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A REVIEW OF THE REMOVAL OF ARUNDO DONAX FROM A RIPARIAN AREA WITHIN SAN TIMOTEO CANYON

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A REVIEW OF THE REMOVAL OF ARUNDO DONAX
FROM A RIPARIAN AREA WITHIN SAN TIMOTEYO CANYON

A Project
Presented to the
Faculty of
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In Partial Fulfillment
of the Requirements for the Degree
Master of Science
in
Earth and Environmental Science:
Professional Science Masters

by
Catherine Elizabeth Howe
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ABSTRACT

A site within San Timoteo Canyon was revisited, 13-14 years after treatment, to look at long-term effects of *Arundo donax* removal. The data obtained were used to determine whether *A. donax* had re-invaded, other non-native species had established the area, or if native species were able to grow in place of the removed *A. donax*. The previous removals included a combination of grinding large patches of *A. donax* and then foliar spraying, foliar spraying of uncut plants, and direct spraying of hand cut stems, depending upon the location and size of the plant. The effects of the *A. donax* removals within San Timoteo Canyon were analyzed in relation to new percent cover of the plant species, other more recent removals, and areas that did not experience removal procedures. The project included the use of data provided by the Inland Empire Resource Conservation District (IERCD) as well as the collection of data from randomized plots to generate plant species percent cover. Plant percent cover data analyzed for this paper had been collected from eight 15 by 15 foot randomly selected plots within an overall project site of 42.3 acres. Additional sites were used to investigate what can happen if *A. donax* is not removed from an area into which it has been introduced, the short-term effects of *A. donax* removal methods, and the role the ever-changing characteristics of riparian areas can play in their own restoration. These additional sites included aerial photographs supplied by IERCD of an ecologically similar area, a plot with a more recent *A. donax* removal date, as well as photographs and data of a site
subject to natural recovery. Based on these comparisons it is concluded that the
treatment methods used led to a lessened presence of *A. donax*, and that other
invasive species did not grow in its place. Further, as the removal procedures
within the project area occurred approximately 13 to 14 years prior, it can be
concluded that there is no regrowth of *A. donax* and that many native species
have been able to re-inhabit those areas previously infested by *A. donax*. The
treatment methods used were successful without the need to continually disrupt
the habitat and allowed for the habitat to recover naturally once the invasive
species had been removed.
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Due to the vast quantity of uses we find for the land and its vegetation, many habitats have been greatly altered. Habitat alterations can cause a variety of issues that may be detrimental to both the native plant life and wildlife. By looking at the history of a particular area, understanding of the land’s natural characteristics as well as the alterations that are now present can be developed. The extent of the effects these changes have had on the natural wildlife and plant species may result in the need to initiate restoration procedures. The type of restoration needed and success of restoration can vary depending on specific habitat characteristics as well as the extent of the alterations and detrimental effects.

The health of a particular habitat depends upon the ability native species have to survive successfully. For this study, a healthy habitat is considered to be one that includes native plant species that make up the majority or all of the percent cover and which provide the appropriate plant structure for the survival of native animal species. Changing environmental characteristics can affect this ability and may ultimately cause additional losses of native species. In such cases the naturally occurring species in the area begin to compete with introduced species. Often these types of situations include introduced species
that have different biological traits, ways of growing, and ways of feeding that provide an overall advantage. In most cases, the invasion of nonnative plant or animal species is directly related to alterations that have occurred within the habitat itself, such as human interferences or even some natural events. These interferences alter the overall structure of the habitat, causing changes to the patterns involved in wildlife survival, such as nesting and feeding.

**Riparian Habitats**

Riparian habitats are important environments that are, generally, prone to habitat decline and loss of functionality. For the purposes of this study functionality is the ability the habitat has to provide needed structure for the survival of native animal species as well as allowing for healthy growth of native plant species. In riparian habitats this functionality includes the ability of the habitat to provide water purification, flood attenuation, nutrient cycling, and the maintenance of stream flow and water temperature (Kauffman et al., 1997). The State of California Wildlife Conservation Board (WCB) identifies riparian habitats as the features and vegetation of those areas within stream banks or flood plains of water bodies (WCB, 2013). Riparian habitats are valuable due to their ability to support a greater diversity of wildlife than most other habitats. This ability is tied to their distinct functionality (Griggs, 2009). As riparian habitats have these specific functional characteristics, they tend to contain species that are able to withstand fluvial events and the changes that these events encompass. Riparian vegetation is capable of not only withstanding flooding and sediment deposition,
but also stem breakage and physical abrasion caused by these events (Richardson et al., 2007). As a result, the flora found within these habitats is usually different in both structure and function than those species found in nearby terrestrial habitats (Richardson et al., 2007). Many of these valuable habitats have been subject to degradation and loss of overall functionality due to the integration of non-native species as a result of environmental changes, both natural and anthropogenic.

In many instances the degradation of a riparian habitat occurs due to human interference that disrupts the habitat’s unique fluvial processes. Within the U.S. approximately 70 percent of the original floodplain forest had been converted to either urban or agricultural uses (Brinson et al., 1981). It was also estimated that, by the early 1980’s, over 70 percent of riparian ecosystems had been altered and less than two percent of the land within the U.S. was that of natural riparian communities (Brinson et al., 1981). Events resulting from human interference include that of channelization, damming, installation of waterway safety measures, recreation, grazing, trampling, and water extraction (Richardson et al., 2007). Interferences such as these lead to changes in river flow, channel form and composition, along with increased sediment deposition, and a larger occurrence of introduced species (Richardson et al., 2007). Therefore, the structure and function of riparian areas can be affected by a large array of human interferences.
The increased degradation of riparian habitats has led to the use of restoration procedures to repair their functionality. Restoration methods used can vary from the use of passive restoration to active restoration measures. This variation is dependent upon the extent of the degradation of the habitat, along with the ability of the habitat to provide natural regeneration and restoration. As riparian habitats include fluvial processes, which offer the ability for natural restoration to occur, passive restoration alone is generally able to increase the health of the habitat. This is in part due to the removal of the source of degradation allowing the habitat and its species to more easily regrow and thus increase overall health. However, active restoration measures, such as the planting of new vegetation, can be necessary in order to encourage a more rapid increase in health and functional growth.

California’s riparian habitats, in particular, have been greatly degraded and disturbed (WCB, 2013). This disruption is a direct effect of the many different uses that the land has endured over time. In response to the large loss of riparian habitats within the state of California, the California Habitat Riparian Conservation Program was created in 1991 (WCB, 2013). Their goals include preserving and enhancing riparian habitats throughout California. San Timoteo Canyon is an example of a habitat where restoration procedures have been systematically implemented in order to preserve and enhance its riparian characteristics.
Disturbance History of San Timoteo Canyon

San Timoteo Canyon runs from Banning, California to an area south of San Bernardino, California (RLC, 2008). This area contains a tributary of the Santa Ana River known as San Timoteo Creek. A map depicting the location of San Timoteo Canyon and the project site in relation to nearby cities is located in Appendix A Figure 1.

San Timoteo Canyon is a region that depicts how uses and changes to the land, over time, have the ability to alter an area’s historical characteristics and functionality. One of the first known records of human activity within the canyon is that of the Cahuilla tribe in the 1830s (RLC, 2008). The presence of the Cahuilla tribe, along with the settlers and their ranches that followed, caused alterations to the land through the introduction of crops and irrigation ditches (RLC, 2008). The detrimental effects of agricultural uses increased as the occurrence of livestock, orchards, and other agricultural activity increased over time (RLC, 2008). In recent decades, other disturbances within the canyon have included off-highway vehicle use, streambed erosion, illegal dumping, recreational shooting, illegal grazing, biological pests, and nitrogen deposition (RLC, 2008). These multiple disturbances have had detrimental effects on the riparian habitat characteristics.

The increased land use in San Timoteo Canyon by humans has led to a drastic alteration of its natural characteristics, especially within the riparian habitat. Much of the native vegetation has been converted to annual grasslands and weedy fields, impeding the recovery of the native riparian habitat (RLC,
2008). Such negative effects have resulted from increased water consumption and soil disruption caused by the introduction of agricultural processes. These alterations have transformed the flow and volume within the creek, as well as creating incised channels (RLC, 2008). Further, these changes that have occurred as a result of increased human activity have altered the habitat in such a way that many of the native wildlife species have been affected.

San Timoteo Canyon has endured both an increase in introduced plant species and the introduction of non-native wildlife species. These non-native wildlife species include those that have been intentionally introduced, such as the feral hog, as well as unintentionally, such as the Brown-headed Cowbird (*Molothrus ater*) (RLC, 2008). In addition to non-native species introduction, native populations of the Least Bell’s Vireo (*Vireo bellii pusillus*) and the Southwestern Willow Flycatcher (*Empidonax traillii extimus*) have decreased. The decline of these species can be related to the changing characteristics of the vegetation present within the canyon as well as to the increased presence of non-native wildlife species (RLC, 2008). An example of the ability of non-native wildlife species to cause detrimental effects to native species is that of the Brown Headed Cowbird, which is known for conducting nest parasitism. Brown-headed Cowbird’s are obligate brood parasites as they use host nests in order to breed (Coppedge, 2009). The use of host nests for their own breeding generally leads to a decrease in the successful breeding rate of the host species. Declining population sizes and habitat degradation has led to the placement of the Least
Bell’s Vireo on the endangered species list in 1986, and the Southwestern Willow Flycatcher in 1995 (USFWS, 2013). This is in part due to the reliance of both species on the native vegetation of riparian areas, such as San Timoteo Canyon, for nesting and feeding.

Alterations to the plant structure within San Timoteo Canyon have led to a decrease in the ability of the Southwestern Willow Flycatcher and Least Bell’s Vireo to use this area during their breeding season. The territories and breeding sites of the Southwestern Willow Flycatcher are predominately made up of native plant species; however, mixed native and exotic sites are also used (Sogge et al., 2002). Although exotic plant species can be found in the habitat of the Southwestern Willow Flycatcher, those areas consisting predominately of exotic species include few Southwestern Willow Flycatcher territories in comparison to the areas made up mainly of native species (Sogge et al., 2002). This demonstrates that the introduction of non-native plant species to the habitat inhibits the ability of the Southwestern Willow Flycatcher to properly nest and breed. In a study conducted by Sogge et al. (2002), approximately 48 percent of the Southwestern Willow Flycatcher territories under observation had greater than 90 percent native vegetation, while only 9 percent included greater than 90 percent exotic vegetation. Based on this information, the Southwestern Willow Flycatcher is less likely to create a territory and nest within an area that consists primarily of non-native vegetation. This information illustrates how a habitat
largely comprised of introduced species hinders the presence and nesting rate of the Southwestern Willow Flycatcher.

Although there are various invasive plant species now present within San Timoteo Canyon, many of which have contributed to the loss of the Southwestern Willow Flycatcher and the Least Bell’s Vireo, one of major concern is *A. donax*. This species is a tall perennial grass which grows best in moist conditions, such as those with water tables near to the soils surface (GISD, 2013). *A. donax* is able to displace native vegetation, ultimately contributing to losses of these avian species, as well as many other native animal species. Some of the characteristics of *A. donax* that allow for its invasiveness include its ability to monopolize soil moisture and reduce shading of nearby streams (CAL-IPC, 2013). The ability of this species to reduce shading is due to its tall massive stands which do not provide the same cover that would be offered by native trees. Soil moisture is monopolized as this species uses takes large amounts of water from aquifers altering hydrology and decreasing groundwater availability (Cal-IPC, 2013). Further, the aquatic habitat is altered due to increased water temperatures, caused by less shading, and altered channel morphology (Cal-IPC, 2013). Unlike *A. donax*, riparian plant species often provide a well-developed overhanging canopy which shades portions of the stream. In addition, *A. donax* leads to altered channel morphology as it instead allows for the retention of sediments and a constricted water flow (Cal-IPC, 2013). On the other hand, many native riparian species are woody with a rooting system that permits
water and sediment flow and includes open branching. *A. donax* causes great concern for Californian riparian habitats, as these areas are already prone to damaging activities such as channelization, damming, agricultural use, and development (Boland, 2006).

As riparian areas are already prone to these damaging activities the introduction of *A. donax* and its ability to alter habitat characteristics can further damage a riparian habitat, such as San Timoteo Creek. Other than these changes, as previously discussed, a reduction in native plant species can lead to a decrease in certain food supplies as well as nesting areas for animals such as the Least Bell’s Vireo and Southwestern Willow Flycatcher. In addition, *A. donax* is able to degrade habitats by increasing fire frequency, altering the structure of the vegetation, and reducing the overall quality of the habitat for native species (Boland, 2006). Riparian vegetation plays a necessary role in the overall function of the habitat by providing food, moderation of water temperatures, shading, bank stabilization, and the filtration of sediments (Richardson et al., 2007). Therefore, the increased presence of *A. donax*, which disrupts these necessary roles, ultimately creates structural alterations that result in further degradation of the riparian habitat.

**Project Scope and Significance**

This project examined the long-term effects of *A. donax* removal on riparian vegetation in San Timoteo Canyon. The project examined whether *A. donax* recolonized sites after removal as well as whether other invasive species
were able to spread in its absence, rather than leading to a desired increase in native vegetation. In order to gain insight into these effects, data from prior removal treatments of the amount of *A. donax* removed were used to make comparisons to newly acquired plant percent cover data of the same area. Percent cover of the plant species was obtained by the use of randomly selected plots within the previous removal site in San Timoteo Canyon. The riparian area within San Timoteo Canyon that was studied has had many restorative measures implemented by the Inland Empire Resource Conservation District (IERCD), as well as many other organizations, to remove the majority of the *A. donax*. However, these removals have not been evaluated for their success rate or the possible need for additional treatments. Therefore, the procedures previously taken by IERCD to remove this species from the area, how much of the species was removed, new measurements to estimate the re-growth in the area, and a comparison of previous data to newly acquired data was completed and evaluated. Evaluation of the long-term effects of *A. donax* removal has given insight into whether or not other steps are necessary in order to keep species, such as *A. donax*, from reoccurring after removal methods have been implemented. Further, as the area is in IERCD’s boundaries, the information gained will, hopefully, allow IERCD to have even greater success in future removals within the riparian area of San Timoteo Canyon.

In order to evaluate the long-term effects of the removal methods completed in San Timoteo Canyon, this project reviews previous studies and
explains the overall parameters and conclusions of the project itself. The studies that are reviewed include those pertaining generally to riparian habitats, invasive traits of *A. donax* and *A. donax* removal methods, and information on endangered wildlife species within San Timoteo Canyon.

Limitations of the Study

As the riparian region of San Timoteo Canyon covers a large area, there are limitations to this study and the inferences it can provide. One limitation is that the study only covers a small percentage of the overall removal area within San Timoteo Creek. This is due in part to the overall treated area being too large to properly and accurately survey as a whole in a timely and feasible manner. In order to combat this limitation, as seen in Chapter Three, plots were randomly positioned throughout the entire previous removal area. The random position of the plots throughout the removal area allows this study to have a higher chance of gaining an unbiased depiction of the current percentage of species located in the overall area. In addition, the previous information supplied by IERCD contained only the amount of *A. donax* removed, an overall area where it was removed from, and the type of treatment used. Therefore, further analysis such as a comparison of the amount of particular native species present before and after was not possible. As a result analysis in this project examined the presence of plant species by comparing current plant percent cover to the amount of *A. donax* previously removed from the area.
Another limitation of this study is due to the uniqueness of riparian habitats. Riparian habitats can vary greatly from one another due to their unique characteristics causing a variety of factors that may play a role in their ability to have success in the overall removal of *A. donax*. As riparian habitats are so distinct from one another the results of this study may not be applicable to all riparian areas infested with *A. donax*. Further, these results may only be generalizable to the project area itself or those riparian areas in close proximity.

The dates in which the new data were obtained may also provide somewhat of a limitation. The data were acquired on two separate dates that were approximately three months apart from one another. Due to the lapse in time in between site visits, alterations may have occurred that could have affected the percent cover obtained for each plant species.
This Chapter contains a review of previous literature, which provides insight into the need for this project. This review will offer an understanding of what types of studies have already been completed and what is known about the relative topics and factors affecting this project. The topics that will be reviewed include the restoration of riparian habitats, the characteristics and control of *A. donax*, and the effects restoration measures have had on the endangered species within San Timoteo Canyon. Each of these topics includes a brief overview of particular studies that were chosen in order to display the need for this study and the ability to understand the long-term effects of *A. donax* removals on the restoration of riparian habitats.

General Characteristics of Riparian Habitat Restoration

The declining riparian habitats found throughout California, as well as the whole United States, are of great concern. These habitats are known to possess unique characteristics that are needed by countless plant and wildlife species. Therefore, the decline in health and increasing loss of this habitat type has resulted in a variety of studies that evaluate how to successfully increase the health and functionality that has been lost due to human and natural alterations. As the project is an evaluation of the restoration of a riparian area in San Timoteo Canyon, the following five studies were reviewed in order to gain an
understanding of restoration procedures and how they may differ within riparian areas. This review will allow for better knowledge of riparian restoration and further the understanding of the results that have been found within this project. The following five papers were chosen as they either define the types of restoration that can be implemented or provide examples of restoration procedures that have been completed in riparian areas.

Riparian Habitats: Study One

In May of 1997 Kauffman, Beschta, Otting, and Lytjen assembled a report discussing a variety of important aspects of riparian restoration. Their study clearly defined commonly used words of watershed restoration procedures while providing insight into these restoration procedures and what they generally consist of.

Kauffman et al. (1997) described ecological restoration as the reestablishment of pre-disturbance riparian functions and their related properties. It notes that ecological restoration begins by identifying the land use practices that are hindering the ecosystem followed by applying strategies that allow for natural recovery (Kauffman et al., 1997). An ecosystem that is being hindered includes those that show signs of advanced non-native species invasion or other interferences that may be affecting the ability it has to provide a functioning habitat for its native species. In accordance, restoration means the process of repairing damage caused by humans to native ecosystems (Kauffman et al., 2007). Rehabilitation was defined as those processes that make the land useful
again after either natural or anthropogenic disturbances (Kauffman et al., 2007). Mitigation refers to methodological effects designed to alleviate detrimental effects that occur due to anthropogenic events while enhancement is any improvement of a feature of a species or habitat (Kauffman et al., 1997).

Kauffman et al. (1997) also discussed the extent to which riparian habitats have been affected. Altered riparian habitat within the United States at the time was estimated to be 70-90% (Kauffman et al., 1997). In addition, degradation of these riparian zones diminishes their overall ability to provide critical ecosystem functions (Kauffman et al., 1997). As discussed previously, the functions that are normally provided by the riparian habitat include water purification, flood attenuation, nutrient cycling, and maintenance of stream flow and temperature (Kaufman et al., 1997). To reverse these negative effects passive or active restoration procedures are generally used. Passive restoration involves stopping any anthropogenic stress that may be causing the degradation to occur, and depending upon its success, active restoration procedures may follow (Kauffman et al., 1997). Therefore, passive restoration generally refers to the integration of very minimal activities, such as those that remove the source of the disruption, which then allow for the habitat to reestablish itself. Active restoration involves more in depth activities that provide structural alterations to help restore the habitat; these can include the planting of native species, reintroduction of native animal species, as well as those activities that may aid in the reconstruction of the natural biotic, geomorphic and hydrologic processes (Kauffman et al., 1997).
Based on the information provided by Kaufman et al. (1997), a greater knowledge of the types of restoration procedures available, and the type of habitats they are successful in, will provide a more effective use of restoration measures. In order to do this, it is necessary to gain a better understanding of the specific habitat of concern before undertaking in any restoration methods. Familiarity with the habitat in question can provide insight into the type of restoration methods that would be the most successful and offer the largest increase in overall habitat health. This is due, in part, to the idea that the way in which the habitat will react to certain procedures can vary depending on whether the habitat has been in decline due to human alterations or natural events as well as the severity of these alterations.

Riparian Habitats: Study Two

This literature review examined riparian habitat diversity, types of anthropogenic disturbances, and the issues surrounding riparian restoration (Goodwin et al., 1997). This review compiled concepts involving natural processes that create riparian habitats. The review depicted two main processes that control and create riparian systems, those of geomorphic and biotic change (Goodwin et al., 1997). Further, Goodwin et al. (1997) explained that geomorphic observations of riparian floodplains have led to two ideas. These ideas are that western floodplains may oscillate between eroded and non-eroded states and that the structures of many of these stream channels may represent transitional responses to past events rather than a state of quasi-equilibrium (Goodwin et al.,
1997). These two concepts enforce the more general principle that riparian ecosystems are subject to natural processes that create an ever-changing habitat.

As reviewed by Kaufman et al. (1997), Goodwin et al. (1997) also acknowledged the idea that successful restoration begins with the understanding of the natural riparian processes and the types of disturbances that have occurred in the area. Therefore, both of these reviews indicate that the specific characteristics of a particular area may affect how the habitat reacts to certain types of restoration measures. As a result, knowing the ecological characteristics of the area and the disturbances it has endured before applying restoration procedures may lead to increased success and greater overall habitat health.

Based on these two first reviews, the need to understand the natural and anthropogenic processes affecting a particular area and how they may alter the success rate of restoration procedures is a necessary aspect of the overall restoration process.

Riparian Habitats: Study Three

Restoration procedures can be costly and, due to the natural processes involved in riparian habitats, can easily fail; therefore, Rood et al. (2003) addressed the restoration of riparian habitats by restoring in-stream flow patterns. To demonstrate the potential success involving flow pattern restoration a case study involving the Truckee River was conducted.
This study included a description of the degradation of the Truckee River habitat along with the results of the implementation of restoration. Rood et al. (2003) identified the Truckee River as having highly reduced flows due to damming and channelization. The reduction of flow transformed the surrounding habitat in such a way that the original riparian woodlands were degraded to sparsely dispersed trees. It also decreased fish populations (Rood et al., 2003). Original restorative measures began in the 1980s involving rather expensive procedures used in the planting of cottonwoods. Rather than continue these same costly restoration procedures, a recruitment box model was created which provided insight into suitable areas for cottonwood seedling establishment, based on the flow and characteristics of the water source (Rood et al., 2003). The recruitment box model is built on the riparian “recruitment box” which is a position, defined by space and time, that is suitable for seedling establishment (Rood et al., 2003). The parameters of this model are that of elevation and the time in which the seed was released (Rood et al., 2003). Therefore, this model recognizes the necessary water pattern needed in order to successfully seed either cottonwoods or willows (Rood et al., 2003). By determining what year the majority of the previously planted sapling bands formed, the water pattern during this time period could be used to create a successful planting scheme. Hydrographs of 1987, the year most of the saplings sprouted, were then used to create the recruitment box model necessary to continue plantings with a lowered cost (Rood et al., 2003). After the use of this model, the cottonwood seedlings
did establish in extensive patches and arcuate bands at the expected elevation (Rood et al., 2003). As a result of this new model the reestablishment of widespread areas of cottonwoods began to resemble historical descriptions of the area (Rood et al., 2003). Therefore, the area was able to increase cottonwood abundance with a model that allowed for more accurate planting techniques and provided for greater likelihood of seedling survival.

Rood et al. (2003) reinforced the idea that the most successful restoration procedures can vary depending on the environment and habitat type. Although some areas would have reacted at a greater pace to the installation of new seedlings, this particular area, due to the alterations in flow and changes in channel morphology, did not react well without the seedlings being planted based on a model directed by the river’s unique characteristics. Therefore, this study led to the idea that a background and knowledge of both previous and new characteristics of an environment can lead to greater success in restoration procedures. Further, this case study depicted how the way in which even small increases in habitat health and functionality are gained can vary greatly. Therefore, it may be necessary to reanalyze areas that have had previous restoration measures to know whether or not the presence of their native species have increased and whether different methods should be carried out.

Riparian Habitats: Study Four

Richardson et al. (2007) provided a review of the structure of riparian vegetation in subtropical and temperate regions. The assessment included the
examination of the functionality of riparian habitats based on the presence of invasive species, human caused changes, and provided an overall outline for restoring riparian zones. The review included the unique characteristics of riparian habitats and the issues that these characteristics provide for restoration.

The composition of riparian vegetation is dependent upon the characteristics of the area itself, including climate, disturbance regimes, and the overall variety of species found within that particular region (Richardson et al., 2007). Fluvial processes of an area play a large part in the structure of riparian vegetation. These processes impact plant patterns and distribution through events such as floods, droughts, fluctuating water tables, erosion, and sediment deposition (Richardson et al., 2007). Not only do the processes within riparian areas affect the plant species present, but these species can also affect the overall environment of the habitat itself. The plants affect the habitat as they play a role in the velocity and flow, groundwater levels, local climates, moisture patterns, erosion, sedimentation, and soil characteristics such as nitrogen levels, salinity, and organic matter (Richardson et al., 2007). Therefore, there is a close relationship between the geomorphological and fluvial processes occurring in a riparian habitat and the plant species the habitat contains.

Riparian areas are known to have diverse vegetation, and alterations made to this diversity can greatly affect ecosystem functions. In many instances introduced plant species are capable of entering riparian areas due to the habitat’s dynamic hydrology (Richardson et al., 2007). In addition, introduced
species can increase due to human-mediated disturbances, which is pervasive in most riparian areas. Although other causes of change may affect the overall degradation of the area, the integration of new plant species into the system may cause a variety of problems. This may include an altered plant structure, increased water use by the non-native plant species, soil salination, modified wildlife habitat, as well as changes in the overall width, depth, or flow of the river or stream (Richardson et al., 2007). With the invasion of non-native species, the ability of the habitat to recover to its former state must be considered (Richardson et al., 2007).

Most restoration procedures aim to repair changes that were made as a result of human interferences. As it is very difficult to provide complete restoration, successful results rely upon a large understanding of the changes that the habitat has tolerated as well as the overall processes now occurring within the riparian zone. As humans are a crucial part of the dynamic aspects of riparian areas, it is necessary to create restoration and management techniques that improve structure based on the need for native wildlife species and improve function rather than try to recreate historic characteristics (Richardson et al., 2007). This concept will lead to greater success as many of the anthropogenic activities may still be present, even after restoration, because many habitats have a greater human population in close proximity than that which was historically found. Therefore, trying to recreate historical versions of the area would be impossible and increasing the overall function of the habitat would be
the most practical outlook to provide the necessary characteristics needed to create a healthy habitat.

Richardson et al. (2007) discussed the unique characteristics found within riparian ecosystems and the issues surrounding these types of habitats. Based on these issues, the integration of non-native species and human disturbance, it was concluded that restoration procedures must not only acknowledge the disturbances within the habitats themselves, but also the natural processes that shape these environments. Consideration of the unique characteristics found within these habitats during the implementation of restoration measures will allow for greater success; however, it is impossible to fully recreate an area's historical structure. Therefore, they suggested that restoration procedures should remove disturbances and restore areas to provide greater overall functionality, instead of attempting to mimic previous characteristics. This indicates that restoration measures aimed at a goal of creating more functional components, such as plant or streambed structure, would greater restore the area than those whose main focus is to have the same species content or streambed structure as what was historically present.

Riparian Habitats: Study Five

Stromberg (2001) provided a review of riparian restoration within the southwestern United States. This review included concepts pertaining to the structure of the riparian habitat as well as the ability to restore riparian vegetation by using the natural ecological processes (Stromberg, 2001). Stromberg (2001)
believed that improved success of restoration measures could arise from greater sharing of important information revolving around riparian restoration procedures. This indicates that restoration of riparian areas needs to be more highly documented and studied in order to aid future restoration measures.

The review by Stromberg (2001) emphasized approaches that are used in riparian recovery, their strengths, compromises, and their weaknesses. One of the weaknesses addressed by Stromberg (2001) was that many failed restoration attempts are due to the underlying factors of the degradation not being addressed in the restorative procedures taken (Stromberg, 2001). Stromberg (2001) discussed the Provo River Restoration Project in which the goal was to create a more natural functioning riparian system. This restoration project demonstrated the strengths that can be seen in many restoration projects as it took into consideration multiple environmental factors that can play a role in its overall success. Although this method provided restoration, this project was not able to fully restore the water and sediment flow within the area due to a dam located upstream (Stromberg, 2001). Therefore, this project also demonstrated the capacity restoration projects have and the compromises they may have to make in their overall success. Stromberg (2001) recommended the integration of experimentation in restoration, as we do not know all of the aspects of the riparian habitat or the reasons behind its degradation (Stromberg, 2001). Further, restorations of natural processes, such as patterns of flood disturbance, have been identified as a way to improve the overall complexity of riparian areas with
the greatest success. In addition, although plantings and other active restoration measures have been used for initial restoration, it is also necessary to provide restoration that allows natural recovery (Stromberg, 2001).

Understanding what is needed by the plant and animal species to successfully survive in a riparian area is especially necessary in the southwestern United States due to limited water availability in this arid region. These factors, limited water and an arid climate, can alter how the riparian habitat reacts and may also contribute to the overall degradation of the area due to water needs of human populations. In order to control stream flows in a way that may lead to increased riparian health, Stromberg (2001) recommends the use of aquifers to store water, the release of recycled municipal water into stream channels, processes to increase water efficiency of human populations, and a decrease in the overall water demand of these populations. Further, as watershed alterations can cause specific riparian habitat decline, restoration measures that span the whole watershed may provide the greatest restoration of structure and function.

Stromberg’s general conclusions are that there is a greater need for the compilation of restoration data based on habitat and degradation characteristics and that the future success of restoration measures taken in riparian habitats needs to be based upon experimental findings. Implementing restoration in the form of an experiment would allow for more data to be available pertaining to specific methods, which may provide insight into whether certain procedures
work better in areas with particular ecological characteristics. Due to the south-western United States having particularly unique characteristics, these concepts may be even more necessary in this area in order to gain successful restoration.

The five studies that have been reviewed in relation to riparian restoration brought into perspective the many different factors that contribute to the ability of a riparian habitat to be restored. These studies provided the overall idea that the ever-changing fluvial states encountered within riparian habitats create the need of restoration procedures that are aimed at restoring the structure of the habitat. This concept is necessary as it will allow for the habitat to provide further restoration through its own ability of natural recovery. In addition, a few of the studies noted that although restoration can be successful in riparian habitats, they may need to be altered for each area due to the varying factors that may be encountered. These factors include the oscillation between states and the ability of the fluvial processes and plant structure to affect one another. Therefore, one of the studies indicated that the best method of restoration for these types of habitats are those that integrate experimentation, as they will not only take into consideration the many factors that are present, but may also provide for a compilation of data that can be used in future riparian restoration. From these studies it can be concluded that riparian restoration is reliant upon many different concepts and is dependent upon whether or not the habitat is capable of its own natural recovery.
As the literature relating to riparian habitats and their restoration have already been discussed, this subsection will look into a species prone to habitat invasion (Arundo donax) and its characteristics and treatment. Having the knowledge of riparian habitats and the factors that contribute to their ability to be successfully restored will create an understanding of why this invasive species is of such high concern in these sensitive habitats. Within this section is a review of the studies that relate to A. donax, which include those that look into treatment methods as well as its overall characteristics and invasive properties.

Arundo donax is a perennial grass native to the Mediterranean region. This species has been able to spread to many other regions of the world leading to its placement on the World’s Most Invasive Alien Species list on the Global Invasive Species Database (GISD, 2013). In addition, the invasive characteristics of this species and its ability to disrupt habitats have led to great concern and the need to implement removal methods. A. donax grows in habitats that have shallow water tables and well-drained soils (GISD, 2013). Due to these needs A. donax can be found in areas that contain streams, riverbanks, and ditches. In addition, this species grows in clumps and generally forms large colonies (Cal-IPC, 2013). Once established, this species can cover many acres as it forms clonal root masses (GISD, 2013). A. donax colonies have been found in various types of habitats including agricultural, coastal, desert, forest, grassland, urban, and riparian (GISD, 2013). This is thought to be a result of its ability to tolerate
many environmental conditions including high salinity levels, the fluvial events
associated with riparian areas, enriched nitrogen levels, and a variety of soil
types (GISD, 2013). As A. donax does not produce viable seeds in western North
America, it appears to reproduce by asexual methods (GISD, 2013).

Within the central portion of the Santa Ana River, A. donax has been
estimated to have infested approximately 68 percent of the riparian vegetation
(Lawson, Giessow, & Giessow, 2005). Once integrated into a new area, A. donax
alters the conditions and characteristics of the habitat. These alterations are due
to A. donax displacing native vegetation and wildlife (Lawson et al., 2005). Not
only does A. donax displace species, but its large stands create both flood and
fire hazards (Lawson et al., 2005). Due to the spreading characteristics of A.
donax it has been classified as an invasive species by the Global Invasive
Species Database (GISD, 2013). Due to the devastation this species has
caused, the following studies have been conducted involving the underlying
characteristics of A. donax.

*Arundo donax*: Study One

Very few studies have examined the lateral expansion and reproduction
methods of A. donax. Due to the lack of such studies Boland (2006) analyzed the
expansion of A. donax clumps within the Tijuana River Valley. The analysis
included both the data obtained from this two-year study as well as the
evaluation of previous literature.
A. *donax* has three means of spreading: rhizomes, fragments, and layers (Boland, 2006). As indicated by Boland (2006), a new plant was determined to be a layer if it was clearly growing from a stem that was still attached to the parent plant. Layering is considered asexual reproduction as it is a form of clump expansion (Boland, 2006). Boland (2006) showed that only slow expansion occurred from rhizomes, expansion from fragments was rare, and that layering resulted in a quick and more extensive expansion. In addition, layering was largely affected by location, as a more rapid spread was seen in areas within the flood zone (Boland, 2006). Therefore, Boland’s (2006) study highlighted the importance of layering in *A. donax* spread. As this study was done in the Tijuana River Valley, results could differ in other areas due to differences in their ecological characteristics.

The analysis provided in Boland (2006) indicated that *A. donax* spreads not only by the use of rhizomes and fragments, but also layering. Further, this study demonstrated that the quickness of this means of spreading is affected by location. Understanding that *A. donax* can spread more rapidly within the flood zone by the use of layering may provide for a greater ability to remove this species. This is because understanding how an invasive species is spreading may allow for better use of removal methods. Therefore, knowing the means of dispersal of any invasive species greatly enhances our ability to manage the spread of non-native species.
**Arundo donax: Study Two**

In Coffman et al. (2010) the invasiveness of *A. donax* was evaluated in relation to wildfires. The growth patterns of *A. donax* following the devastation of a fire were compared to that of native species. *A. donax* has different growth capabilities than those of native species, allowing it to more quickly re-establish in an area after a wildfire. These abilities include early re-sprouting, increased shoot elongation rate, and increased productivity (Coffman et al., 2010). *A. donax* began to show new growth within a few days of the fire, while new growth in native species was not seen until approximately two months post fire (Coffman et al., 2010). As a result species composition changed: native species made up approximately 25 percent of the total cover before the fire, and only one percent nine months after the fire (Coffman et al., 2010). In comparison, the abundance of *A. donax* increased by approximately 25% and was approximately 99% of plant cover one year after the fire (Coffman et al., 2010).

Based on the findings of Coffman et al. (2010) it can be concluded that the success of *A. donax* as an invasive species can be furthered in areas prone to wildfires. This is of great concern in riparian areas already infested with *A. donax*, as this species increases fire frequency and intensity (Coffman et al., 2010). Therefore, growth characteristics of *A. donax* allow it to out-compete species both within previously healthy habitats and after devastating events. The results seen in this study affirm the need to have successful removals of *A. donax* so
that subsequent disturbances such as fire do not cause its populations to expand again, particularly in the fire-prone ecosystems of southern California.

*Arundo donax:* Study Three

Quinn and Holt (2008) undertook a study that evaluated *A. donax* and its establishment in southern California riparian habitats. The study analyzed the surrounding community, rhizome characteristics, and the riparian environment (Quinn & Holt, 2008). This particular study took place over three years, in which measurements and analyses were completed within three different riparian areas of southern California. Areas that contained high soil moisture and bare ground had an increased establishment of *A. donax* (Quinn & Holt, 2008). In addition, greater rhizome weight provided greater survival rates and shoot heights in a majority of the sites (Quinn & Holt, 2008). Based on the results of this study, *A. donax* is capable of surviving in a large range of environments.

The invasive success of *A. donax* is thought to be due to its physiological tolerance of many environmental conditions, such as high salinity levels, various fluvial events, enriched nitrogen levels, and many soil types (GISD, 2013 (Quinn & Holt, 2008). Therefore, the characteristics of *A. donax* allow it to out-compete native vegetation even in changing environments such as that seen within the Mediterranean climate and riparian areas of southern California. Due to *A. donax* tolerating a large array of environment types, the health of those riparian areas infested by this species would be expected to continue to decline if *A. donax* is not successfully removed from these areas. Therefore, knowledge of removal
methods and the overall success of these methods are important in order to best aid these habitats and prevent future or further invasion.

**Arundo donax: Study Four**

Passive or active restoration efforts can include the removal of invasive species, which can occur by the use of a variety of methods. The most efficient and successful restoration procedures are those that best fit the characteristics of the particular species that is being removed and the habitat from which it is being removed (Racelis, 2012). In Racelis (2012), the success of the removal of *A. donax* from the area was evaluated based on whether passive restoration was successful without the need for further active restoration measures. In this study, one of the methods used for passive restoration was that of the above-ground removal of *A. donax*. This method was considered passive as it did not include subsequent direct plantings of native species, but only the removal of the species causing degradation to the area. For 27 months all *A. donax* stems within each study plot were cut and the basal diameter of each stem was measured (Racelis, 2012). Further, all *A. donax* stems reaching above one meter were cut at each subsequent visit, every two to three months for the duration of the study. Therefore, the study simulated repeated, selective mechanical control (Racelis, 2012). In addition, all other plant species present within the plots at the beginning of the study, as well as those that emerged throughout the study, were identified. Their data indicated that persistent passive restoration methods can increase species richness. Further, the study resulted in a greater increase in
native species abundance than that of non-native (Racelis, 2012). Originally \textit{A. donax} dominated the entirety of the plots, but in the final month of observation there were a total of 34 plant species of which 74 percent were found to be native species (Racelis, 2012). Through these results, Racelis (2012) concluded that passive restoration of this particular species is effective, but requires persistent control. As it is labor-intensive removal of the non-native species as a means of passive restoration may only be practical in areas with little infestation (Racelis, 2012).

\textit{Arundo donax: Study Five}

Puértolas et al. (2010) undertook a study to analyze the effects of the herbicide Herbolex, with glyphosate as the active ingredient, on the function of a river ecosystem in Spain. Herbolex is an herbicide used in riparian ecosystems to help control \textit{A. donax}. Through this study the effects glyphosate has on \textit{Daphnia magna}, caddisfly (\textit{Hydropsyche exocellata}), and benthic macro-invertebrates were evaluated (Puértolas et al., 2010). In addition, the environmental fate of glyphosate within the surrounding water system was also documented (Puértolas et al., 2010).

Although glyphosate levels immediately following herbicide application were high, glyphosate levels decreased substantially within three days of application and it was undetectable in surface waters after approximately 12 days (Puértolas et al., 2010). In addition, for the most part, the abundance of macro-invertebrate taxa was not changed by the use of this herbicide (Puértolas et al.,
However, toxic effects on *Daphnia magna* and *Hydropsyche exocellata* were found to be significant (Puértolas et al., 2010). These effects are likely to have been carried up through the aquatic food chain, further affecting other species in this habitat.

As indicated in Puertolas et al. (2010), it is necessary to fully understand the overall effects treatment methods can have on the ecosystem as a whole rather than just non-native species of interest. Also, as this study examined an area that already had low suitability for invertebrate fauna before herbicide application, it can be inferred that a healthier environment may experience relatively greater detrimental effects. This is because there could be a greater chance of herbicide treatments, such as the use of glyphosate, affecting native plant and animal species.

**Arundo donax: Study Six**

The use of glyphosate to reduce the presence of *A. donax* was evaluated in two separate locations, Sonoma Creek in Sonoma, CA and Sycamore Island Ranch Preserve by Fresno, CA (Spencer et al., 2008). At both locations plants were randomly assigned to treatments which included a control, 1.5%, 3%, and 5% glyphosate (Spencer et al., 2008). In addition, another treatment at the Sonoma Creek location included 5% glyphosate with stem breakage. For all plants receiving treatment, application consisted of approximately 2.5 L of herbicide solution for every one meter of basal plant width (Spencer et al., 2008). Plant response was measured based on leaf greenness, number of living and
dead stems, and the number of newly emerging shoots. Through these measurements it was determined that leaf chlorophyll declined following treatments starting with 1.5% glyphosate at both locations and that the greatest decreases were observed on plants treated with 3% or 5% glyphosate (Spencer et al., 2008). Further, responses of those plants broken prior to the application of the 5% glyphosate treatment did not differ much from the 5% treatment without breakage.

Spencer et al. (2008) determined that the most successful single application treatments for killing *A. donax* are that of 3% or 5% glyphosate. Treatments of only 1.5% glyphosate were not capable of inhibiting new stem production in comparison to the higher treatments. Further, as the 5% solution without breaking the stems did not differ greatly from that with breakage it was determined that the breaking approach can be used to limit the exposure to nearby non-target species, while providing the same results (Spencer et al., 2008). This approach limits the possibility of the herbicide affecting any remaining native species as it is directly applied to the target specie within the broken stems. Based on the results of this study glyphosate was found to be a successful treatment in not only killing those *A. donax* species currently present at a site, but also inhibiting future regrowth even with a one-time application. Therefore, this study shows that using a treatment method such as glyphosate to remove *A. donax* from a site can be successful without the need to continuously disrupt the habitat.
Arundo donax: Study Seven

Bell (1997) discussed the restoration of riparian areas in southern California previously infested with A. donax. This discussion began by explaining the overall invasive characteristics of A. donax, such as its need of water equal to approximately 2,000L/meter of standing A. donax and incredible growth rate of approximately 5 cm per day under optimal conditions (Bell, 1997). In addition, the unique characteristics of riparian habitats are explained including their dependence on periodic flooding to restore the community to earlier stages (Bell, 1997). Bell (1997) indicated that A. donax does not only overtake the native plant species, but also does not provide suitable food or habitat for native wildlife species. In explaining both the characteristics of the invasive A. donax and the riparian area it has infested, the discussion was then directed to the methods used to remove A. donax in order to allow for the restoration of these areas.

Depending on the extent of the infestation of A. donax within the riparian habitat different removal methods can be selected. Some of these methods include foliar application, cut-stem treatment, and aerial application of herbicide (Bell, 1997). Foliar application has been identified as having larger control success than the cut-stem treatment; however, the cut-stem method requires less herbicide and can be applied to avoid nearby non-target species (Bell, 1997). Although the cut-stem method uses less herbicide and may provide some other advantages in application, it requires more time and labor (Bell, 1997). Therefore, foliar application of herbicide is generally used unless the target is an
individual plant or small patch (Bell, 1997). Those areas found to have large percent cover of *A. donax*, approximately 90 percent or greater, generally receive aerial application. However, aerial application depends upon whether the area is capable of being accessed by helicopter, for instance those large patches that are under native canopy are not accessible by this option (Bell, 1997). These three methods of treatment for *A. donax* are generally used, but there can be variations made to them based on the environmental or structural conditions within the area.

**Arundo donax: Study Eight**

Lawson, Giessow, and Giessow (2005) conducted a study in the Santa Margarita River watershed to aid in the control of the invasive *A. donax*. This study included treatment methods such as foliar application, cut stem method, and mechanical control. Mechanical control included the removal of stems and rhizomes with a trackhoe; to prevent re-sprouting these were then processed in a grinder (Lawson et al., 2005). Both the cut stem method and mechanical control produced re-sprouts that were retreated with foliar spraying in following years (Lawson et al., 2005). In order to monitor the effectiveness of these three methods transects were established. The sampling of these transects were first conducted in October of 1997, after the initial treatment, as well as sampling in October of 1998, 1999, and 2000 (Lawson et al., 2005). The sampling included the use of a height pole at every meter of the transect line and recording all plant species that intersected the pole (Lawson et al., 2005). This study resulted in the
conclusion that both foliar herbicide application and mechanical control are effective for the use in the removal of *A. donax* (Lawson et al., 2005). However, it was determined that depending on specific situations, such as the amounts of *A. donax* or the location, all treatment methods were potentially useful in the eradication of the invasive species.

The eight studies reviewed involving the control and invasive characteristics of *A. donax* were comprised of many similar key aspects. Many of the studies looked into *A. donax* control through the use of the chemical glyphosate applied to cut stems or foliage and mechanical control. The two studies that reviewed the use of glyphosate identified that it is a successful treatment method and may allow for less habitat disruption, but one also explained that it may have unintended effects on native species within the habitat. Further, those studies that looked into the different methods used to disperse herbicide found that foliar application is the most effective; however, as previously stated, its use depends upon the location where treatment is needed. Another of the studies provided a similarity to the previously reviewed riparian habitat studies, as its results indicated that the most effective control within a riparian community is that which provides the removal of invasive species allowing for the natural recovery of the habitat. This need to remove invasive species was also indicated by the study involving the capability of *A. donax* to quickly regenerate after natural events such as wildfires, as it showed that *A. donax* grows more rapidly than most native species following these events.
Therefore, this review demonstrated that there are many different treatment methods used in the control of *A. donax*, and that the most successful treatment is that which fits the characteristics of the habitat this species has invaded.

San Timoteo Canyon

With the knowledge provided by the previous studies of both riparian habitats and the invasive *A. donax*, we are now able to investigate a particular riparian area that has been invaded by this species. The riparian area of San Timoteo Canyon will be reviewed as it is the area in which this project is located. This Canyon also houses endangered species making its ability to be successfully restored of great concern. As San Timoteo Canyon houses endangered species it has been previously studied in order to assess the health of these species as well as the health of the overall habitat. This review will examine two endangered species, the Southwestern Willow Flycatcher and the Least Bell's Vireo, and how their abundance and nesting capabilities have been enhanced by previous restoration.

San Timoteo Canyon: Study One

The Santa Ana Watershed Association (SAWA) prepares annual studies that evaluate the presence of two endangered species, the Least Bell’s Vireo and Southwestern Willow Flycatcher, in the Santa Ana River Watershed. Based on the monitoring completed by SAWA (2007) the Least Bell’s Vireo (LBV) territories identified within San Timoteo Canyon have increased substantially from 14 sites in 2003 to 32 sites in 2006. Although the majority of the pairs identified for the
year 2006 made only one nesting attempt, nesting success increased from 44 percent in 2005 to 64 percent in 2006 (SAWA, 2007). Further, predation and nest parasitism rates both decreased from 2005 to 2006. These results portray an overall increase in the health and presence of this species compared to previous years. The SAWA survey also evaluated the Southwestern Willow Flycatcher, but this species, although sighted within the watershed, was not found to be breeding in the year 2006. Therefore, the results of the SAWA survey depict the overall need to continue monitoring the habitats used by these species in order to gain knowledge of whether restoration procedures are providing a continued increase in the presence and health of these species and their breeding season.

All of the previous studies reviewed in this chapter have provided insight into not only the need to restore the riparian area of San Timoteo Canyon, but also the difficulties that may affect the restoration process. From these studies we can acknowledge that the most successful restoration methods for riparian areas are those that not only provide the least disturbance to the habitat, but also those that allow the habitat to be capable of natural recovery. This is in part due to the idea that riparian areas are unique in that they have many different fluvial and structural processes that are continually changing. In order to allow for these natural processes to function properly, it is necessary to remove non-native species, such as A. donax, that may be affecting them. Therefore, the next few chapters investigate some of the control methods of A. donax that have taken...
place within San Timoteo Canyon and whether these methods have allowed for any form of natural recovery by this riparian habitat.
CHAPTER THREE

METHODS

The concepts identified in the introduction and literature review present the need to provide successful restoration methods within riparian habitats. Further, the literature review identified the many invasive characteristics of *Arundo donax*, which has invaded the San Timoteo riparian area. Therefore, this study takes information from past removals within the San Timoteo riparian area and revisits a portion of the removal site in order to identify the species present and their percent cover. With the new percent cover, this project is able to identify how successful the *A. donax* removals were as well as their ability to hinder this invasive species from spreading within the project site. Within this chapter we will cover the methods used to obtain the data as well as where these methods were conducted.

I received data from previous removal projects within San Timoteo Canyon from the Inland Empire Resource Conservation District (IERCD) (IERCD, 2013). These data included the total acreage of the removal area, amount in acres of *Arundo donax* removed, and the removal procedures taken. The original removal took place within an approximately 110 acre area and included a removal of 30 acres of *A. donax* (Figure 2 in Appendix A). In order to determine whether or not the previous removal measures, performed by IERCD, had reduced the cover of *A. donax* in the study area, I conducted field visits to obtain
new percent cover data of all plant species present. The field visits involved returning to a section, approximately 42.3 acres, of prior removal sites and setting up randomly assigned plots in order to determine the current percent cover values of all species present within the plot. Each of these plots was randomly assigned by the use of ArcGIS. Further, ArcGIS was used to create a map of the, approximately 42.3 acres, project area which contained 16 random points. To further randomize the sampling location only eight of these random points, or half of the originally assigned points, were chosen at random (without knowing their specific location). The points can be seen in the maps in Appendix A, Figures 3 and 4. Figures 3 and 4 depict the points in relation to the number they were originally assigned from one to sixteen, before the final eight points were chosen. However, the numbering for one of the plots, Plot 17, was lost and instead of picking one of the previous numbers not used from 1 to 16 it was assigned a new number. In addition, the data presented in the appendices for each plot are labeled according to these numbers. Also, before viewing the site, it was decided that these points would designate the northeast corner of each plot.

Site visits were made on February 27, 2013 and May 24, 2013, to set up plots and collect data. The sites visited in February had only two observers, Catherine Howe and Quinn Cypher, while the sites visited in May had three, Catherine Howe, Quinn Cypher, and Lee Menke. Each plot was 15 feet by 15 feet measured from the designated northeast corner. At every corner of each plot a flag was placed to indicate the plot’s edge. To start the evaluation every plant
species that was present in the plot was written down. The next step was to estimate the percentage of the plot that each of these individual species occupied. In order to estimate percent cover, the observers used the CNPS figures located in Appendix A, Figures 5 and 6. These figures demonstrate the CNPS method, which relies upon the estimation of percent cover based on the provided charts. In addition to plant species, ground cover, such as the amount of leaf litter and deadfall, was also assessed by the use of Figures 5 and 6. After data were obtained for all species, photographs were taken of the plots (Appendix C).

Once the new cover data set was complete, it was compared to the previous data of the amount of _A. donax_ removed from the site provided by IERCD (IERCD, 2013). Comparisons were made between the acreage of _A. donax_ previously removed from the overall removal site (prior cover) and the new percent cover of _A. donax_ obtained within the random plots (current cover). This comparison of data allows for an understanding of whether or not the removal methods from previous years successfully controlled growth of _A. donax_ in the area. _A. donax_ removal methods generally used by IERCD include grinding the large patches of _A. donax_ using a fecon attachment on heavy equipment. This breaks the above-ground biomass into pieces smaller than six inches which then resprout from underground rhizomes. The resprouts are then sprayed with a foliar herbicide when they reach three to six feet tall. The most common herbicide used in the removal of _A. donax_ is an aquatically formulated glyphosate such as
Aquamaster or Rodeo. With this type of treatment it is normally necessary to repeat treatment for two to five years in order to obtain complete control over the area. Other similar measures were also taken within this site, including foliar spraying without cutting, or cutting *A. donax* by hand and treating the cut stumps with herbicide. As before, all of these other methods require re-treatments for two to five years after the first application. As these are the general removal methods taken by IERCD and other organizations, a combination of these were used within the original removal area depending on the size and location of each of the patches of *A. donax* removed.

In addition, as San Timoteo Canyon has had many previous removal procedures, another ecologically similar location was used to show what could occur if *A. donax* removals do not take place. This area is considered to be ecologically similar as it is also located within the Santa Ana Watershed, has similar climate, and includes similar native species. The location of this area is approximately 24.7 miles southeast of the project site and can be seen in Appendix E Figures 1 and 2. For these comparisons aerial helicopter photography was provided by IERCD, which show the extent of the *A. donax* infestation (IERCD, 2013). These photographs were then compared to aerial photography from GoogleEarth of the project site in San Timoteo Canyon. The photographs were used to analyze what may occur if *A. donax* is not either controlled or removed. The analyses of these two sets of photographs are located in Chapter 5.
Additional Study Sites

Two other areas within or near the project site were made into non-random plots. These two plots were not chosen through the previously described random plot assignment as they were directly identified by IERCD as areas that should be looked into for further examination. As these two areas were not generated by the use of a random plot assignment, these two sites were only used to provide further insight into the more immediate effects of removals on riparian habitats and the ability of riparian habitats to undergo natural recovery.

Washout Area

This particular spot, called the “washout area” in all further discussion, was used to provide information pertaining to the natural processes, such as those relating to the fluvial events, and their ability to alter and change the habitat’s structure and function. Therefore, this area was assessed in order to show the ability of riparian areas to naturally recover through the use of natural processes, such as the movement of the water’s path. IERCD provided old photographs of this area, and new data and photographs were collected by this project. The new data and photographs of the washout area were collected on February 27, 2013. As with the random plots, the CNPS method, Figures 5 and 6 in Appendix A, were used to estimate overall percent cover of each species. Photographs of the washout area were provided by IERCD and were taken in August of 2011 (Appendix D), along with the data and new photographs taken for this project. The new data acquired from the washout area were not a part of the
data collected from the randomly designated plots, but was instead collected in order to provide further evaluation of riparian areas and their unique characteristics.

Plot 16

Plot 16 is located in an area approximately 7.25 miles southeast from the center of the randomized plots, as seen in Appendix A, Figure 4. Although the data taken from this plot are not used in the long-term analysis of treatment, as it was not a randomly assigned plot, the data are located in Appendix D. In Appendix A, Figure 4, this plot is labeled as plot 16; this is due to the original randomized plot 16 not being used within the analysis allowing this number to be used for this plot’s data. This plot underwent recent *A. donax* removals by IERCD in October of 2012. Therefore, this plot is being used to provide a picture of what may occur within the first few years of herbicide application and invasive species removal. By looking at the species present within this plot the more immediate effects of these methods can be identified and compared to the long term effects being studied.
CHAPTER FOUR
RESULTS

Within the eight random plots observed, plant species include giant reed \((A. \text{ donax})\), arroyo willow \((Salix \text{ lasiolepis})\), red willow \((S. \text{ laevigata})\), black willow \((S. \text{ gooddingii})\), mulefat \((Baccharis \text{ salicifolia})\), native and non-native annual grasses, native and non-native perennial grasses, mugwort \((Artemisia \text{ douglasiana})\), cottonwood \((Populus \text{ fremontii})\), southern black walnut \((Juglans \text{ californica})\), shortpod mustard \((Hirschfeldia \text{ incana})\), poison hemlock \((Conium \text{ maculatum})\), prickly lettuce \((Lactuca \text{ serriola})\), sweet clover \((Melilotus \text{ officinalis})\), and caterpillar phacelia \((Phacelia \text{ cicutaria})\). All plant percent cover data derived from the plots are located in Appendix B. One plot (Plot 17) had \(A. \text{ donax}\) where it made up approximately 11 percent of total species cover. Even here, a little less than half of standing plant mass was alive and the rest was dead. As this was the only plot with \(A. \text{ donax}\), of the total eight random plots, this invasive species represents approximately 1.38 percent of the total plant cover of all plots, (both live and dead plants). Therefore, live \(A. \text{ donax}\) makes up approximately 0.64 percent of the eight random plots. IERCD’s field ecologist, Quinn Cypher, reported that Plot 17 had a more recent removal, October 2, 2012, than the majority of the site. The removal within this plot occurred only about a year prior to this project. Most removals took place between the years 2000 and 2001. Therefore, this plot does show that \(A. \text{ donax}\) is present in the overall project site,
but also that results pertaining to the time elapsed between removal and data collection may vary in certain areas.

Other than A. donax, some of the other species found within the plots have also been identified as invasive species. These species included that of Hirschfeldia incana and Conium maculatum. Hirschfeldia incana was present in two different plots, 2 and 17, at less than one percent, and Conium maculatum was found only in Plot 14, at less than one percent. As these invasive species were found within the plots at less than one percent, the majority of the vegetation within the plots are native plant species. For further review, tables of the data taken for the random plots are in Appendix B and photographs are in Appendix C.

The original removal area (Figure 2 in Appendix A) includes approximately 110 acres with a removal of approximately 30 acres of A. donax (about 27 percent of the area). Within the random plots, live A. donax made up approximately 0.64 percent of the total area. If these data reflect the overall project area, then the 42.3 acre project site consists of approximately 0.27 acres of A. donax. Consequently, if the total project site provides a likeness of the original removal area there is now approximately 0.70 acres of A. donax within the 110 acre removal site.
Additional Study Sites

Washout Area

The species found during the site visit included milk thistle (*Silybum marianum*) (<1%), poison hemlock (*Conium maculatum*) (<1%), mustard (*Hirschfeldia incana*) (<1%), annual grasses (5%), mulefat (*Baccharis salicifolia*) (25%), arroyo willow (*Salix lasiolepis*) (20%), red willow (*S. laevigata*) (5%), black willow (*S. gooddingii*) (2%), sandbar willow (*S. exigua*) (3%), cottonwood (*Populus fremontii*) (2%), tamarisk (*Tamarix ramosissima*) (1%), tree tobacco (*Nicotiana glauca*) (1%), and mugwort (*Artemisia douglasiana*) (<1%). The two dominant species were *Baccharis salicifolia* and *Salix lasiolepi*, both native. The invasive species present included *Hirschfeldia incana, Tamarix ramosissima, Conium maculatum*, and *Nicotiana glauca*, but were only a small percentage (<4%) of the cover of the total area.

Plot 16

Plot 16 was found to contain milk thistle (*Silybum marianum*) both alive and dead, dead bull thistle (*Cirsium vulgare*), dead *A. donax* rhizomes, dead stinging nettle (*Urtica dioica*), and dead shortpod mustard (*Hirschfeldia incana*). The approximate percent cover for these species included five percent *Cirsium vulgare*, less than one percent live *Silybum marianum*, 10 percent dead *Silybum marianum*, 25 percent dead *A. donax* rhizomes, less than one percent dead *Urtica dioica*, and 50 percent dead *Hirschfeldia incana*. Of these species four of the five species are considered non-native, including *A. donax, Hirschfeldia*
*incana*, Cirsium vulgare, and *Silybum marianum*. For further detail, the data obtained from this plot can be viewed in Appendix D.
Summary

The riparian area along San Timoteo Creek has undergone many anthropogenic alterations causing degradation and an increase in non-native inhabitants. The non-native plant species within this area have altered the structure of the habitat allowing for the integration of non-native wildlife species and a decrease in the presence of native wildlife. Such changes throughout their ranges have resulted in placing both the Least Bell’s Vireo and Southwestern Willow Flycatcher on the endangered species list. As a result, restoration procedures have been implemented in this and other areas in order to combat further degradation, and to encourage an increase in the populations of these two species. The majority of these restoration measures in San Timoteo Canyon have included the removal of *A. donax* from this riparian habitat. As *A. donax* is a known invasive species that grows in massive stands, outcompetes native vegetation for resources such as water, and provides little functional habitat for wildlife species, it has been targeted as a leading inhibitor of the ability of this habitat to properly function and grow. Within San Timoteo Canyon this species has been treated and removed multiple times (Figure 2 in Appendix A).

To understand whether or not these alterations have in fact increased the health of this riparian habitat, one particular area of previous removal was
evaluated based on species content. As discussed in Chapter Four, the data shows only a small incidence of A. donax throughout the project site. Other than A. donax, invasive species present include Hirschfeldia incana and Conium maculatum. Although these two other invasive species were found, their percent cover was very small, and therefore their presence does not indicate that the removal of A. donax allowed for their increased survival and growth in place of other native species. As live A. donax was found to cover only approximately 0.64 percent of the area of all eight of the random plots, it appears that the treatments used have been successful in reducing this species from the area.

Previous removal within this portion of San Timoteo Canyon included approximately 30 acres of A. donax over a 110 acre area (Appendix A, Figure 2). Therefore, A. donax previously covered up to approximately 27 percent of the overall area showing the high incidence of A. donax before treatment was implemented. The new data documents approximately 0.64 percent cover of A. donax for a 42.3 acre project site. In comparing the estimated previous cover to the present day percent cover, it is clear that the treatments have certainly reduced the infestation of A. donax. In addition, as the new data were acquired 12 to 13 years after the removals had been implemented, earlier removal methods did in fact hinder the re-growth of this species.

Interestingly, not only did the treatments hinder the re-growth of A. donax, but the other invasive species found were also of a very small percent cover. This could indicate that the removal of A. donax does in fact provide a greater
chance of native species growth, rather than allowing competing invasive species to have an increased ability to integrate themselves into the habitat. As there has been little re-growth within the area, further methods of restoration, such as active plantings, may not be necessary. Without the presence of this invasive species, this riparian habitat has the potential to naturally increase its health and functionality. However, because there are still small patches of this species within the project area continued treatment of the species may be necessary to prevent *A. donax* from spreading. Continued treatments will provide aid to the habitat as it will allow the plant species to grow and mature without the presence of this invasive species.

**Washout Area Discussion**

The differences in plant cover between the old and new photographs shows the ability of riparian areas to provide natural restoration (Appendix D, Photographs 2 through 5). The older photographs (Photographs 2 and 3) show little plant cover, consisting of immature vegetation. This sparse plant structure may be a result of the area being directly within the water course of San Timoteo Creek. The more recent pictures (Photographs 4 and 5) show more mature vegetation with little bare ground. The creek’s path has moved slightly to the south relative to the older channel (compare Photographs 2 and 3 to 4 and 5). The difference in plant cover and the corresponding alteration in the creek channel indicate that riparian areas can provide their own treatment method for potential habitat degradation. The idea of natural recovery of riparian areas after
the removal of *A. donax*, and other invasive species, was also discussed in a few of the previous studies identified in the literature review.

As discussed previously, fluvial processes in riparian areas aid in the overall functionality and health of a riparian habitat. It is not clear, based on the photographs, whether or not the washout area was previously infested with *A. donax*, but it is located just west of the original removal areas providing for the likelihood of some form of invasion by this species (Figure 2 in Appendix A). In comparing the photographs it is obvious that the area has undergone a large transformation over time. As no known recent restoration procedures were completed in this area, this transformation appears to be a result of the natural regenerating characteristics that can occur in riparian habitats. This natural restoration is linked to the dependence riparian habitats have on fluvial processes and their ability to recreate earlier stages of plant structure. Plant species in riparian areas are prone to stem breakage and physical abrasion caused by water flow. Therefore, riparian habitats that lie within the water’s path can include sparse or immature plants. The removal of old plants and the ability to regrow after movement may allow for the greater ability of riparian areas to provide their own forms of natural restoration. As a result, this could offer an indication that non-native vegetation may struggle to withstand these events in the same manner as native species. However, some non-native species, such as *A. donax*, could spread after stem breakage.
The movement of the water’s path and the return of more mature, mainly native vegetation, indicates that some degraded areas are capable of increasing habitat health without the need of outside resources. Although these processes may be able to provide portions of the habitat with natural regeneration other areas, not within the water’s path, may not have the same capability. Therefore, other areas may still need the addition of other passive and/or active restoration measures to inhibit the infestation of invasive species. In addition, the areas undergoing natural passive restoration measures may also need some other form of passive restoration in order to properly inhibit invasive species or their regrowth. Understanding the extent of the natural processes occurring within this particular riparian habitat would help determine what types of restoration measures are necessary and to what extent they should be implemented.

As previous removals of the highly invasive A. donax have been completed in close proximity to this site, there may be other reasons why this area has had the ability to grow more rapidly than before. The introduction of invasive species affects the ability of many native plant species to grow as they can limit the availability of necessary resources. Therefore, removing A. donax from the proximity may have caused it to have a lessened ability to invade the area, which may have provided for a greater likelihood of the regeneration of the native plant species. This indicates that the increase in plant cover within the study area may be a result of a variety of factors such as the movement of the water’s course, the removal of A. donax upstream, other characteristics of this
riparian habitat, or that *A. donax* may not have entered this particular area. Therefore, if changes seen within this area are in fact related to the upstream removals, this area may demonstrate that the integration of restoration measures within one area may in fact aid similar areas nearby, without the need to implement further restoration procedures. As riparian areas have the ability to increase their own health and functionality, through normal cyclical changes in species and structure, depending on whether areas have been degraded and the extent of the degradation restoration measures may not be needed.

**Plot 16 Discussion**

As described in Results, Plot 16 had very little live vegetation. Of the five species present only *Silybum marianum* was recorded as alive. This indicates that the treatment method used did eradicate the invasive *A. donax*; however, other species were also affected. The effects on the other species within this plot show that treatment methods may not only eradicate the target invasive species, but could also impact the health of nearby native species as well as other non-native species. The extent of this impact could allow the introduction of other non-native species rather than provide for an increased presence of native species. Of the five species identified within this plot, only one may be considered to be native (*Urtica dioica*). In addition, the only native species found within this plot was also found to be dead. This could be an indication that the treatment methods generally used for *A. donax* may also have a large impact on the health and survival of nearby native species. Therefore, data from this plot
indicates that removal of *A. donax*, although causing some effects to native species, does eradicate invasive species, which could lead to a higher likelihood of native species survival and regrowth rates.

**Aerial Photography Discussion**

Aerial photographs, taken in September of 2001, were provided by IERCD of an ecologically similar location, while aerial photography of the project site was obtained from Google Earth (Appendix E Photographs 1 through 7). The aerial photographs provided by IERCD (Photographs 1 and 2) demonstrate an advanced infestation of *A. donax* and the specie’s capability to outcompete native species. Photographs one and two are of an area within the Santa Ana River Watershed as is the project site. Therefore, these photographs are used to discuss the impacts this invasive species could have on an area if it is not managed with proper treatment and removal procedures.

As seen in Photographs one and two in Appendix E, the majority of the ecologically similar area has been overrun by *A. donax*, illustrating the ability of this species to produce massive stands and out-compete native vegetation. The increased incidence of *A. donax* within this area could lead to a drastic alteration in the structure of the habitat that may cause, or may have already caused, a decline in the health of its native species, both plant and wildlife. This areas increased infestation emphasizes the need for restoration of riparian habitats that have been invaded by *A. donax*. In order to provide the greatest increase in the health of a degraded habitat, such as this, it is essential to fully understand the
success rates of removal methods and whether they need further implementation or additional steps to provide the greatest increase in overall functionality of the habitat. As this area is so highly infested, it will most likely need extensive removal methods, but as indicated by the data supplied from the random plots it will presumably be able to allow for native plant regrowth without the need of future active restoration. However, due to the extent of infestation of $A. \ donax$ in this area the success of these treatments may not be as great as in areas where these methods have previously been implemented. As the removal of $A. \ donax$ in such a highly infested area is reliant upon the success of the methods used, it can be indicated that restoration measures should be more highly studied in order prevent unsuccessful attempts in areas of high devastation.

Additional aerial photography, from Google Earth, includes a close up view of the center of the project area for the years 2003, 2007, 2009, 2011, and 2012. These photographs are located in Appendix E, Photographs 3 through 7. The majority of these aerial photographs show well-matured vegetation surrounding the stream, except for the year of 2011, Photograph 6. In these photographs, the distinct views of $A. \ donax$ present in the ecologically similar area are not existent. The capability of the area to endure a large increase in growth, seen in the 2011 to the 2012 aerial photographs, Photographs 6 and 7, indicates a healthy habitat capable of natural restoration and regrowth of its previous structure. In addition, the increased plant cover seen in the 2012 photograph, Photograph 9, does not indicate large increases in $A. \ donax$ growth.
This may indicate that areas that have undergone invasive species removals are more likely to be capable of subsequent natural restoration of their native vegetation rather than allowing for the integration of other invasive species. When comparing Photographs 1 and 2 to 3 through 7, it is apparent that without removal methods an area can easily be overrun by *A. donax*. Furthermore, allowing *A. donax* to overrun an area may lead to the prevention of the ability of the native species to regrow after periods of degradation or altered growth.

Conclusions

The health and functionality of many riparian habitats have declined as a result of their use for anthropogenic activity. An example of this usefulness has been demonstrated in San Timoteo Canyon, which has undergone an increased human population leading to alterations in the historical flow and velocity of its creek. The alterations that have been made by the prevalence of these anthropogenic sources, generally in order to transfer water, have provided for additional negative changes in the habitat. These changes include that of the increased incidence of non-native species, both wildlife and plants, accompanied by a decline in native populations. The increased prevalence of non-native species and the reduction in some of the native species, such as the Southwestern Willow Flycatcher and Least Bell’s Vireo, has created an altered structure and a decrease in the overall functionality of this riparian habitat. These alterations have prompted various organizations to implement restoration
measures in the canyon in order to offer an increased likelihood of survival for these endangered species.

The restoration measures that have been implemented in San Timoteo Canyon have generally consisted of removing the highly invasive A. donax. This species is capable of producing massive stands in place of native vegetation, which leads to a decrease in suitable wildlife habitat and also decreases needed cover over the watercourse. The procedures that have been used within San Timoteo Canyon are known to reduce A. donax allowing for an increase in the health of most riparian habitats. Nevertheless, habitats can react differently to these treatments depending on their characteristics as well as the extent of their degradation. Therefore, one particular site’s ecological characteristics may result in the need for continued treatments, while another may be able to recover after very few treatments. As a result of this concept, this project looked more closely at one particular area of previous removal in order to identify whether previous treatments were successful in this particular habitat type and if any further restoration procedures may have been necessary to increase native plant cover.

The randomized plots used within this project found very little A. donax within the project area. Live A. donax was estimated to cover only approximately 0.704 acres of the original 110 acre removal site, while the removal had included 30 acres of A. donax. This suggests that the treatments were successful in the eradication of A. donax from the project area, and after approximately 13 to 14 years of elapsed time indicated that they also hindered the regrowth of this
invasive species. As indicated by these results, it can be inferred that the treatments used by IERCD have provided for a greater ability of this habitat to increase its overall functionality and has provided for a more suitable habitat for its native wildlife species, such as the endangered Least Bell’s Vireo and Southwestern Willow Flycatcher.

Recommendations

The data was obtained in order to create a representative of the overall area, but only reviewed one of the known removal sites within San Timoteo Canyon. Figure 2 in Appendix A, shows the many other removal sites within San Timoteo Canyon. Therefore, this project only provided a small representation of restoration activities that have occurred within San Timoteo Canyon. It is recommended that further analysis of the treatment methods used within Timoteo Canyon be completed. A larger study, including more plots throughout the project area and within the other removal sites, would provide a greater understanding and additional direction for future restoration procedures.

Additional work may provide greater insight into whether active restoration procedures, such as plantings, are needed to further increase the habitat’s health and functionality. While this study indicates that past treatments have aided in the reduction of *A. donax*, it did not provide great insight into the health of the native species relative to their previous health. This was due to the lack of previous data that could have provided an estimate of the overall percent cover and health of the native species during the time of removal. In order to fully
investigate the functionality and health of the native species, data should be acquired within this area of both the native health and the non-native abundance. This additional data would then be available for comparison to the data obtained in future restoration studies. In gaining this type of data future studies would be able to not only understand whether the invasive species are being eradicated, but also whether native species are in fact thriving after their removal.

Future studies looking at a larger number of the previous removal sites would also allow for restoration procedures in ecologically similar areas to be more successful. For instance, the ecologically similar area seen in the previously discussed in the Aerial Photograph Discussion, as seen in the photographs in Appendix E, would benefit from studies that fully examine what has occurred in San Timoteo Canyon. As this area is so heavily infested with *A. donax*, successful restoration methods will be difficult and would need to take into consideration many other factors, such as the invasiveness of the species as well as the structural fluvial processes of the riparian habitat. Implementing removal procedures that are known to provide positive results in similar areas, such as those seen within the study area of this project, would be most likely to deliver a decrease in the presence of this highly invasive species. Therefore, further studies looking further into the recovery of this area post removal will only provide additional information needed for future removal success in areas with similar characteristics.
APPENDIX A

MAPS AND FIGURES
Figure 1. Map showing the location of the San Timoteo Canyon Project site in relation to nearby southern California cities.

Figure 2. Map depicting IERCD’s previous removals and the amount removed. The current project site is located within the light pink, Phase IV, but does not cover the whole light pink area as seen in Figures 4 and 5.

Figure 3. Overall study area with the random plots as well as their location in relation to Plot 16. Plots are identified on the map by their corresponding number.

(IERCD) Inland Empire Resource Conservation District. 2013.
Figure 4. Close up view of the overall study area depicting the location of each plot in relation to one another. Plots are labeled based on their originally supplied number.

Figure 5. This is one of two figures used by this project in order to estimate percent cover.

California Native Plant Society. Website
Figure 6. This is the second figure that was used by this project in order to estimate percent cover.

APPENDIX B

RANDOM PLOT DATA TABLES
### Plot 2 (Date: 5/24/13)

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<th>Latin Name</th>
<th>Vegetation Type</th>
<th>Percent Cover</th>
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**Ground Cover**

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**Ground Cover**

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**Ground Cover**

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<td>Mulefat</td>
<td><em>Baccharis salicifolia</em></td>
<td>Shrub/Forb</td>
<td>50%</td>
</tr>
<tr>
<td>Caterpillar Phacelia</td>
<td><em>Phacelia cicutaria</em></td>
<td>Forb</td>
<td>2%</td>
</tr>
<tr>
<td>Arroyo Willow</td>
<td><em>Salix lasiolepis</em></td>
<td>Tree</td>
<td>2%</td>
</tr>
<tr>
<td>Mugwort</td>
<td><em>Artemisia douglasiana</em></td>
<td>Shrub</td>
<td>1%</td>
</tr>
</tbody>
</table>

**Ground Cover**

<p>| | | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Leaf Litter</td>
<td>-</td>
<td>-</td>
<td>75%</td>
</tr>
</tbody>
</table>
### Plot 14 (Date: 2/27/2013)

<table>
<thead>
<tr>
<th>Common Name</th>
<th>Latin Name</th>
<th>Vegetation Type</th>
<th>Percent Cover</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mulefat</td>
<td>Baccharis salicifolia</td>
<td>Shrub</td>
<td>15%</td>
</tr>
<tr>
<td>Arroyo Willow</td>
<td>Salix lasiolepis</td>
<td>Tree</td>
<td>2%</td>
</tr>
<tr>
<td>Red Willow</td>
<td>Salix laevigata</td>
<td>Tree</td>
<td>4%</td>
</tr>
<tr>
<td>Poison Hemlock</td>
<td>Conium maculatum</td>
<td>Forb</td>
<td>&lt;1%</td>
</tr>
<tr>
<td>Mugwort</td>
<td>Artemisia douglasiana</td>
<td>Shrub</td>
<td>1%</td>
</tr>
<tr>
<td>Annual Grasses</td>
<td>-</td>
<td>Forb</td>
<td>&lt;1%</td>
</tr>
</tbody>
</table>

**Ground Cover**

<table>
<thead>
<tr>
<th>Common Name</th>
<th>Vegetation Type</th>
<th>Percent Cover</th>
</tr>
</thead>
<tbody>
<tr>
<td>Leaf Litter</td>
<td>-</td>
<td>90%</td>
</tr>
<tr>
<td>Deadfall</td>
<td>-</td>
<td>10%</td>
</tr>
</tbody>
</table>

### Plot 15 (Date: 5/24/13)

<table>
<thead>
<tr>
<th>Common Name</th>
<th>Latin Name</th>
<th>Vegetation Type</th>
<th>Percent Cover</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arroyo Willow</td>
<td>Salix lasiolepis</td>
<td>Tree</td>
<td>33%</td>
</tr>
<tr>
<td>Mugwort</td>
<td>Artemisia douglasiana</td>
<td>Shrub</td>
<td>60%</td>
</tr>
<tr>
<td>Cottonwood</td>
<td>Populus fremontii</td>
<td>Tree</td>
<td>40%</td>
</tr>
<tr>
<td>Caterpillar Phacelia</td>
<td>Phacelia cicutaria</td>
<td>Forb</td>
<td>&lt;1%</td>
</tr>
<tr>
<td>Perennial Grasses</td>
<td>-</td>
<td>Forb</td>
<td>&lt;1%</td>
</tr>
<tr>
<td>Southern Black Walnut</td>
<td>Juglans californica</td>
<td>Forb</td>
<td>&lt;1%</td>
</tr>
</tbody>
</table>

**Ground Cover**

<table>
<thead>
<tr>
<th>Common Name</th>
<th>Vegetation Type</th>
<th>Percent Cover</th>
</tr>
</thead>
<tbody>
<tr>
<td>Leaf Litter</td>
<td>-</td>
<td>95%</td>
</tr>
<tr>
<td>Deadfall</td>
<td>-</td>
<td>1%</td>
</tr>
<tr>
<td>Common Name</td>
<td>Latin Name</td>
<td>Vegetation Type</td>
</tr>
<tr>
<td>------------------------</td>
<td>--------------------------</td>
<td>-----------------</td>
</tr>
<tr>
<td>Mulefat</td>
<td><em>Baccharis salicifolia</em></td>
<td>Shrub</td>
</tr>
<tr>
<td>Cottonwood (Live)</td>
<td><em>Populus fremontii</em></td>
<td>Tree</td>
</tr>
<tr>
<td>Cottonwood (Snag/Dead)</td>
<td><em>Populus fremontii</em></td>
<td>Tree</td>
</tr>
<tr>
<td>Shortpod Mustard</td>
<td><em>Hirschfeldia incana</em></td>
<td>Shrub</td>
</tr>
<tr>
<td>Annual Grasses</td>
<td>-</td>
<td>Forb</td>
</tr>
<tr>
<td>Giant Reed (Live)</td>
<td><em>Arundo donax</em></td>
<td>Shrub</td>
</tr>
<tr>
<td>Giant Reed (Dead)</td>
<td><em>Arundo donax</em></td>
<td>Shrub</td>
</tr>
<tr>
<td>Sweet Clover</td>
<td><em>Melilotus officinalis</em></td>
<td>Forb</td>
</tr>
<tr>
<td>Mugwort</td>
<td><em>Artemisia douglasiana</em></td>
<td>Shrub</td>
</tr>
</tbody>
</table>

**Ground Cover**

<table>
<thead>
<tr>
<th>Common Name</th>
<th>Vegetation Type</th>
<th>Percent Cover</th>
</tr>
</thead>
<tbody>
<tr>
<td>Leaf Litter</td>
<td>-</td>
<td>50%</td>
</tr>
<tr>
<td>Deadfall</td>
<td>-</td>
<td>25%</td>
</tr>
</tbody>
</table>
APPENDIX C

RANDOM PLOT PHOTOGRAPHY
Photograph 1. Plot 2, the northeast corner of the plot is shown by the red flag at the bottom right hand corner of the photograph. View is to the southwest and west. The main view within this photograph is that of leaf litter and *Salix lasiolepis*. 
Photograph 2. Plot 2, with a yellow flag at the bottom right hand corner of the photograph, at the southwest corner of the plot. View is to the northeast and shows deadfall, annual grasses, *Baccharis salicifolia*, *Salix lasiolepis*, and *Salix laevigata*.
Photograph 3. Plot 7 in which the northeast corner can be seen by the red flag at the bottom left of the photograph. The view is to the south and southwest. This photograph shows leaf litter, deadfall, and *Populus fremontii*.

Photograph 4. Plot 8, the northwest corner is depicted by the red flag at the bottom left. Views are to the south and southwest. Within the photograph are deadfall, water, *Baccharis salicifolia*, and *Salix lasiolepis*. 
Photograph 5. Plot 11 in which two of the plot corners can be seen. The red flag, at the northwest corner, is at the bottom left hand of the photograph and the other is a yellow flag, at the southwest corner, at the center right of the photograph. Views are to the east and mainly show sand and *Baccharis salicifolia*. 
Photograph 6. Plot 12, the northeast corner is marked by the yellow flag at the bottom right hand corner of the photograph. Views are to the southwest and show leaf litter and *Salix lasiolepis*. 
Photograph 8. Plot 14, the northeast, bottom left, and southeast, top left, corners of the plot are displayed by the two red flags. Views are to the southwest and south west. This photograph shows leaf litter, deadfall, annual grasses, *Salix lasiolepis*, and *Baccharis salicifolia*. 
Photograph 9. Plot 15, the northeast corner can be seen in the bottom right of the photograph at the red flag. Views are to the southwest and show *Artemisia douglasiana*, *Salix lasiolepis*, and *Populus fremontii*. 
Photograph 10. Plot 17 showing the live, in background, and dead, in foreground, A. donax.
Photograph 11. Plot 17, showing deadfall, leaf litter, *Baccharis salicifolia*, *Populus fremontii*, and *Artemisia douglasiana*. 
APPENDIX D

WASHOUT AREA AND PLOT 16
Plot 16 (Date: 2/27/2013)

<table>
<thead>
<tr>
<th>Common Name</th>
<th>Latin Name</th>
<th>Vegetation Type</th>
<th>Percent Cover</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bull Thistle (Dead)</td>
<td><em>Cirsium vulgare</em></td>
<td>Shrub</td>
<td>5%</td>
</tr>
<tr>
<td>Milk Thistle (Live)</td>
<td><em>Silybum marianum</em></td>
<td>Shrub</td>
<td>&lt;1%</td>
</tr>
<tr>
<td>Milk Thistle (Dead)</td>
<td><em>Silybum marianum</em></td>
<td>Shrub</td>
<td>10%</td>
</tr>
<tr>
<td>Stinging Nettle (Dead)</td>
<td><em>Urtica dioica</em></td>
<td>Shrub</td>
<td>&lt;1%</td>
</tr>
<tr>
<td>Giant Reed (Rhizomes-Dead)</td>
<td><em>Arundo donax</em></td>
<td>Shrub</td>
<td>25%</td>
</tr>
<tr>
<td>Shortpod Mustard (Dead)</td>
<td><em>Hirschfeldia incana</em></td>
<td>Shrub</td>
<td>50%</td>
</tr>
</tbody>
</table>

Photograph 1. Plot 16 on February 27, 2013, showing that the majority of the species present were not found to be alive. The red flag is the northeast corner and views are to the southwest.
<table>
<thead>
<tr>
<th>Common Name</th>
<th>Latin Name</th>
<th>Vegetation Type</th>
<th>Percent Cover</th>
</tr>
</thead>
<tbody>
<tr>
<td>Milk Thistle</td>
<td><em>Silybum marianum</em></td>
<td>Shrub</td>
<td>&lt;1%</td>
</tr>
<tr>
<td>Poison Hemlock</td>
<td><em>Conium maculatum</em></td>
<td>Shrub</td>
<td>&lt;1%</td>
</tr>
<tr>
<td>Shortpod Mustard</td>
<td><em>Hirschfeldia incana</em></td>
<td>Shrub</td>
<td>&lt;1%</td>
</tr>
<tr>
<td>Annual Grasses</td>
<td>-</td>
<td>Forb</td>
<td>5%</td>
</tr>
<tr>
<td>Mulefat</td>
<td><em>Baccharis salicifolia</em></td>
<td>Shrub</td>
<td>25%</td>
</tr>
<tr>
<td>Arroyo Willow</td>
<td><em>Salix lasiolepis</em></td>
<td>Tree</td>
<td>20%</td>
</tr>
<tr>
<td>Red Willow</td>
<td><em>Salix laevigata</em></td>
<td>Tree</td>
<td>5%</td>
</tr>
<tr>
<td>Black Willow</td>
<td><em>Salix gooddingii</em></td>
<td>Tree</td>
<td>2%</td>
</tr>
<tr>
<td>Cottonwood</td>
<td><em>Populus fremontii</em></td>
<td>Tree</td>
<td>2%</td>
</tr>
<tr>
<td>Tamarisk</td>
<td><em>Tamarix spp.</em></td>
<td>Shrub</td>
<td>1%</td>
</tr>
<tr>
<td>Tree Tobacco</td>
<td><em>Nicotiana glauca</em></td>
<td>Tree</td>
<td>1%</td>
</tr>
<tr>
<td>Sandbar Willow</td>
<td><em>Salix exigua</em></td>
<td>Tree</td>
<td>3%</td>
</tr>
<tr>
<td>Mugwort</td>
<td><em>Artemisia douglasiana</em></td>
<td>Shrub</td>
<td>&lt;1%</td>
</tr>
</tbody>
</table>
Photograph 2. Washout Area in August of 2011, view is to the east. This photograph shows bare ground and sparse vegetation.

Photograph 3. The Washout Area in August of 2011, view is to the southeast. This photograph shows the immature vegetation present at this time.
Photograph 4. Washout Area on February 27, 2013, view is to the east. In comparison to Photograph 2 the area has limited bare ground and is less sparsely vegetated.

Photograph 5. Washout Area on February 27, 2013, view is to the southeast. In comparison to Photograph 3 the area has increased cover and taller, more mature, vegetation.
APPENDIX E

AERIAL PHOTOGRAPHY
Figure 1. This map shows the location of the ecologically similar area in relation to the San Timoteo Canyon project site. The ecologically similar location is located approximately 24.7 miles southeast of the project site and is within the Santa Ana River and Prado Dam.

Figure 2. A closer view of the ecologically similar location showing its location within the Santa Ana north of the city of Corona.

Photograph 1. An aerial photograph of the ecologically similar area taken by IERCD in September of 2001. The light green vegetation is *Arundo donax*. This photograph shows the high infestation of *A. donax* within this area.
Photograph 2. Another aerial photograph of the ecologically similar area taken by IERCD in September of 2001. The light green vegetation is *Arundo donax*. This photograph is a closer view and shows the extent of the infestation of *A. donax*.

Photograph 3. An aerial view of the center portion of the 42.3 acre project site taken in 2003.

Photograph 4. An aerial view of the center portion of the 42.3 acre project site taken in 2007.


2014.

Photograph 5. An aerial view of the center portion of the 42.3 acre project site taken in 2009.


2014.
Photograph 6. An aerial view of the center portion of the 42.3 acre project site taken in 2011.


2014.

Photograph 7. An aerial view of the center portion of the 42.3 acre project site taken in 2012.


2014.
REFERENCES


Coffman, G.C.; Ambrose, R.; Rundel, P. Wildfire promotes dominance of invasive giant reed (\textit{Arundo donax}) in riparian ecosystems. \textit{Biological Invasions} 2010, 12, 2723–2734.


Griggs, F.T. California Riparian Habitat Restoration Handbook  


Lawson, D.M.; Giessow, J.A.; Giessow, J.H. *The Santa Margarita River Arundo donax Control Project: Development of Methods and Plant Community*
Response; Report PSW-GTR-195; USDA Forest Service: Albany, 2005; p229-244.


