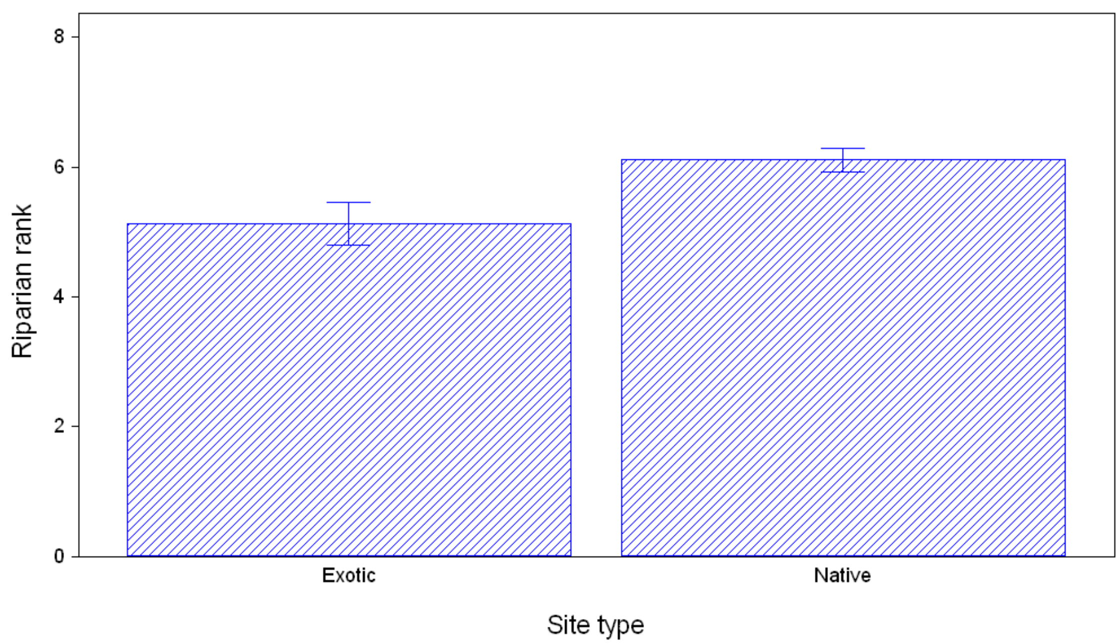


Figure 3. Proportional pie chart showing the percent of total nectar counts from Exotic and Native vegetation sites sampled in 2008 from the Las Vegas Wash.

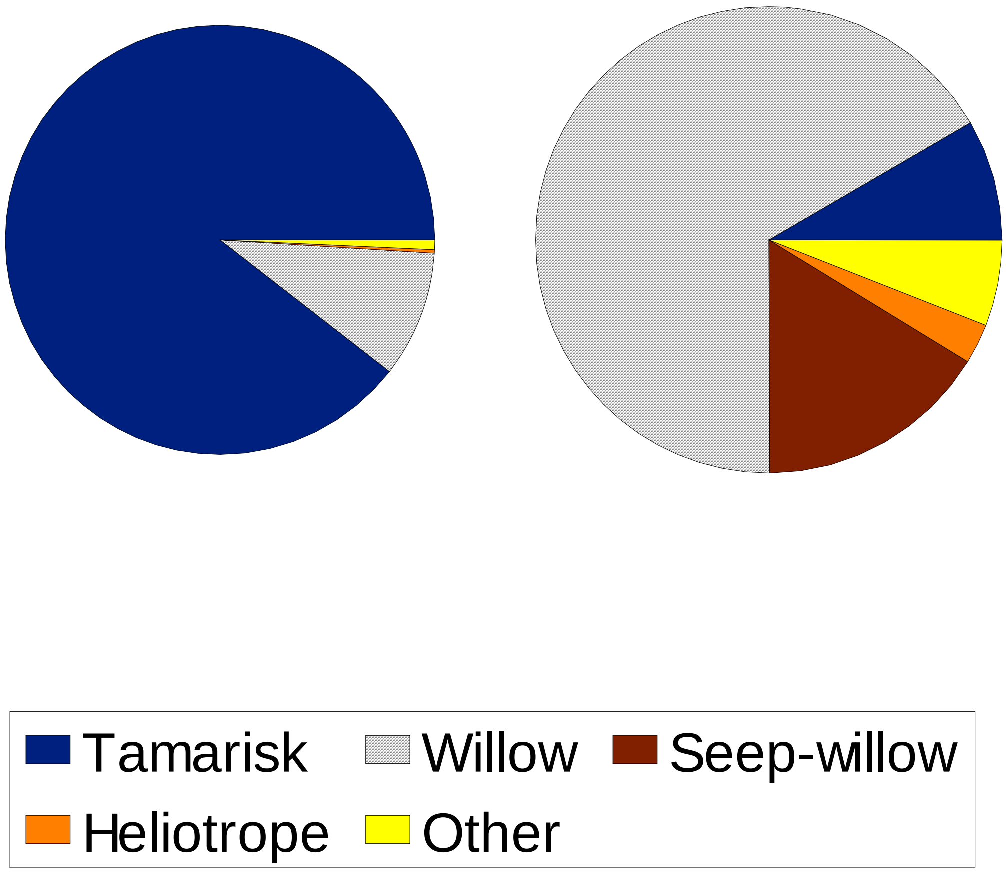
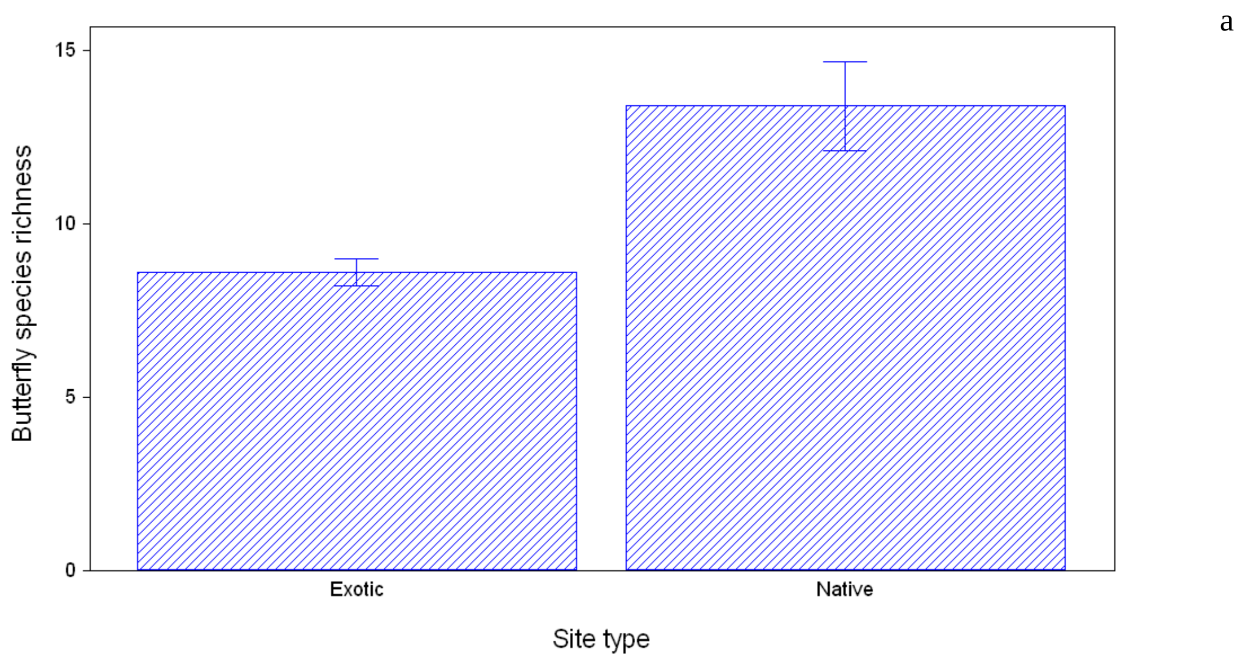


Figure 4. Mean butterfly species richness (a) and abundance (b) at Exotic and Native vegetation sites. Values were significantly different (P<0.05) between site type. Variance is presented as standard error.



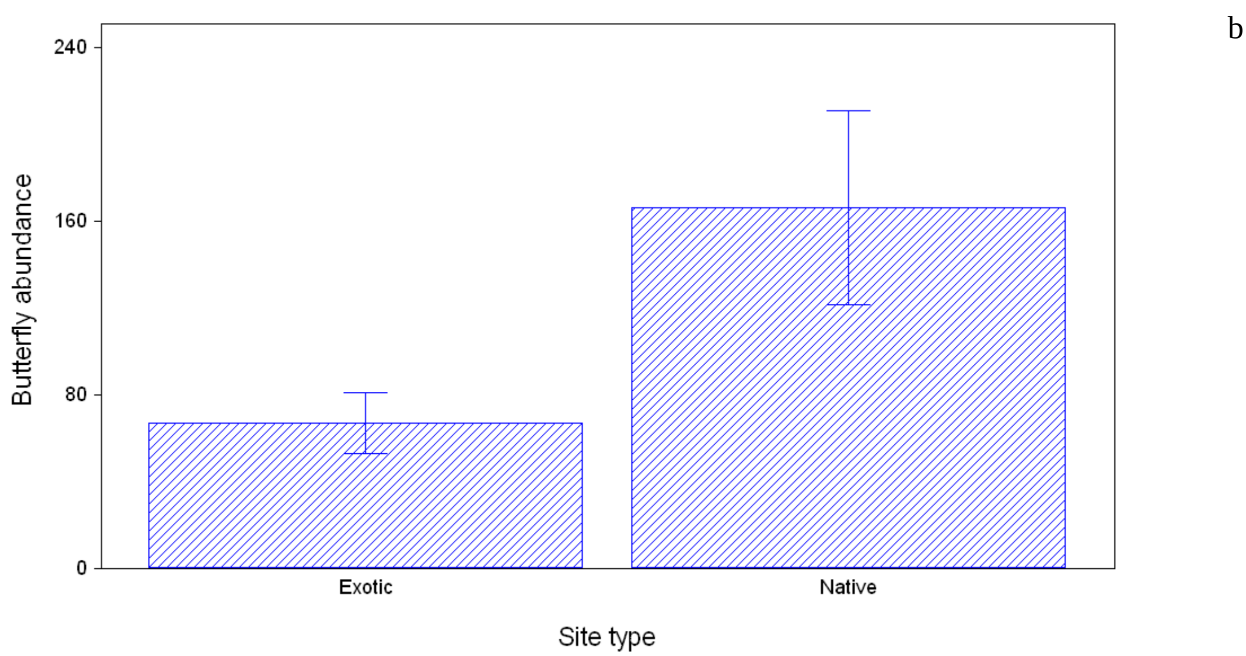


Figure 5. Triplot of butterfly data collected from 2006-2008 based on redundancy analysis (RDA). Only species with at least a 20% fit are included in the figure. Filled circles represent Exotic vegetation sites and open circles represent Native sites.

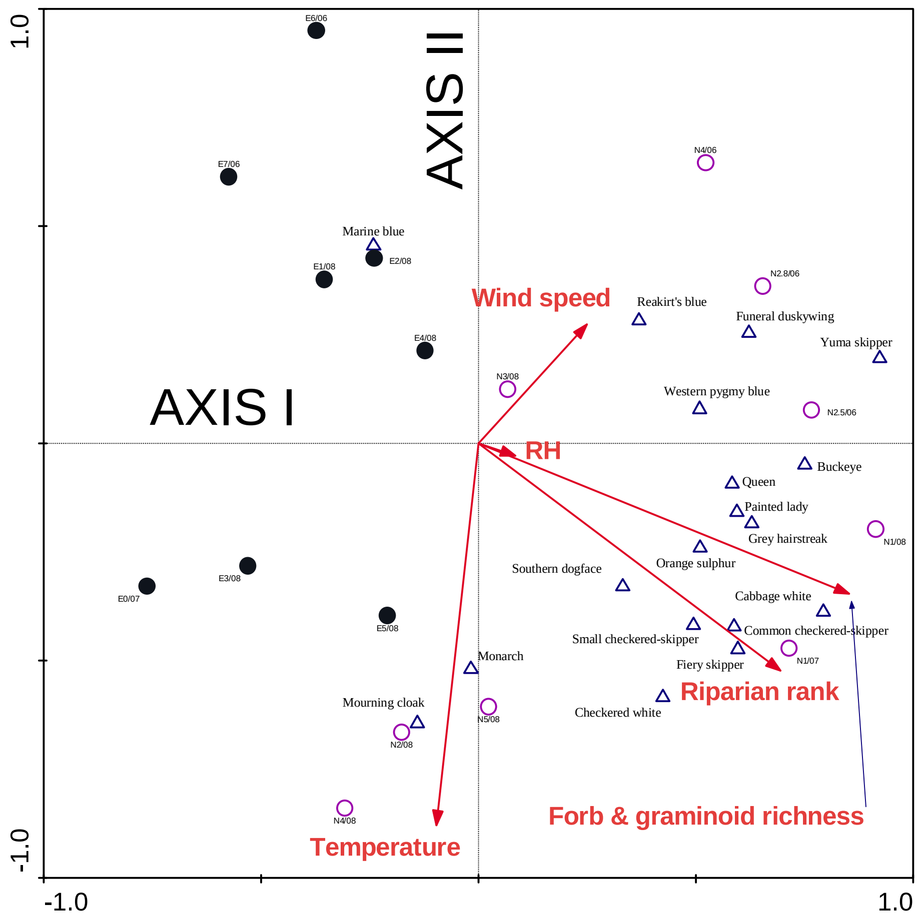


Figure 6. Abundance contours for Yuma skippers from RDA analysis.

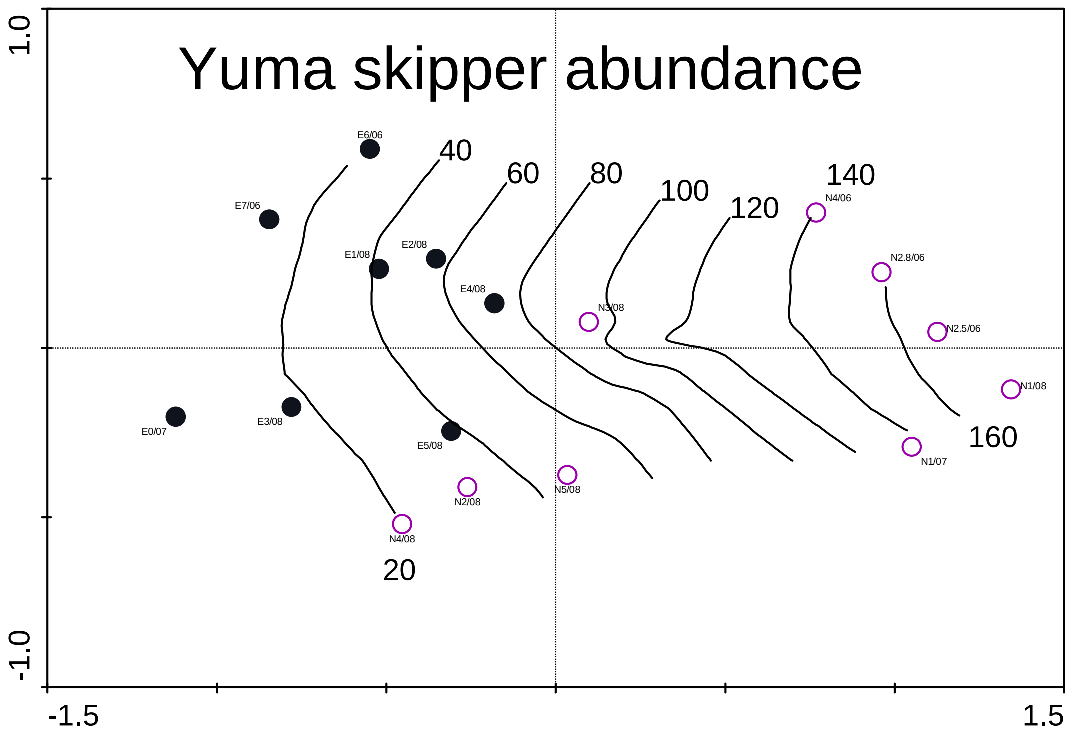
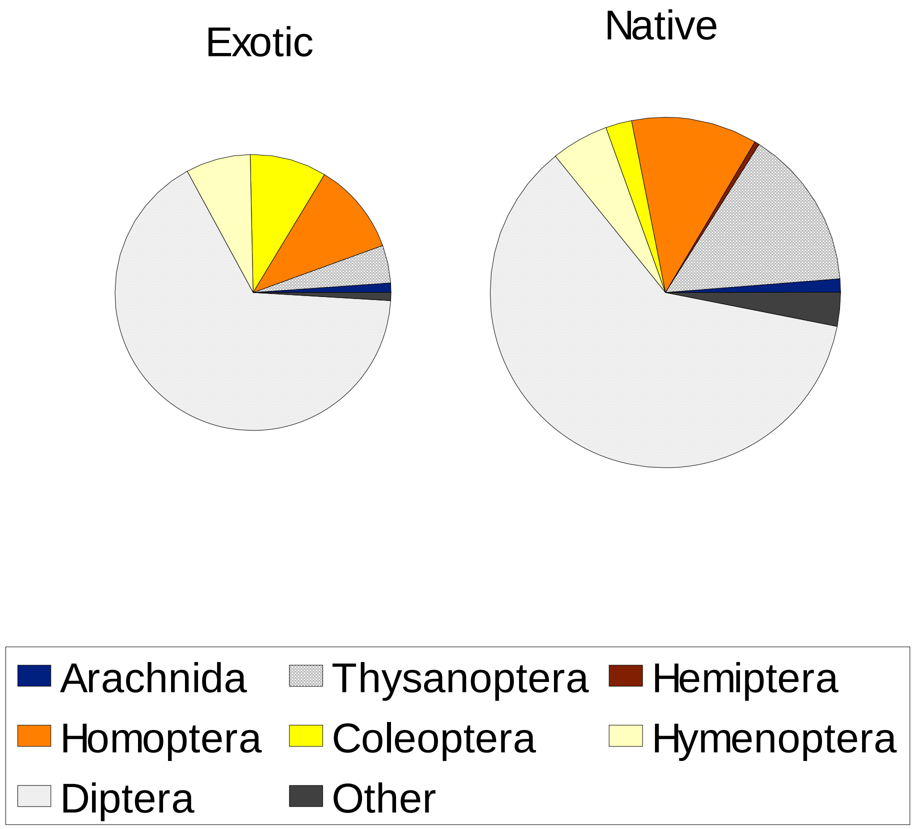


Figure 7. Proportional pie chart showing percentage of various orders of invertebrates found on sticky-traps at Las Vegas Wash riparian sites.



PEER REVIEW DOCUMENTATION

PROJECT AND DOCUMENT INFORMATION

Project Name Las Vegas Wash Invertebrates WOID LC926

Document Comparison of Terrestrial Invertebrates Associated with Las Vegas Wash Exotic Vegetation and Planted Native Vegetation Sites

Document Date September 2009 Date Transmitted to Client

Team Leader S. Mark Nelson

Leadership Team Member

Document Author(s)/Preparer(s) S. Mark Nelson

Peer Reviewer

REVIEW REQUIREMENT

Part A: Document Does Not Require Peer Review

Explain

Part B: Document Requires Peer Review: SCOPE OF PEER REVIEW

REVIEW CERTIFICATION

Peer Reviewer - I have reviewed the assigned Items/Section(s) noted for the above document and believe them to be in accordance with the project requirements, standards of the profession, and Reclamation policy.

Reviewer: Doug Andersen Review Date: 9-09
Signature

Reviewer: Seth Shanahan Review Date:
Signature (see acknowledgements)

Preparer - I have discussed the above document and review requirements with the Peer Reviewer and believe that this review is completed, and that the document will meet the requirements of the project.

Team Member: S. Mark Nelson Date: 9/28/09
Signature