Texas State Soil and Water Conservation Board
FY04 CWA Section 319(h)
Project 04-15

NONPOINT SOURCE SUMMARY PAGE

1. Title of Project: Mathematical Model for the Dispersal of the Leaf Beetle, Diorhabda Elongata from the Old World Released in the United States for Biological Control of Invasive Saltcedar

2. Project Goals/Objectives: The goal of this project is to aid in implementing the Implementation Plan for Sulfate and Total Dissolved Solids (TMDLs) in the J.B. Thomas, E.V. Spence and O.H. Ivey Reservoirs by biological control of saltcedar in riparian areas along the Colorado River of Texas and its tributaries in an effort to reduce nonpoint source (NPS) pollution loadings resulting from invasive brush species on agricultural lands.

3. Project Tasks: (1) To demonstrate and predict the rate of dispersal of the leaf beetle, *Diorhabda elongata*, released at Lake J.B. Thomas and near Big Spring, TX; (2) For coordination of biological control with other saltcedar control, revegetation, and wildlife programs; (3) To promote project participation and public interest in the project; (4) To monitor the success of the leaf beetle using satellite imagery.

4. Measures of Success: (1) To develop a model that can be used as a planning and implementation tool for long-term control of saltcedar; (2) To demonstrate that the model developed through the project accurately predicts the dispersal of the *Diorhabda* beetles and the associated defoliation of saltcedar from point release sites, during the 3 years following releases made during 2003, with 75% accuracy both spatially and temporally; (3) Increase public perception and awareness of the use of biological controls

5. Project Type: Statewide ( ); Watershed (X); Demonstration ( ).

6. Waterbody Type: River (X); Groundwater ( ); Other ( ).

7. Project Location: E.V. Spence Reservoir (Segment 1411); Colorado River above Lake J.B. Thomas (Segment 1412).

8. NPS Management Program Reference: *Texas Nonpoint Source Pollution Assessment Report and Management Program* approved October 1999.

9. NPS Assessment Report Status: Impaired (X); Impacted ( ); Threatened ( )

10. Key Project Activities: Hire Staff ( ); Monitoring (X); Regulatory Assistance ( ); Technical Assistance ( ); Education (X); Implementation (X); Demonstration (X); Other ( )

11. NPS Management Program Elements: Milestones from the *1999 Texas Nonpoint Source Pollution Assessment Report and Management Program*, which will be implemented include: (1) coordinating with federal, state, and local programs; (2) committing to technology transfer, technical support, administrative support, and cooperation between agencies and programs for the prevention of NPS pollution.

12. Project Costs: Federal ($136, 724); Non-Federal Match ($0); Total Project ($136,724)

13. Project Management: Texas State Soil and Water Conservation Board (State Board). Cooperating Entities: USDA-ARS, Texas Agricultural Experiment Station

14. Project Period: Three years from start date.

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WORKPLAN

Problem/Needs Statement: A need exists for a model that will predict the dispersal rate of the *Diorhabda elongata* beetles and the degree of control of saltcedar, for use both in evaluating potential effects in ongoing large-scale field experiments begun in 2001 and in predicting long-term affects of the saltcedar control program. The model will help to evaluate affects of the recently initiated biological control of saltcedar program in 8 western states. In Texas, the model will support the "Colorado River Saltcedar Control Project", which compares biological and herbicidal control in this entire river basin set to begin in 2004 (McGinty and Thornton, 2003). Specifically, the model is needed for the following:

A. To predict the arrival of the beetles, and the reduction of saltcedar, at the breeding sites of the endangered southwestern willow flycatcher that now nests extensively in saltcedar stands in Arizona. The major concern of the U.S. Fish and Wildlife Service is that the beetles will disperse and control saltcedar so quickly that native willow breeding habitat will not have time to revegetate and the bird will be left with insufficient habitat for a few years. All present release sites are from 200 to 850 miles from where the swWIFL nests in saltcedar. At the present sites where beetles were released in May 2001, they dispersed outward within a radius of ca. 100 m from the release point after the 2nd growing season (August 2002), and within a radius of one-fourth to 1 mile during the 3rd growing season (September 2003). So far, the rate of dispersal is increasing geometrically but future rates may decline or increase. At the present rate, several years (5 to 20 years?) may be required to reach flycatcher nesting grounds in Arizona from the present release sites. If unauthorized dispersal occurs by private individuals, the beetles could reach flycatcher breeding grounds much sooner. If dispersal can be predicted, revegetation efforts can begin so suitable native nesting habitat will be in place before the beetles arrive, an important factor for the recovery of the swWIFL. If the dispersal rate can be predicted, then beetles could be released, and the damage from saltcedar reduced, nearer to flycatcher breeding grounds. Previous research indicates that, if water depth and soil salinity are suitable, willows can grow to suitable nesting habitat within 3 to 5 years. Salinity and water table conditions at all major flycatcher breeding areas appear to be satisfactory for revegetation (natural or manual) by willows and cottonwoods; more are not present because of competition from saltcedar. At two major breeding sites (Roosevelt Lake, AZ and Elephant Butte, NM, dramatic increases in flycatcher populations have occurred when willows increased following flooding and subsequent decline in the lake levels.

B. For coordination with revegetation programs that aim to restore native plant and animal communities after saltcedar control, including the flycatcher breeding habitat. Large scale revegetation experiments were begun by the U.S. Bureau of Reclamation at San Marcial, NM in 2002 and will be established at Big Bend National Park, Lake Merideth National Recreational Area, TX in 2004. These experiments will develop best procedures for revegetation of saltcedar infested areas after control, in case natural revegetation is inadequate. BOR also has proposed a model to predict optimal areas where saltcedar can invade and areas with the best potential for revegetation after saltcedar control.

C. For coordination and integration with herbicidal control programs that also aim to control saltcedar. Large-scale programs on herbicidal control of saltcedar are in progress along the Pecos River of Texas and New Mexico and are set to begin in 2004 on the middle Rio Grande, NM and the upper Colorado River, TX. The herbicidal and biological control programs can augment each other or interefere with each other. The main disadvantage of the biological control program is that it requires 3 to 5 years to become fully effective in an area, whereas chemical control is effective within a few weeks. A model is

needed to predict how rapidly effective biocontrol will spread within an area, or how closely release sites should be located to produce control within a given time period.
D. For predicting how rapidly biological control can produce improvement in water quality and quantity urgently needed for agriculture and municipalities.

E. For comparing the effectiveness of the various biotypes of the control insect, *Diorhabda elongata*. The beetles released during Mary 2001 were from Fukang, China and Chilik, Kazakhstan. They appear unable to reproduce and establish south of the 37th parallel (the northern border of Oklahoma, New Mexico and Arizona) because they require a minimum of 14 hr 45 min daylength to prevent premature overwintering diapause and daylength in the southern areas is too short. Therefore, these beetles appear to pose no threat to the swWIFL which breeds in saltcedar (except very occasionally in other vegetation) only south of the 37th parallel; also, they appear incapable of controlling saltcedar in the southern areas where most of the damage occurs. The new biotypes of *D. elongata* recently obtained from Crete, Greece, Sfax, Tunisia, and Karshi, Uzbekistan, and released during the summer 2003, appear not to require such long summer daylengths and to be adapted to the areas south of the 37th parallel. The Crete beetles overwintered well at Temple, TX during the winter of 2002-2003; they reproduced vigorously and heavily damaged saltcedar during the spring and summer of 2003. These beetles now have been placed in field cages at several locations in Texas, New Mexico, and California. A biotype from Turpan, China has been placed in field cages and released into the open field at Seymour, but they entered diapause during late July and may not be able to establish. More information on establishment ability of these biotypes will be available in March or April of 2004.

The *Diorhabda* dispersal model described in the present grant application will draw heavily on the 3 years of dispersal data available at Lovelock and Schurz, NV, Delta, UT, Pueblo, CO, and Lovell, WY. The releases of *Diorhabda* beetles made during August 2003 at Seymour, Lake Thomas, Big Spring, TX and Artesia, NM will provide data on dispersal, beginning with the date of release. This gives a total of 6 years of data at the 5 northern sites and 3 years of data at the 4 southern sites by the end of the grant period. Monitoring at the Texas sites can be adjusted to meet the needs of the model.

General Project Description: The statistical methodology is designed to achieve the following objectives: 1) to establish the rate of dispersion of *Diorhabda*; 2) to identify the biotic and abiotic factors that affect the rate and direction of the dispersion; 3) to predict the rate and dominant direction of *Diorhabda* dispersion in potential release areas.

The study to pursue these three objectives will be separated in two phases, objectives 1 and 2 will be the goal of Task 2 during years 1 and 2, and objective 3 will be the goal of Task 3 in year 3. Some of the sites included in the study have already data from three seasons, that data already collected will be used for the design of sampling scheme for further seasons in the same sites and for the sites where the study will start with release of the beetles. That means that for some of the sites there will be six years of data and in others three years of data to achieve the three objectives of the study. The statistical methodology is designed to achieve the following objectives: 1) to establish the rate of dispersion of *Diorhabda*. 2) To identify the biotic and abiotic factors that affects the rate and direction of the dispersion. 3) To predict the rate and dominant direction of *Diorhabda* dispersion in potential release areas.

Tasks, Objectives, Schedules, and Estimated Costs:

Task 1: Development of a Quality Assurance Project Plan (QAPP) (Month 1 thru Month 3)

Estimated Cost: Federal $5,000; Nonfederal $0; Total $5,000

Objective: Develop a QAPP to be approved by EPA

Deliverables:
Quality Assurance Project Plan - A QAPP must be submitted to EPA, through the TSSWCB, 60 days prior to the initiation of any sampling.

Task 2: Data collection and analysis for estimation of dispersion rate and identification of factors affecting the dispersion of *Diorhabda*: (Month 1 thru Month 24)

Estimated Cost: Federal $87,816; Nonfederal $0; Total $87,816

Figure 1 represents the expected shape of the beetle dispersion in most areas. The center of the ellipses represents the release point and each of the three concentric ellipses represents a growing season. The area colonized by the beetle in the first season is represented for the area of the central ellipse, the areas colonized by the insect in the following seasons will be represented by the area between consecutive ellipses. Shapes of the ellipses are expected to be closely associated with the spatial distribution of salt cedar. In areas where the dispersion of salt cedar has a defined longitudinal shape, like along a stream, the ellipses would be very elongated and after the second or third season the sampling will be probably restricted to the direction of the ellipse main axis.

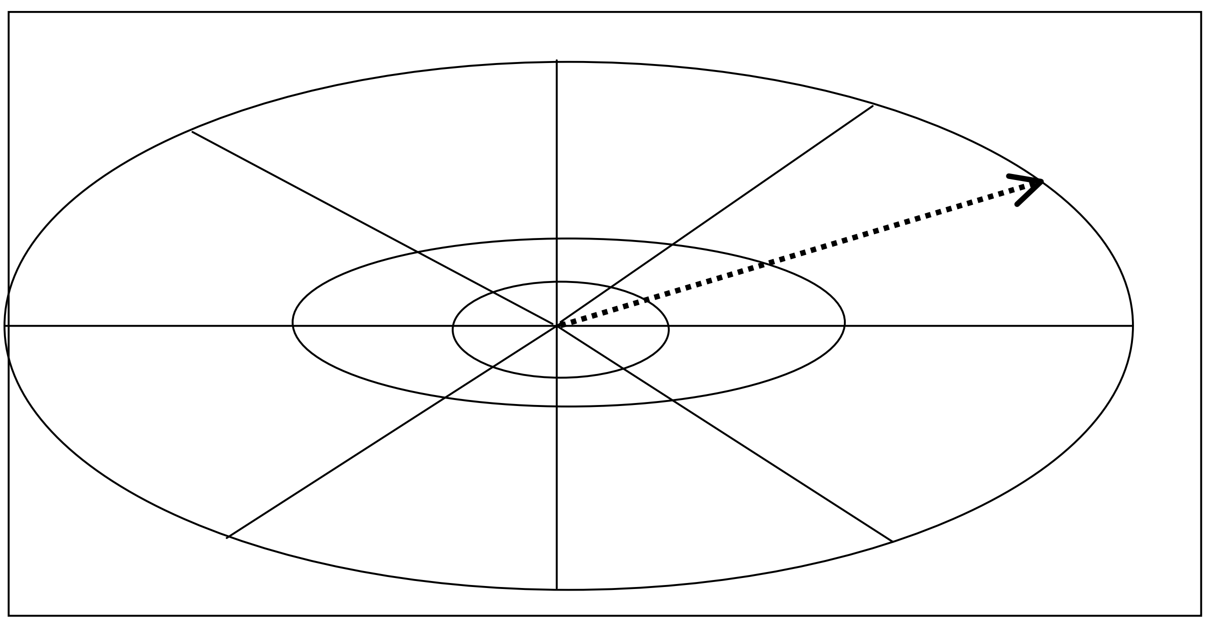

Figure 1. Sampling scheme for the study of *Diorhabda elongata* dispersion

For the sampling design it will be assumed that the beetle dispersion will take place in all directions from the release point. The 360o around the release point are partitioned in eight sections of 45o each as shown in Fig. 1. Sampling for *Diorhabda* population, Saltcedar damage, and other variables associated with the tree and with micrometeorological conditions under the canopy will be measured in every 45o section. The sampling intensity will be varying for the different variables. Sample size for the insect population will be calculated from data available from the three-season sampling in the old sites following an adaptation of the method that Radin and Drummond (1994) used to study dispersion of the cucumber beetle. Key factors on the estimation of sample size will be density and homogeneity of saltcedar distribution, uniformity of *Diorhabda* adult distribution, mean and variance of the adults counted, and degree of precision assumed. Sample size calculations based in the presampling done in old sites will basically describe the number of sampling points needed for a unit of radial distance, this will work to get a good sample size without knowing the are that will be colonized by the beetle in a growing season. Sample points will be arranged along the doted line shown in Figure 1. The sample unit will be a saltcedar tree. It is possible that definition of the sample unit be escalated up to a set of trees or escalated down to a portion of the tree. Severity of the tree damage caused by *Diorhabda* will be measured in each sample point where the adult beetles are counted. The number of sample points will grow through the growing season as the insect increases its colonized area. The temporal intensity of the sampling will be dictated by the length of the beetle life cycle, adult beetle counting and assessment of tree damage will be done at every *Diorhabda* generation, measurement of tree damage can be done in percentage or evaluating it with a nominal scale for damage severity. Other variables that will be measured at every sampling point and at every beetle generation are distance to the release point, tree density, tree homogeneity, and tree vigor.

Sampling of micrometeorological variables such as temperature, relative humidity and radiation in a season will be dictated by availability of equipment and uniformity of vegetation, it would be good to have at least three sampling points along the sampling transect in a growing season. Weather variables such as wind velocity, wind direction, and precipitation will be recorded by a portable weather station on the site.

To calculate the area colonized by *Diorhabda* in one season it is necessary to define a dispersion boundary in each season. It could be established assuming that the insect stopped advancing at the end of the season when the tree damage and /or the adult count start decreasing below adopted thresholds. Another more objective way to establish the location of the season boundary is calculating the probability of getting values of tree damage lower than the threshold adopted, and building a graph like the one in Figure 2, where $P(x \leq t)$ is the probability of tree damage (x) being lower than or equal to the adopted threshold t. The best probability distribution will be chosen after having the data. The distance is measured from the release point. ‘d’ is the location of the season boundary. This probabilistic approach requires an additional sampling along the edge of the colonized area at the end of the season when it is apparent that the beetles have stopped advancing.

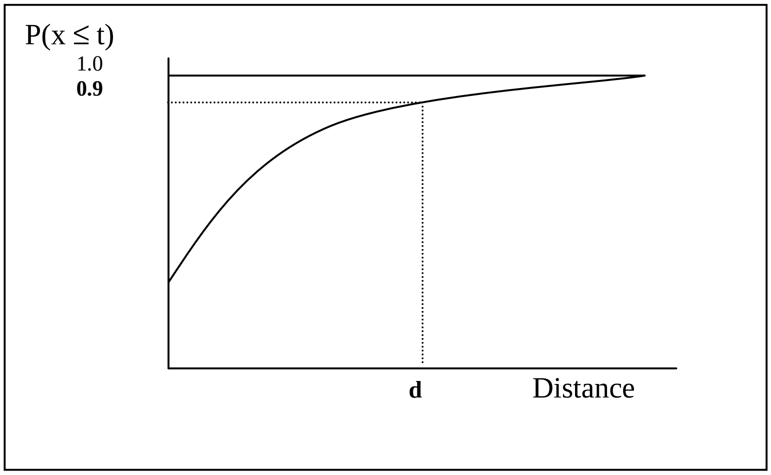

Figure 2. Estimation of colonization boundary in a season.

The data collected from a season will allow the calculation of area colonized and defoliated during the growing season. Non linear models (Neter and Wasserman, 1989) like the ones shown in Figure 3 for defoliation or adult number at a given distance ‘i’ from the release point will lead to find out the dominant directions of dispersion in a season.

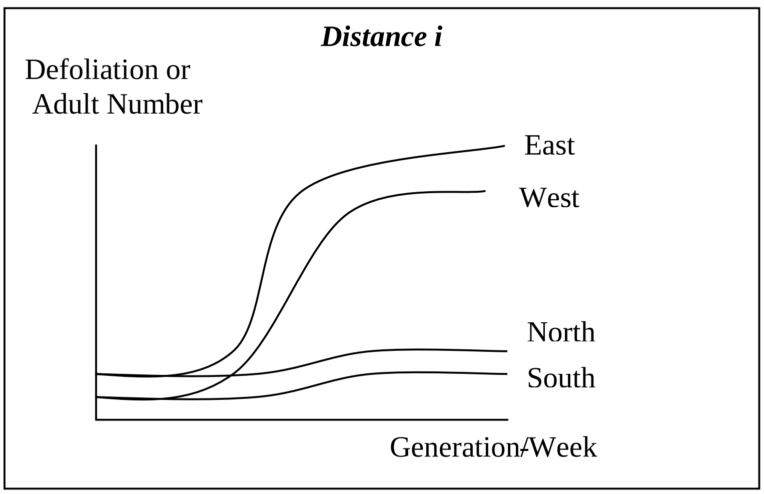

Figure 3. Dispersion of *Diorhabda* in one season.

From models like the ones in Figure 3 developed for several distances the rate of dispersal within the season can be estimated. Correlation analysis and regression analysis of the response variables severity of defoliation and number of adults with saltcedar variables and micrometeorological variables will allow identification of factors that affect the direction and rate of dispersion of *Diorhabda.*

Figure 4 shows the type of analysis that will be performed for studying long term dispersion of *Diorhabda.* Non-linear models will be fitted to the accumulated defoliated area as a function of growing season. After three years of data collection, six seasons will be available at the old release sites. After the six years there may be indication of whether the colonization rate will continue increasing or become constant. Another possibility is that the colonization area could be restricted by the saltcedar area and the colonization of the total area could occur in six or less seasons in some release sites.

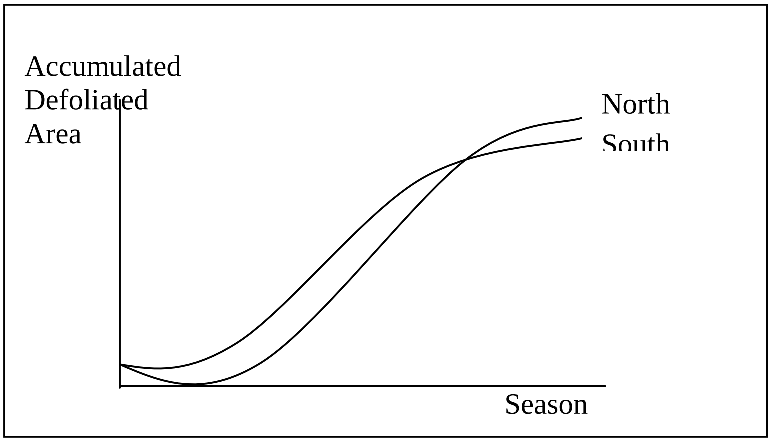

Figure 4. Long term dispersion of *Diorhabda*

Combining data from all the seasons in a site a long-term dispersion rate can be estimated, and additional tree, micrometeorology, and weather data can be analyzed to identify factors that affect rate and direction of *Diorhabda* dispersion.

Between sites analysis will help to identify critical factors that affect the dispersion and defoliation of saltcedar by *Diorhabda elongata.*

Deliverables:
Quarterly Reports
Copy of any publications generated through the project

Task 3: Prediction of rate and dominant direction of *Diorhabda* dispersion in potential release areas (Month 24 thru Month 36)

Estimated Cost: Federal $43,908; NonFederal $0; Total $43,908

Objective: Develop a model that will predict the rate and direction that leaf beetles will disperse after a release to aid in the development of future implementation strategies.

After identifying the critical biotic and abiotic variables that drive the dispersion of *Diorhabda,* and the defoliation of saltcedar, it is possible to predict how the defoliation will continue in future seasons at a site where there has been beetle release, or the rate and direction of defoliation can be predicted in new areas of good potential for *Diorhabda* release.

A combination of two methods will be used for this spatial modeling of Salt Cedar defoliation by *Diorhabda*. The methods are **spatial regression** and **cokriging** (Schabenberger and Pierce, 2002).

Spatial regression and cokriging are multiple spatial prediction methods where the mean of a primary attribute, in this case saltcedar defoliation, is modeled as a function of secondary attributes, in this case variables as *Diorhabda* population, saltcedar density and distribution, micrometeorological and weather variables and predation on parasitization. The general model in which the methods is based is as follows:

$$\mathbf{Z1(s) = \beta 0 + \beta 1Z2(s) + \beta 2Z3(s) + \ldots + \delta(s)}$$

Where Z1(s) is the prediction of saltcedar defoliation in point s; $\beta 0$, $\beta 1$ and $\beta 2$ are the parameters of the model; Z2(s) and Z3(s) are the secondary attributes at point s; and $\delta(s)$ is the error term.

The nature of **$\delta(s)$** is what establishes the essential difference between these methods for spatial distribution estimation and conventional linear multiple regression. $\delta(s)$ contains the spatial structure of the area where the defoliation prediction will be done. In the case of spatial regression $\delta(s)$ is made up of only the spatial structure of the primary attribute. In cokriging, $\delta(s)$ contains the spatial variability of the primary attribute, the spatial variability of every secondary attribute included in the model, and the spatial covariability of the primary attribute with each of the secondary attributes. Spatial variability is estimated with semivariograms, spatial covariability is estimated with cosemivariograms. Variograms and semivariograms are modeled in a separate procedure using the basic principle that close by points have higher similarity than points separated by larger distances. Exponential, gaussian and spherical are some of the models commonly used for variograms or covariograms.

Sites where the spatial model will be performed need to be sampled for the factors identified in Task 2. Spatial models can be validated in sites where *Diorhabda* distribution has been studied in the field. The spatial modeling and generation of surfaces from the predictions will be done with a combination of software: ArcGIS, SAS, and S+SpatialStats.

Deliverables:
Verified model of leaf beetle dispersion
Final report

Measures of Success:

- To develop a model that can be used as a planning and implementation tool for long-term control of saltcedar.
- To demonstrate that the model developed through the project accurately predicts the dispersal of the *Diorhabda* beetles and the associated defoliation of saltcedar from point release sites, during the 3 years following releases made during 2003, with 75% accuracy both spatially and temporally
- Increase public perception and awareness of the use of biological controls

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Project 04-15 ***Leaf Beetle Dispersion Modeling***

VIII. Three Year Budget

	Federal	Non-Federal Match	Total
1. Personnel			
2. Fringe Benefits			
3. Travel			
4. Equipment			
5. Supplies			
6. Contractual	$136,724	$0	$136,724
7. Construction			
8. Other			
9. Total Direct Costs	$136,724	$0	$136,724
10. Indirect Costs			
11. Total Project Costs	$136,724	$0	$136,724

*See Budget Justification, next page.