Detecting alien plant species early in the invasion process: a sampling strategy for the detection of *Chromolaena odorata* (L.)
R.M.King and H.Rob. (Siam weed)

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**Summary** Once a potentially serious weed species has been identified in Australia, it is essential to determine the full extent of its occurrence. This information is required for decision-making regarding the most appropriate response to the incursion. It is also necessary for planning purposes should eradication or containment be attempted. The extent of the surveillance campaign is generally resource limited. Accordingly, a sampling strategy that maximises the chance of detecting the weed must be implemented. An eradication program was initiated in 1994 to manage an outbreak of *Chromolaena odorata* (L.) R.M.King & H.Rob. (Siam weed) in North Queensland. In this paper, data from a survey conducted in 1994 are explored and used to develop a sampling strategy that could have been employed from that point onward. The characteristics of the survey data and some of the limitations that prevent the development of more effective sampling techniques are discussed. Improvements in data collection are suggested that would facilitate the construction of more detailed and meaningful survey methods that could be applied to *C. odorata* and other species.

**Keywords** *Chromolaena odorata*, survey design.

**INTRODUCTION**

Generally, when a serious new weed has been identified in Australia it has been necessary to determine the spatial extent of its distribution. This information is required for decision-making about the management of the incursion. It is also necessary for planning purposes should eradication or containment be attempted. The availability of information required to make these decisions is often limiting. Regardless, once a decision has been made to eradicate an alien plant species from a region, the organisation that carries out the eradication usually conducts a survey of the area that the plant is expected to inhabit.

A weed that has recently invaded a catchment or region is, in all likelihood, quite scarce. The lack of data on the weed often limits the analyst’s ability to design a survey that will assist in determining its distribution. In this situation traditional survey designs are redundant, as their aim is to ensure that a representative survey is made of the plant community as a whole. By default, such surveys are unlikely to detect a relatively infrequent plant. An alternative approach is required, whereby the discovery of a weed in an area results in an intensive survey of the surrounding regions. In this paper an example of how an iterative survey procedure might be implemented is demonstrated, using data collected from an existing survey of *Chromolaena odorata* (L.) R.M.King & H.Rob. (Siam weed) in the Tully region of North Queensland. Aspects of the survey design are discussed and suggestions made to facilitate the construction of a survey, based on plant population dynamics that may increase the likelihood of detecting an alien plant species.

**SURVEY DESIGN**

McFadyen (1989) warned that tropical regions in Australia were at risk of invasion by *C. odorata*. When this weed was discovered in 1994 near the Tully River in North Queensland, an eradication program was commenced. Initial searches were conducted along the Tully River and associated tributaries. If *C. odorata* was discovered, its location, plant maturity and habitat (open, scrub, creek, regrowth, forest or hill) were recorded. Absence, and therefore the search pattern *per se*, was not documented. Surveys of the Cardwell and South Johnstone Shires have continued since 1994, with recordings made of the years when plants were found in these areas.

In this paper, simple comparisons are drawn between the results of the initial survey and surveys conducted after 1994, to highlight changes that could be made to regional surveys with the aim of improving the chance of locating *C. odorata* in the future. We use the data from the 1994 survey iteratively to design surveys for *C. odorata* in the existing region. The application of this design is then tested on the data collected after 1994.

**SURVEY RESULTS**

In 1994, 476 sites with *C. odorata* were found in the Tully and South Johnstone areas. Over the next eight years an additional 321 sites were identified, although the year of discovery was not recorded in 59 cases. The
area that *C. odorata* was known to inhabit in 1994 was notably smaller than its known distribution in 2002 (Figure 1). Over the entire dataset, the average distance from one plant to its nearest neighbour was 281 m. However, this distribution was highly skewed and the nearest neighbour in one instance was 4 km away. In 1994 the mean neighbour distance was just 165 m and less skewed, whereas only 2% of plants were more than 750 m from their nearest neighbour (Figure 2a). The weeds discovered after 1994 were more dispersed, with a mean neighbour distance of 455 m. Sixteen percent of these plants were found 750 m or more from their nearest neighbour (Figure 2b).

The mean distance from a river or major creek was 432 m for the total population of *C. odorata*, but this distribution was also highly skewed. As in the nearest neighbour analysis, *C. odorata* found in 1994 were on average 162 m from a river or major creek and the distribution was comparatively normal relative to the distribution of plants discovered after 1994 (Figures 2c and 2d). Plants found after 1994 were on average 831 m from a watercourse, but with a highly skewed distribution. Some plants were found nearly 5 km from a major river system on floodplain country near the coast.

In the 1994 survey, 223 of the 476 plants (46.8%) were mature, the remainder being seedlings. In the post 1994 survey, 199 of the 321 (62.0%) plants were mature. As the age of *C. odorata* plants was not determined (apart from the distinction made between seedlings and mature individuals), it is impossible to build a temporal picture of the invasion process. Remaining information captured in the survey or derived from a geographic information system, including habitat and topography, yielded little information that could be used to design a survey.

Figure 1. Location of *Chromolaena odorata* discovered in 1994 (Δ) and after 1994 (○) in the Cardwell and South Johnstone Shires, North Queensland.
A FRAMEWORK FOR WEED SURVEYS

There were two major differences between the first and later surveys. Initially, weeds were perceived to be closer to both watercourses and each other than they were in later surveys. This suggests the initial search was limited in its scope. However, information relating to the area searched was not available and it is impossible to test this hypothesis.

Most statistical concepts revolve around analysing the mean and the variance, but the invasion front is actually a data extreme. If a survey is going to find the invasion front, then the extremes should be considered as the boundary to the area surveyed. In the 1994 neighbour analysis, 2% of weeds were 1 km or more from their nearest neighbour. On this basis, if a weed is found, at least the surrounding 1 km should be searched. Alternatively, if the weed is found near a watercourse it is possible that the watercourse could act as a dispersal medium, and should therefore be searched as well. This process was actually carried out by the Queensland Department of Natural Resources and Mines. In 1994, only 1.4% of *C. odorata* sites were more than 1 km from a watercourse. These two findings could then form the basis for a revised survey. First, if a weed is found, the surrounding 1 km should be searched in every direction. Second, if the weed is within 1 km of a river or creek then that river system should also be searched. This survey design, if implemented, would have uncovered 96% of all *C. odorata* sites found after 1994 and covered an area of approximately 260 km². The remaining 4% of weed sites were on the floodplain areas south of the Tully area. This 4% is arguably the most difficult component to find.

It is difficult to design a more elaborate survey using the data in its current form. However, the quality of the survey design may be substantially enhanced if several issues are addressed. First, the lack of absence

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**Figure 2.** Frequency distribution of distance to (a) the nearest *Chromolaena odorata* individual for those plants found in 1994; (b) the nearest *C. odorata* individual for those plants found after 1994; (c) a creek or river for those plants found in 1994; and (d) a creek or river for those plants found after 1994.
data is critical, as it precludes the chance to thoroughly review the search protocol implemented in 1994 or any time thereafter. For example, if the area surveyed is not recorded, it becomes difficult either to assess the frequency of occurrence in different habitats or to assess the economic cost of the search program per unit area of land surveyed. With absence data, it may eventually be possible to reduce the extent of the survey in areas the weed is unlikely to inhabit. However, the decision to scale back the scope of the survey should be adequately justified. Second, the lack of absence data precludes the construction of more sophisticated rule-based or logistic models that could be used to design future surveys in the region. This is, in part, the reason for the relatively simplistic analysis presented here.

The potential to determine the age of plants should also be explored. If plant age were known, a temporal process could be introduced into the evaluation of the invasion process (i.e. the invasion front could be mapped and modelled both temporally and spatially). With this information various management scenarios, ranging from no management to full control, could be simulated with some precision and used to make informed policy decisions regarding weed management.

During the early stages of the invasion process an alien species represents a very small proportion of the plant community within a catchment and many initial finds are due to chance. However, the implementation of a random survey stratified across habitats within a certain distance of the initial find may be worthwhile, as initial assumptions regarding the specific habitat requirements of the weed are likely to be premature. Importantly, the absence of a weed from a specific habitat early in the invasion process does not mean it cannot invade that area in future. The adoption of the random survey approach suggested above may have helped find the 4% of weeds missed by the survey model described previously. Of course, the extent of any survey is dependent on the resources available and the longer the weed has been established, the more substantial the survey required. The likelihood of success of an eradication program is thought to be dependent on the size of the area invaded by a weed (Rejmánek and Pitcairn 2002), although if the location of the weed is known with some certainty it can be eradicated from relatively large areas (Dodd and Randall 2002). In the case of C. odorata, however, locating the target weed is one of the biggest problems. Shafii et al. (2003) developed a predictive model to assist in locating yellow star thistle (Centaurea solstitialis L.) using landscape characteristics combined with information on the incidence of this weed. In the present study the incidence (which includes absence) of C. odorata was not recorded, so predictive models could not be developed.

A survey that has a reasonable chance of finding a weed can be designed by using the extremes of the initial data on species occurrence to determine the aerial extent of the survey, in conjunction with a consideration of the likely dispersal mechanisms, directions and distances. Detailed information on the survey should be recorded in order to facilitate the production of models that can assist in refining the survey protocol. By adopting such an approach, the amount of resources required to locate and control a weed can be minimised.

The objective of the methods presented here is to design a survey that maximises the chance of locating an alien plant species within a confined catchment or general area. With human-assisted dispersal, however, the weed might escape this general area. C. odorata was recently discovered near Townsville, some 250 km south of Tully and South Johnstone and the methods discussed herein do not cope with such a dramatic shift in the area occupied by the weed. However, they could be employed to design a survey for the infestation near Townsville.

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REFERENCES

