Proceedings of the Eighth International Symposium on Biological Control of Weeds
2-7 February 1992, Lincoln University, Canterbury, New Zealand.
Delfosse, E.S. and R.R. Scott (eds.). DSIR/CSIRO, Melbourne, pp. 695-9 (1995).

Use of Geographic Information Systems (GIS) Distance Measures in Managed Dispersal of *Apion fuscirostre* for Control of Scotch Broom (*Cytisus scoparius*)

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Scotch broom (*Cytisus scoparius*) is widespread in Oregon west of the Cascade Mountains, infesting an area of >65,000 km^2. Throughout much of this range, Scotch broom excludes desirable forages in pastures, interferes with reforestation, and is regarded as a serious problem weed. *Apion fuscirostre* was first released in Oregon for control of broom in 1983. By 1987, populations at the original site and at the sites of other releases made in 1985 and 1986 had increased enough that collecting for managed dispersal commenced. The goal of this effort is realizing distribution of *A. fuscirostre* throughout the range of broom in Oregon. Early in 1991 the cumulative distribution of releases was mapped using a raster-based geographic information system. Distribution was somewhat uneven, with large areas where the distance to the nearest known release of *Apion* was >50 km. To prioritize areas for future releases, a distance measure was calculated and mapped which quantified distance to releases, and the mean distance to nearest known release was also calculated. Our paper explains the application of the distance measure to release data, discusses its utility in managed dispersal of *A. fuscirostre*, and provides maps and figures showing distribution of Scotch broom and this biological control agent.

Introduction

The Oregon Department of Agriculture (ODA) Noxious Weed Control Program (NWCP), the unit responsible for biological weed control in Oregon, has a policy of promoting the distribution and establishment of available agents for biological control over the entire range of host weeds as quickly as possible. This policy was first adopted for distribution of agents for control of tansy ragwort (*Senecio jacobaea* L.; Asteraceae) in Oregon (Isaacson 1978). Later it was applied to other target weed species, and Hawkes (1985) argued that well-organized distribution of agents was a requirement of an efficient biological control program. The policy has now been refined so that the status of each agent species is monitored with respect to availability and need for further distribution (Coombs *et al.* 1992).

The NWCP now monitors 42 species of classical biological control agents for control of 20 species of weeds (Coombs *et al.* 1992). Most of the agent species are not yet established throughout the range of their target hosts. Management of these agents requires location-specific information on both the target and the agent, and this information usually has been collected and organized using paper forms for recording locations of releases of biological control agents. Maps of target weeds and control agents typically has been by the use of "high-lighters" on small-scale base maps.

For the 1991 field season, it was decided that a pilot project involving the use of a Geographic Information System (GIS) would be evaluated as a tool for the collection, analysis and summarization of data on status of one weed control agent. Records of releases of *Apion fuscirostre* (Fab.)(Coleoptera: Curculionidae), a classical biological control agent introduced against Scotch broom (*Cytisus scoparius* L..; Leguminosae) in Oregon, were

analyzed. This paper reports the results of the evaluation.

Scotch broom is distributed throughout Oregon west of the Cascade Mountains (Fig. 1). Both the extent and the density of infestations seems to have increased with road-building and timber harvesting after the use of herbicides was curtailed in the mid-1980s on federal lands, about half of the area of western Oregon. There are areas where broom has become the dominant species over entire clearcut-harvested forest patches.

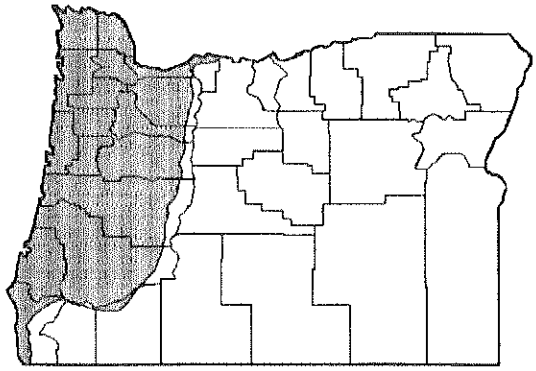

Figure 1. The distribution of Scotch broom (*Cytisus scoparius*) in Western Oregon, 1991.

A. fuscirostre was first released in Oregon for control of broom in 1983 at a site near Salem, Oregon. This seed-feeding weevil has survived and increased in numbers enough at this, and at sites of other earlier releases, so that they have been used as sources for collection and redistribution to other areas in western Oregon. The success of establishment of *Apion* releases has been high, and in an informal 1991 survey weevils were found to have dispersed 10-13 km from the original release site. Adults are easily collected and processed for release into new areas.

Methods and Materials

Release locations of *A. fuscirostre* for each year, starting in 1983, were entered into a DOS-based microcomputer spreadsheet template of western Oregon townships. This template represents an area of Oregon west of the Cascade Mountains where Scotch broom is found, and is 50 rows and 27 columns of cells 9.6 x 9.6 km (6 x 6 miles) in dimension. The completed templates were exported and saved as printer files.

These files were converted to GIS files using an importing routine in IDRISI, a grid-based GIS (Eastman 1990). Files were combined to create a series representing cumulative distributions of weevil releases by year and then processed with a distance-calculating routine. The distance routine created files within which each template cell represents a value equal to the calculated distance to the nearest cell with a recorded *A. fuscirostre* release (Fig. 2).

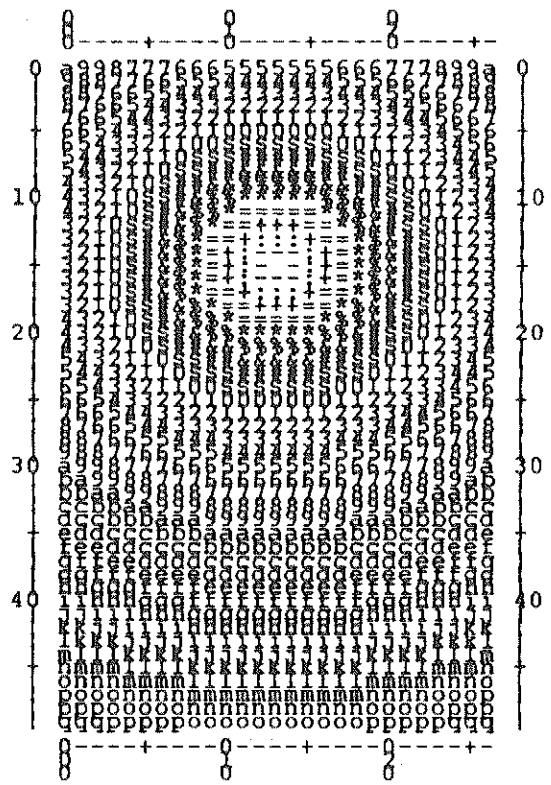

Figure 2. A 50-row by 27-column template representing distance to the nearest cell with a recorded release for 1983, the site of the original *Apion fuscirostre* introduction.

The current distribution of Scotch broom in Oregon was also entered into the spreadsheet template and exported and saved as a printer file. After importation into IDRISI, the 50 x 27 template existed as a binary file with "one" representing a cell (or township) with Scotch

broom, and "zero" representing cells where there was no Scotch broom (see Figure 3). Seven hundred fifty-two cells describe the distribution of broom, a total area of about 65,000 km^2.

Mean distances to the nearest release for each year were determined by multiplying the binary broom template, or layer, by the distance layers for each year, totaling cell values for the resulting layer and dividing by the number of Scotch broom-containing cells. In addition to the mean distance to nearest release, the maximum distance and the standard deviation of the mean distance were also calculated. A map of distances to releases for 1983 was also generated (Fig. 4).

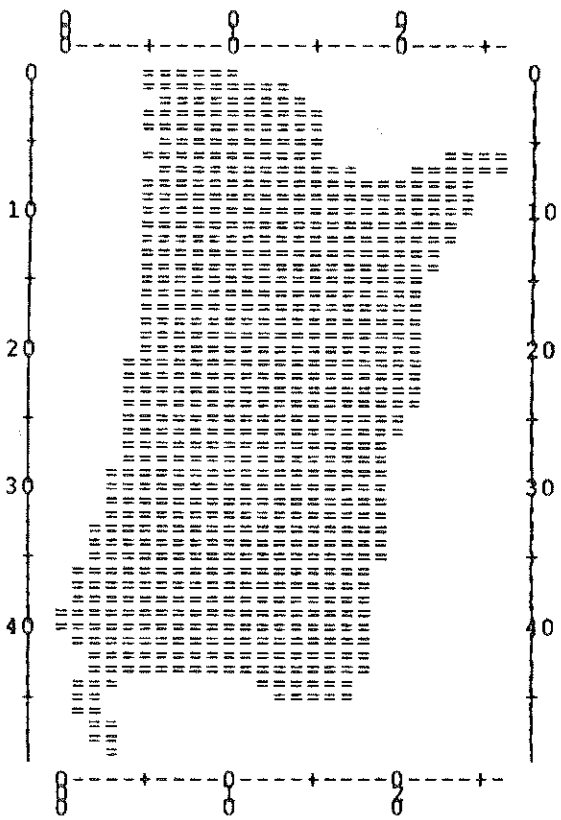

Figure 3. A digitized 50-row by 27-column template showing distance of Scotch broom (*Cytisus scoparius*) in western Oregon. The "=" symbols represent cells or townships with broom present.

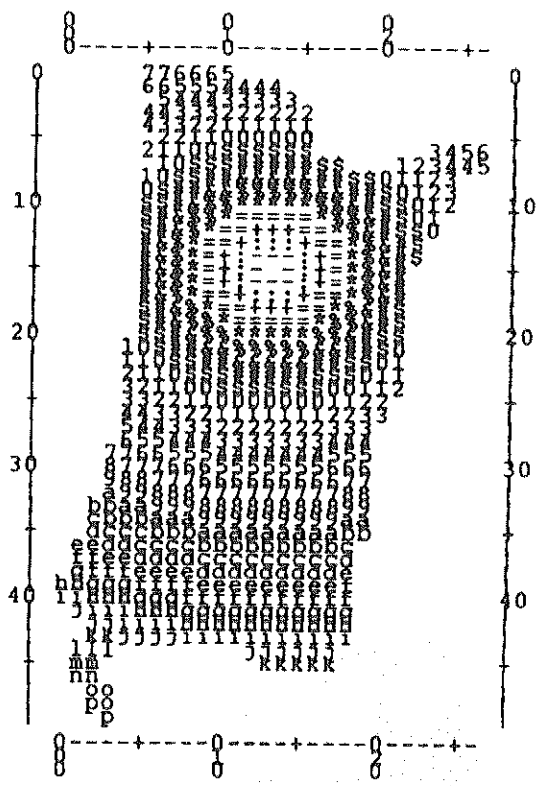

Figure 4. A map showing distance to the nearest *Apion fuscirostre* release in 1983, created by multiplication of GIS layers represented in Figs. 2 and 3.

Using the distance measures developed from *A. fuscirostre* releases through 1990, a map was created by reclassifying the 1990 distance values to identify priority areas for releases for the 1991 field season. Townships nearest those with prior releases were assigned to low priority classes, and those furthest from earlier releases were placed in high priority classes (Fig. 5).

Results and Discussion

A summary of the results of distance analyses by year is presented in Table 1. As expected, mean distance to the nearest release decreases each year releases of *A. fuscirostre* were made. In the years 1987 through 1990, however, when distribution began in earnest, there were minimal decreases in mean distance. This is true also of the standard deviation of the mean distance, a measure of the "evenness" of the cumulative distribution of *Apion*. Through this

period, the maximum distance to the nearest release did not decrease at all.

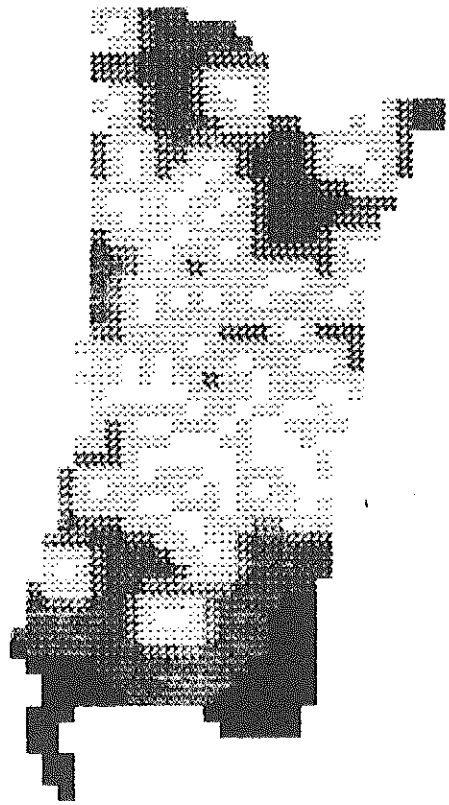

Figure 5. A map of priority areas for releases of *Apion fuscirostre* for the 1991 season. Darker areas represent high priority areas.

Patterns in the maps of distribution of *A. fuscirostre* and distances to releases were visually evident in map output that are not apparent in statistical summaries. One example was the cluster of large distance values seen in the lower right portion of Fig. 5. The broom distribution for this area was not well delimited, and in constructing the binary mask, we may have included non-broom townships. The need for additional survey was apparent, and in the spring of 1991 our surveys determined broom was distributed throughout most of the area in question. Thus the mapping data of the host plant with the GIS aided in identification and location of required field work.

Table 1. A summary of distance measures for releases of *Apion fuscirostre* in Oregon, 1983-91.

Year	No. of Releases	Mean Distance to Release (km)	Std. Dev. of Mean	Maximum Distance to Release (km)
1983	1	74.7	87.7	336.0
1984	0	74.7	87.7	336.0
1985	1	69.3	87.3	336.0
1986	8	25.5	30.0	144.0
1987	32	18.4	23.8	124.8
1988	18	14.5	20.0	124.8
1989	23	13.6	19.7	124.8
1990	92	11.4	18.4	124.8
1991	159	7.0	9.3	57.6

The data in a GIS format can be easily used in simulations of different distribution strategies. We examined two strategies for demonstration. In one case we assumed no further releases of *Apion* would be made and projected distance measures for 1997 assuming only natural dispersal of 1.6 km/yr. In another case, we targeted 10 townships for releases in 1992 and calculated distance measures. In the former case the mean distance to nearest release was 2.21 km with a standard deviation of 6.14, and in the latter these values were 2.48 and 5.61, respectively. This suggests that 10 well-placed releases is roughly the equivalent of 6 yrs natural dispersal for *Apion*.

These applications of GIS to managed dispersal have been relatively inexpensive and require minimal investments in software and hardware. The specific system used here, IDRISI, is compatible with common spreadsheet and database programs that are used by NWCP for routine data collection, management and analysis, and nicely complements current computing capability. The evaluation of use of GIS to increase efficiency of redistribution of *Apion fuscirostre* has been judged a success, and it will be used for other biological control projects in the future.

Acknowledgment

This work was supported in part by contracts with the U.S. Department of Interior Bureau of Land Management and the U.S. Department of Agriculture Forest Service. The financial

support and the assistance of many personnel in both these agencies is gratefully acknowledged. We thank Sherry Kudna for her help in typing and preparing the manuscript.

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