

Effective Landscape Scale Management of *Cirsium arvense* (Canada Thistle) Utilizing Biological Control

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Abstract

The stem mining weevil, *Ceutorhynchus litura* Fabricius, the gall forming fly, *Urophora cardui* L., and the seedhead weevil, *Larinus planus* Fabricius, were established as biological control agents on an 1800 hectare multiple-habitat wildlife refuge in northwestern Oregon in the mid-1990s. At the time, Canada thistle was the most wide spread, aggressive, and difficult weed to control and was being contained only by an extensive herbicide control program. A ten-year monitoring program for these natural enemies (1997 through 2007) showed a significant decline in Canada thistle (*Cirsium arvense* (L.) Scop.) plant abundance along with a measurable decrease in individual plant size and flowering. A few small stands of Canada thistle still remain that seem resistant to biological control but the need for direct control using herbicide has been discontinued as it is felt that the few scattered remaining populations are no longer an ecological threat and instead serve an important role in acting as a permanent reservoir for the biocontrol agents.

Introduction

The spiny, perennial weed *Cirsium arvense* (L.) Scop., commonly known as Canada thistle, California thistle, creeping thistle and European thistle, is of Eurasian origin and is now established in over 39 countries (Holm et al., 1979). In North America, Canada thistle can be found in a broad band across the entire northern half of the United States and adjacent southern Canada and is the most frequently cited problem weed in surveys and weed lists for North America (Skinner et al., 2000). The plant spreads readily, both by seeds and through root fragments during cultivation. It is clonal and most patches, therefore, are formed by a single individual plant with many aerial shoots, but are interconnected by an extensive lateral root system that make it very difficult to control with herbicides (Donald, 1994; Moore, 1975; Nadeau and Born, 1989).

Up to 1995, it was generally considered that

the impact of the approved agents for Canada thistle was minimal (Julien and Griffiths, 1998) and they were providing little or no effective control (Piper and Andreas, 1995; McClay et al., 2002). However, a review of the earlier studies indicate that these conclusions were mostly based on either controlled studies using potted plants or small research plots in which only the direct impact of the insect feeding was monitored for such short durations that they would not have detected long-term, cumulative stress that might compromise the extensive root system. A long-term biological control program under field conditions was needed where the combined attack of these agents over a long period of time might stress the Canada thistle population enough that desirable plants could replace them.

In 1995, the opportunity for a long-term study presented itself in the Ladd Marsh Wildlife Management Area and Refuge (= Refuge) near La Grande, Oregon, USA. The Refuge provided a stable landscape scale area for a long-term study where land

uses, management practices, and ownerships would not change within the ten years or longer required for population changes to become obvious. In 1995, a cooperative effort was undertaken between the Oregon Department of Fish and Wildlife, Ladd Marsh Wildlife Management Area and Refuge, the Oregon Department of Agriculture, and the US Forest Service's Rocky Mountain Research Station's Bozeman, Montana biological control program, to study a complex of biocontrol agents of Canada thistle on the Refuge, and conduct a long-term monitoring program to determine their effectiveness.

Target area

Ladd Marsh Wildlife Management Area and Refuge lies in Union County in northwestern Oregon at an elevation of approximately 780 meters (8 kilometers) east of the community of La Grande. In 1995, the Refuge consisted of approximately 1800 hectares of land (it has since expanded considerably) that had originally been a natural marsh, but extensive draining during historic times had converted much of it to agriculture. When cultivation stopped and extensive earth moving began for dam and reservoir construction for waterfowl a major surge of Canada thistle occurred. For the first ten years after its founding, Refuge managers considered Canada thistle the most severe threat to their goal of returning the land to a natural environment suitable for sustaining wildlife and conducted an extensive herbicide spray program in an attempt at its control.

Agents utilized

Urophora cardui L. [Diptera: Tephritidae].

This gall-forming fly had been released in 1993 at two locations in the Refuge using galls obtained from the Willamette Valley in western Oregon. Two years later, in 1995, it was confirmed that the fly had established and naturally dispersed 100 to 200 meters. Two more redistributions using galls from this local population were made in 1996 to far sides of the Refuge.

Ceutorhynchus litura (= *Hadroplontus litura*) (Fabricius) [Coleoptera: Curculionidae].

In 1995, this stem mining weevil was well established (Julien and Griffiths, 1998) in the lower elevation, warmer coastal environment of western Oregon, but despite earlier releases, was not found established at the start of this study in Ladd Marsh in eastern Oregon. We therefore used a cold-adapted strain established in Gallatin Valley, Montana (Rees, 1990). Two collections of newly emerged adults were obtained from the Gallatin Valley in May 1995 and released at two sites in Ladd Marsh. By 1996, both populations established. Redistributions to two other points within the Refuge made in 1997 and three additional redistributions in 1998.

Larinus planus Fabricius [Coleoptera: Curculionidae].

A seedhead feeding weevil was found already established at the beginning of the study. Initially we believed it to be *Rhinocyllus conicus* Frölich, an agent of musk thistle known to be established in the area, however, on rearing we found it to be a similar seedhead attacking weevil, *Larinus planus*. *L. planus* is not an approved biological control agent in North America, i.e. one that has been deliberately introduced after extensive testing, but since it was already present we included it in our monitoring. It has a single generation per year with adults emerging in spring to feed on plant foliage. When flower buds are forming, the female inserts an egg into the bud and the growing larva mines into the flower (Wheeler and Whitehead, 1985).

Methods and Materials

Permanent monitoring plots

A grid was laid over an aerial photograph of the Refuge and 50 points randomly located. After on-the-ground visits, 10 locations were discarded because they fell in open water or cultivated land.

At the remaining 40 locations, an open area of land containing a representative population of Canada thistle was marked with a white fiber glass fence post to use as a permanent vegetative sample site. After establishment, the plots were visited in 1995 and 1996 but limited monitoring conducted while we concentrated on releasing and redistributing the insects. Intensive monitoring began in 1997 and the plots were then visited regularly through 2007.

Sampling Canada thistle

Sampling was conducted in late fall after plant growth and insect activity had terminated, using four quadrats encompassed by a one-fourth meter square metal frame dropped randomly onto the ground within a three meter radius of the central stake.

Density

The total number of all Canada thistle plants in each quadrat was counted and the four samples combined together to give a total number of plants in one square meter at each sample site.

Height

The mean canopy top height was determined by selecting the five tallest plants in each quadrat and measuring their height. The canopy top height for each sample site was therefore based on the 20 tallest plants.

Insect sampling

We did not measure the actual number of gall flies but used the number of galls as an indication of their population. The galls in each quadrat were recorded as either being terminal galls that had formed at the growing tip of the elongating shoot, or as lateral galls forming along the sides of the shoot on the leaves' petioles. Five random plants in each quadrat were selected and dissected for evidence of attack by *C. litura*. The frass-filled, and discolored empty mines in the plants were still clearly visible in the dead plant stalks in late fall and the lengths of these mines were used as an indicator of the relative abundance of *C. litura* larvae that had formed

them. Finally, at each quadrat, a sample of 25 to 50 seedheads were collected at each sample site, returned to the laboratory, and opened to determine if they had been attacked by *L. planus*.

Results and Discussion

Urophora cardui

The gall fly had been introduced earlier and was well established when this study began. When monitoring began in 1996, it was found that the gall fly had already reached 12 of the studies in 40 locations, and by 2000 had dispersed throughout the entire Refuge. A steady build up in abundance of galls was found through the remainder of this study and seemed to still be increasing when the sampling was terminated in 2007 and averaged 1.2 galls per plant.

Ceutorhynchus litura

C. litura was first released at two locations in 1995, establishment confirmed by 1996 and redistributed to five locations in the Refuge in 1997 and by 2002 the *C. litura* had dispersed to all parts of the Refuge. During this time, percent of the plants attacked by *C. litura* steadily increased until 2003, but since then has leveled off at between 70 and 80%. By the end of this study in 2007, the plant in the Refuge had 33% of its stem length (height of the plant) mined; since a single larva only mines two to three cm of stem, an unusually high population of larvae must have been present.

Larinus planus

The seedhead weevil, *L. planus*, was already well established in the Refuge when the sampling began. However, sampling of seedheads to determine possible impact and whether there was a trend in its population levels was difficult. When we sampled in late fall, the plants had often lost many of their seedheads. However, we obtained good samples on four separate years to obtain an estimate of *L. planus* attack that ranged from 28 to 43%.

Impact on Canada thistle population

Plant density (plants per m²) showed an increase for the first few years until the Canada thistle populations reached 50 plants per square meter. However, a significant decline began after 1999 and the population in 2007 seemed to have stabilized at approximately 8/m² (Fig. 1).

Besides the obvious change in Canada thistle density, we were also able to observe and measure several changes in the plant morphology. Over the period that the Canada thistle population was declining, we noticed a slow decrease in the height of the canopy top (Fig. 2). This decline was caused in part by an increase in the frequency of plants with *U. cardui* terminal galls. When the fly attacked the apical tip of the growing shoot, this formed a large gall which generally stopped the further growth of the plant (Fig. 2). A second cause in stunting was when the *C. litura* larval populations were great enough that their mines inside the stem expanded faster than the rate of shoot elongation. When the mine reached the apical tip, it killed it. Usually the plant then sprouted a number of vertical shoots from lateral buds below the dead tip that formed a shorter plant. The increase in abundance of these shorter, "branched" plants contributed to the overall decline in plant height observed.

Conclusion

The sampling methods used to measure Canada thistle plant density indicated that during the ten years of the study, a progressive decline in Canada thistle occurred. But was the decline real or an artifact of the sampling design? Other personal observations made of the overall population along with a yearly photo record indicate that this decline was real. Other supportive evidence that a major population change took place is the herbicide spray records maintained by the Refuge. Founded in 1985 until we began work there in 1995, the annual Canada thistle spray program required 80 to 100 gallons of herbicide. However, by the end of our study, the thistle population had declined to the point where Canada thistle was no longer a problem but only a minor component of the ecosystem that no longer need to be controlled. After 2004, spraying for Canada thistle was discontinued since, in the

opinion of the Refuge management staff (junior author), the main objective of our biological control program to render the plant no longer ecologically damaging had been met.

We have concluded that the combined impact of the biological control agents, both through direct impact on the plants themselves and through the reduction of over wintering root reserves probably stressed the Canada thistle population enough that the existing complex of grass was able to out-compete the stressed plants. Presently, the Refuge management staff is satisfied with the control obtained and the few small remaining patches or scattered plants of Canada thistle are no longer being sprayed, but accepted as a component of the ecosystem that will form a permanent reservoir for our biological control agents. These few scattered plants and patches are therefore now a key component of a long-term stable plant community.

Acknowledgements

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Figure A

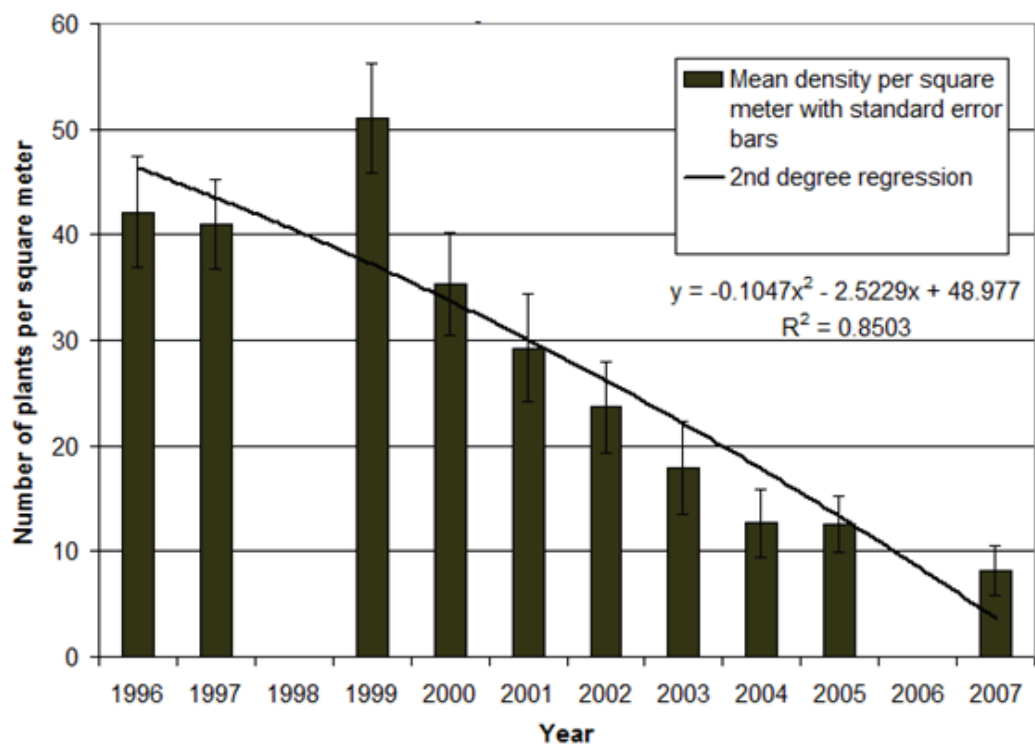


Figure B

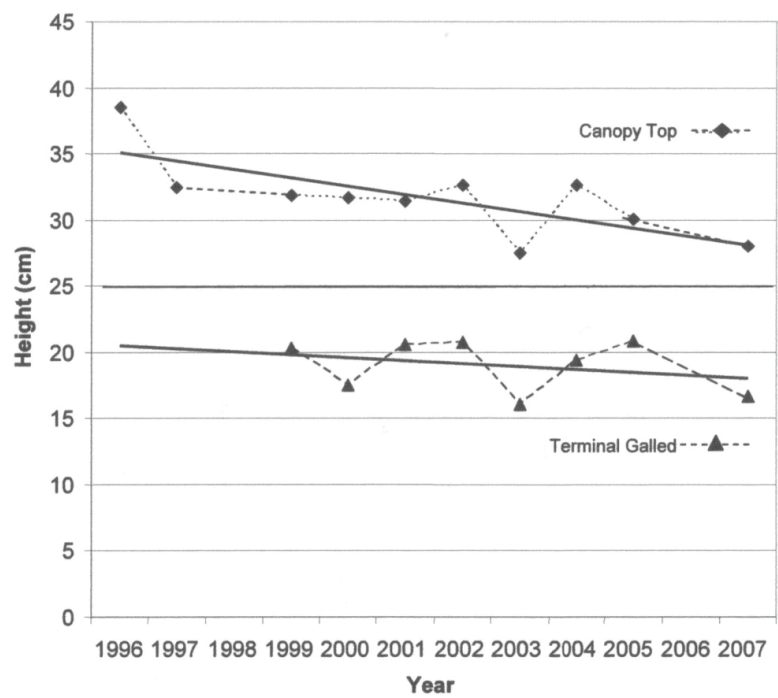


Figure 1: Impact on Canada thistle. (A) Density of Canada thistle plants (#/m²) at Ladd Marsh Refuge over the 12-year duration of study. (B) Mean height of Canada thistle plants sampled at Ladd Marsh Refuge over 12-year duration of study.