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A Survey of the Insect Fauna of Canada Thistle, Cirsium Arvense, in South Dakota; and Studies Relating to Biological Control by Ceutorhynchus Litura and Cassida Rubiginose

Lance Jerome Nearman

A SURVEY OF THE INSECT FAUNA OF CANADA THISTLE, CIRSIUM ARVENSE, IN SOUTH DAKOTA; AND STUDIES RELATING TO BIOLOGICAL CONTROL BY CEUTORHYNCHUS LITURA AND CASSIDA RUBIGINOSA

BY

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This thesis is approved as a creditable and independent investigation by a candidate for the degree, Doctor of Philosophy, and is acceptable for meeting the thesis requirements for this degree. Acceptance of this thesis does not imply that the conclusions reached by the candidate are necessarily the conclusions of the major department.

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ABSTRACT

LANCE JEROME NEARMAN

Under the supervision of Professor Benjamin H. Kantack

A total of 121 indigenous insect taxa representing 9 orders, 64 families, 103 genera and 118 species was collected from Canada thistle (Compositae: Cirsium arvense (L.) Scop.) in South Dakota during 1970 through 1973. This survey identified the major phytophagous and entomophagous insect fauna associated with this noxious weed. The common phytophagous species observed feeding on thistle were all polyphagous and failed to control Canada thistle below the economic level.

Field cage releases of adult Ceutorhynchus litura (F.) weevils were made on a thistle infested pasture site located in east central South Dakota during 1972-1973. Ninety-nine weevils were released in 1972 and approximately 150 in 1973. Initial overwintering success was observed when 2 adults were found in the field cage in April and May 1973. The thistle stand in the field cage declined during the summer due to insect damage caused by large infestations of the aphid, Dactynotus cirsii (L.), the four-lined leaf bug, Poecilocapsus lineatus (F.), and possibly the weevil C. litura. These results indicate that C. litura probably can be colonized in South Dakota. No natural enemies of this insect were found during the study. Attempts to

establish a laboratory colony of the tortoise beetle, Cassida rubiginosa Müll., were not successful.

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In the United States losses of agricultural income caused by alien and natural weeds are believed to equal the combined losses from insects and disease, and rank second only to those caused by soil erosion (Andres and Goeden 1971). During the period 1950-1960 the annual loss of income was estimated by the U.S. Department of Agriculture to be 5.1 billion dollars.

In South Dakota, Canada thistle, Cirsium arvense (L.) Scopoli, infests about 363,000 acres on 24,000 farms (Derscheid and Wrage 1972b). This noxious weed reduces yields of economic crops. Derscheid and Wrage stated that light infestations sometimes are not recognized as a crop hazard, however, they do reduce yields. One experiment showed that 2 Canada thistle plants per square yard reduced yields 36 percent (Derscheid and Wrage 1972b).

Controlling Canada thistle with combined cultural and chemical methods has met with varying degrees of success. Peschen (1971) stated that control measures must extend for several years with the aim of starving the aggressive and extensive root system of the weed. This can be done by planting competitive crops, by clean cultivation practices, and by mowing.

The use of biological agents for controlling C. arvense is a relatively new approach to the problem. In Europe, three beetles, Ceutorhynchus litura (F.) (Coleoptera: Curculionidae), Altica carduorum (Guérin-Méneville) (Coleoptera: Chrysomelidae), and Cassida rubiginosa Müller (Coleoptera: Chrysomelidae), were found to parasitize Canada thistle (Wolfer and Eichhorn 1966, Peschen 1971). Studies abroad

indicated that these insects were likely candidates for introduction for biological control studies on C. arvense.

In 1970, the Entomology-Zoology Department, South Dakota State University, began investigations to determine the feasibility of introducing insect enemies of Canada thistle into South Dakota. Schaber (1973) conducted laboratory and field studies on A. carduorum. The purpose of these studies is threefold. First, to study, identify, and characterize the native insect fauna associated with Canada thistle in South Dakota. This study should measure the degree of control exerted by natural enemies of this weed already established. Second, to determine the feasibility of establishing populations of C. litura in South Dakota for thistle control. Third, to establish a laboratory colony of C. rubiginosa and conduct feeding studies to determine the host plant range of this insect.

LITERATURE REVIEW

History of Canada Thistle, Cirsium arvense (L.) Scopoli.--

Throughout the world, C. arvense is known by a variety of common names. The most often used are Canada thistle, creeping thistle, California thistle, field thistle and cursed thistle (Hodgson 1968). The common or popular name in America, Canada thistle, has given the misconception that this thistle is a native of Canada (Detmers 1927). Actually, this weed is indigenous to Europe, western Asia, and northern Africa. The plant was accidentally introduced into the Provinces of Quebec and Ontario as an impurity in seed about 1777 (Detmers 1927, Dewey 1901). It was introduced into the New England states and New York at about the same time (Detmers 1927).

Canada thistle was named Carduus arvensis by Tabernaemontanus in 1687, Serratula arvensis by Linné in 1753, Cirsium arvense by Scopoli in 1772, Carduus arvensis by Robson in 1777 and Cnicus arvensis by Hoffman in 1804. The name Cirsium arvense Tournefort was adopted by Detmers (1927), but more recently Canada thistle has been referred to as Cirsium arvense (L.) Scop. (Derscheid and Schultz 1960).

Since its introduction, Canada thistle has spread rapidly throughout the northern half of the United States and in Canada. Man appears to have been the active agent for its dispersal by planting seeds or contaminated forage and small grains (Hodgson 1968). By 1952, it was reported to infest more acreage than any other noxious weed in a four-state area of Montana, Idaho, Oregon, and Washington

(Hodgson 1968).

This weed is a distinctly northern plant, and in the United States, temperature conditions between 40° - 49° N latitude are most favorable for its development (Detmers 1927). Canada thistle grows under a wide variety of conditions. It thrives on fertile, well-drained soils, in overgrazed pastures, and small grain fields (Peschen 1971), and adapts to productive, deep, well-aerated soils where temperatures are moderate. It grows best with 16 to 30 inches of rainfall, or under irrigation. Poorly aerated soils or high water tables limit the growth of this weed (Hodgson 1968).

Canada thistle is a perennial which can be distinguished readily from all other thistles by its deep green spiney leaves, by small heads of flowers borne in clusters, by its growth in patches, and by its horizontal branching roots (Detmers 1927). The stems grow erect from 24 to 48 inches (or higher) arising from numerous buds on the horizontal roots. Stems are usually green but may be brownish to reddish purple on some plants (Hodgson 1968). The leaves are deeply lobed and ruffled on the margin, with spines around the margin and the tips of the lobes. Flowers are borne at the apex of the stems. The stems are terminal or arise from the leaf axils and branch several times. The flowers are mostly purple, or blue with various shades; occasionally they are white (Hodgson 1968).

The extensive branching fibrous root system of C. arvense grows each year and contains an abundance of stored food that gives

perennial life to the plant. The food reserve of the roots enables the plant to initiate new shoots for about 1½ growing seasons (Hodgson 1968), by which means the thistles spread. These roots may be at a depth of a few inches to 2½ feet below the surface. The root branches are of three kinds: absorbing, storage, and propagating roots from which stems grow upward toward the surface, and, on exposure to light, become the green-blossom bearing shoots (Detmers 1927).

A second method of propagation and dissemination of the thistle is by the seed. Seed production by the plant is the major means of spreading from farm to farm, and from farms and roadsides to ranges and watershed areas (Hodgson 1968).

Damage caused by Canada thistle includes displacement and consequent reduction in yields of valuable field and forage crops, or competition in pastures, range lands, and lawns and gardens. This weed has established in forest lands and other watershed areas, on roadsides, riverbanks, and in ditchbanks (Hodgson 1968).

Peschen (1971) reported that studies in Canada showed that a density of 25 thistle shoots per square yard can reduce wheat yields by 60 percent. A further study showed that an initial density of 18 plants per square yard can reduce alfalfa production by 7.4 tons per acre over a four-year period.

Because of the undesirable characteristics of Canada thistle, control measures have been extensively sought over the past 100 years (Hodgson 1968). Methods of control fall into three broad categories--

cultivation practices, cropping programs, and chemical treatments. Derscheid and Wrage (1972a) reported that, in South Dakota, studies showed that combinations of intensive cultivation, cropping, and chemicals can reduce the stand of thistles 75 percent or more in one year. Chemical sprayings using 2,4 D amine or MCPA (2-methyl-4-chloro-phenoxyacetic acid) are recommended in South Dakota for controlling thistle.

Biological Control of Weeds.--Cultural and chemical control practices have been the main approach to weed control for many years. More recently, however, various workers have attempted to use the biological approach for controlling weeds. Holloway (1964) stated that the first published report on the deliberate use of insects to control an unwanted plant species involved work undertaken in Hawaii in 1902. An introduced ornamental plant, Lantana camara L., had escaped cultivation and was a serious pest on range land. A search was initiated to locate insects attacking Lantana and an accidentally introduced scale insect, Orthezia sp. was found that fed on and damaged the plant. The use of this scale insect met with varying degrees of success. It was decided to extend the search for insects to the native home of the plant. The search led to Mexico and Central America from which numerous insect introductions occurred over a 50-year period (Holloway 1964). These introductions brought Lantana under "partial" to "substantial" control on the islands of Hawaii, Maui and Molokai, and under "partial" control on Oahu and Kauai (Andres and Goeden 1971).

Numerous other projects have been conducted using introduced insects to control weeds. Andres and Goeden (1971) stated that weed control with insects is no dangerous, untested, unproven "pipe dream", but rather, a well documented accomplishment. One of the more spectacular examples in the United States has been the control of the Klamath weed, Hypericum perforatum L. This European plant is considered a noxious weed in the range lands of Australia, New Zealand, Canada and the United States (Holloway 1964). In the United States, the weed was a sericus pest in California, Oregon, Washington, Idaho, Nevada, and Montana. The California Department of Agriculture in 1951 estimated that there was a total of 2 1/3 million acres of Klamath weed infested range land in the state (Huffaker and Kennett 1959).

Control of Klamath weed by insects had been under consideration in the United States for many years. This method was successful in other countries, notably Australia, but had not been used in this country (Holloway and Huffaker 1952). As early as 1920, Australian entomologists began to search for insect enemies of the Klamath weed in Europe. From this study, two leaf feeding beetles, Chrysolina spp. and the root borer Agrilus sp. were found to feed on the weed and were later established in Australia (Holloway 1964).

The encouraging results in Australia prompted the University of California, in cooperation with the Bureau of Entomology and Plant Quarantine, U.S. Department of Agriculture, to begin studies and import

Chrysolina hyperici (Forster), C. quadrigemina (Suffrian) and Agrilus hyperici (Creutzer) (Coleoptera: Buprestidae) into California (Holloway and Huffaker 1952).

Following extensive feeding studies to insure that these insects would not feed on economic crops, releases of Chrysolina hyperici and C. quadrigemina were made in 1947-1948. Both species became established, and after two years there was no further need for importation (Holloway and Huffaker 1952). Within a short period of time it became apparent that Chrysolina quadrigemina was making a much greater increase than was C. hyperici. This could be explained by their slightly different environmental requirements (Huffaker and Kennet 1959).

Huffaker and Kennet (1959), in summarizing the success of this project, stated that the Chrysolina beetles, were introduced in 1947-1948, but the results were slight through 1951. By 1953, the Klamath weed was reduced to 26.4 percent, by 1954, to 12.5 percent and by 1955 to 5.6 percent. The weed now exists at less than 1 percent of its former occurrence and has now been removed from the list of California's noxious weeds.

Other examples used to demonstrate the success of biological control of weeds are the destruction of over 60 million acres of prickly pear cacti, Opuntia sp., in Australia, primarily by the imported Argentine moth, Cactoblastis cactorum (Berg) (Lepidoptera: Pyralidae) and the more recent attempt to control the aquatic alligatorweed, Alternanthera philoxeroides (Martius) Griesbach,

in the South, by the leaf and stem feeding Agasicles flea beetle which is native to South America (Andres and Goeden 1971).

One of the first steps in an effective biological control program is to survey the extent of biological control already established by natural enemies in an area. Many faunistic surveys have been conducted in recent years on various plants, both beneficial and unwanted species. Goeden and Ricker (1968) studied the phytophagous insect fauna associated with Russian thistle in Southern California during 1965-1966. The purpose of this study was to identify and ecologically assess the insects now attacking this weed before investigations were undertaken to locate host-specific enemies in Eurasia. Goeden and Ricker collected 91 phytophagous insect species, representing 6 orders and 25 families, from Russian thistle.

Frick (1964, 1972) and Frick and Hawkes (1970) studied the insect fauna feeding on the introduced weed, tansy ragwort, Senecio jacobaea L., in California. They reported a total of 42 endemic or cosmopolitan oligophagous or polyphagous insects and mites that could survive on this plant. It was concluded, however, that none of these more-or-less general feeders was capable of exerting sufficient pressure upon S. jacobaea to control its abundance or distribution.

Biological Control of Canada Thistle.--Paschen (1971) stated that C. arvense differs from most other weeds against which biological control has been tried in that it is a serious problem in its native range as well as in newly colonized areas. The weed is not controlled below its economic level despite stresses caused by numerous insect

enemies, the rust Puccinia suaveolens, and the virus causing "yellow top".

In 1961, the Commonwealth Institute of Biological Control, Delmont, Switzerland, began work on the biological control of Canada thistle with a study of its parasites in Europe (Peschen 1971). Zwölfer (1965) listed 80 insect species feeding on this weed in Europe, from which A. carduorum, C. litura, and Urophora cardui L. (Diptera: Trypetidae) were selected for further study because of their apparent host specificity and climate suitability (Peschen 1971).

A. carduorum.--Both the adults and larvae of the flea beetle, A. carduorum, feed on the leaves of C. arvense. The host range of the beetle is restricted to the genera Carduus, Cirsium and Silybum. Field release of A. carduorum were made in the Canadian provinces of Ontario, British Columbia, Nova Scotia, and Alberta during 1963-1968 (Peschen et. al. 1970). These beetles did not become established, due to climate, to excessive dispersal of adults, and to predators (Peschen 1971). From these studies it was recommended that no further releases of A. carduorum should be made in Canada, except for one area in Ontario, where the climate was more suited for the beetle.

Attempts to establish A. carduorum in the field were also made in England during 1969-1970 (Baker et al., 1972). The beetle failed to become established. It was concluded that A. carduorum is not suited to the climate in Britain.

Schabor (1973) conducted laboratory colonization and field release studies on A. carduorum in South Dakota during 1970-1972. This was the

first attempt to establish field colonies of A. carduorum in the United States. In the field, the beetle successfully overwintered at one release site located in eastern South Dakota. At the site, the overwintering adults laid viable eggs, but the population failed to become established. Schaber (1973) stated that the major limiting factors of establishing field colonies in South Dakota are the carabid predators, Lebia viridis Say and Harpalus pennsylvanicus DeGeer; very high summer temperatures; low relative humidity; and combinations of the above.

C. litura.--C. litura is a weevil that attacks the rosettes of C. arvense. This insect has a European-Atlantic distribution, and occurs more frequently in the northern than in the southern part of its range (Zwölfer and Harris 1966). It is found in a wide variety of habitats but more abundantly in cultivated fields than in grassland, forest borders or swamps (Zwölfer and Harris 1966, Peschen 1971). Since this insect thrives in cultivated land and it attacks in early spring before thistle becomes troublesome, it is of special interest for biological control of thistle. Zwölfer and Harris (1966) investigated the suitability of C. litura for biological control on the basis of its biology, host range, and specialization to its host. These studies showed that its host range was restricted to the Cirsium - Silybum - Carduus complex, which does not include any economic plants. They concluded, the host specificity of C. litura and its compatibility with other thistle insects justified its introduction into Canada for biological control of C. arvense.

In Switzerland, adults emerge from hibernation between the end of March and mid-April. The adults feed on young shoots of thistle and the females oviposit in the main vein of the thistle leaves, from the end of March to mid-May (Zwölfer and Harris 1966, Peschen 1971). Eggs are laid in groups of 1-5 (average 2.5) in roundish cavities made by the rostrum in the underside of young leaves. The larvae mine through the mid-rib of the leaf into the stem and root collar, and occasionally into the root. Usually several larvae tunnel each vein and cause the vein to become black. A few days later the whole leaf changes color and dies.

Three larval molts occur and the mature third-instar larva leaves the stem or root of the plant, enters the soil and constructs an oval cocoon, about 4-6 mm. in diameter, using small particles of soil.

Zwölfer and Harris (1966) found that C. litura larvae did most damage to thistles growing under stressful conditions. Studies showed young rosettes of C. arvense are more liable to heavy attack by C. litura in cultivated fields than in dense grasslands or in swamps or hedgerows. Suboptimal conditions reduce vitality and resistance of Canada thistle to larval attack.

Peschen (1971) first released C. litura at four locations near Belleville, Ontario in 1965 and 1967. He reported that on each of three sites, where from 22-56 adults were released, and where the thistle infestation was low, the colonies died. On the fourth site, a heavily infested permanent pasture, where 230 beetles were released in a field cage, there was initial establishment. Observations are

continuing on this site. Peschen (1971) recommended that further releases of C. litura should be made in Canada, preferably using specimens from the release in Ontario.

C. rubiginosa.--Among the European insect species found feeding on C. arvense was C. rubiginosa. Zwölfer and Eichhorn (1966) found C. rubiginosa to be one of the most common insects in Europe.

Member of the genus Cassida, subfamily Cassidinae, are without exception leaf feeding insects, both in the larval and adult stages. The insect feeds entirely on the leaf surface, never mining between the outer leaf layers as do some of their relatives (Gressitt 1952).

The females construct papery ootheca which protects their eggs. Egg cases are laid on the underside of leaves. The larval and pupal stages possess a caudal appendage to which is attached the successive molted larval skins and also accumulated larval feces. This structure, called a "parasol", apparently serves as a protective device for the slow moving larvae and also for the exposed, sessile pupae, both by helping to arm and to hide these stages. The pupa remains attached to the leaf surface with the "parasol" generally held horizontally over the body (Gressitt 1952).

Although native to Europe, this insect has been introduced into North America and can now be found in many of the eastern states and provinces of Canada (Brown 1940).

Investigations were made by Zwölfer and Eichhorn (1966) in Switzerland to determine the host plant range of adult C. rubiginosa and other Cassida spp. found associated on European thistles and

knapweeds. When laboratory feeding studies were conducted on various host plants, it was concluded that because of the potential danger of an attack on artichoke, Cynareae scolymus L., neither C. rubiginosa nor C. vibrex could be recommended for introduction into foreign countries for use in controlling thistles and knapweeds.

Natural Insect Enemies of C. arvense in North America.--A number of insects have been reported found on Canada thistle in the United States and Canada. Detmers (1927) lists several insects found on C. arvense in Ohio. Among the most conspicuous insects found feeding on the weed was The Painted Lady or thistle butterfly Cynthia cardui L. (Lepidoptera: Nymphalidae). Detmers noted that during the summer of 1924, a large larval infestation of Pyramis cardui L. (C. cardui) occurred in northern and western Ohio, resulting in extensive defoliation of the food plant.

Unfortunately, C. cardui is not host specific to Canada thistle. Essig (1926) stated that the caterpillars ordinarily feed on thistles, malva, amsincka, burdock, lupine, nettle and other weeds, but when abundant also attack the globe artichoke, beans, sunflower, and prune. Detmers (1927) reported that when starved the larvae will feed on mint and soybeans.

In 1973, a large buildup of C. cardui was noted in many western states, including Montana, Idaho, Oregon, Nevada, Utah and South Dakota (U. S. D. A. 1973, Kantack et al. 1973). It was noted feeding on bull thistle, musk thistle, peppermint plants, soybeans, as well as Canada thistle.

Other insects noted by Detmers (1927) include Dasyneura gibsoni Felt (Diptera: Cecidomyiidae), a seed midge, which causes "blasted" heads in Canada thistle; the sodwebworm, Crambus sp. (Lepidoptera: Pyralidae), which girdles the stem of thistles below the ground; and larvae of Trypeta florescentiae L. (Diptera: Trypetidae) which feeds in the heads of the weed; and two aphids, Anuraphis cardui L. and Capitophorus carduinus Walker (Homoptera: Aphididae) were found feeding on the leaves. Eklund (1970) stated that Rogers (1928) found the same insect fauna on C. arvense in Colorado in 1927 that Detmers did.

Peschen (1971) reported that in Canada, the most conspicuous enemies of C. arvense are the insects C. rubiginosa, Cleonus piger Scop. (Coleoptera: Curculionidae) and Orellia rufipalpia F. (Diptera: Trypetidae). He also noted that these do not control Canada thistle below the economic level.

MATERIALS AND METHODS

Survey of Native Insects.--Surveys and collections of indigenous insects associated with Canada thistle were conducted during the summers of 1970 through 1973 in South Dakota. The survey was primarily conducted in the eastern part of the state, however, the Black Hills area in the western part of the state was surveyed during a one-week period in August, 1972. In eastern South Dakota, field data were primarily collected in Brookings and Moody Counties. Periodic surveys were made in Kingsbury, Lake, Lincoln, and Minnehaha Counties.

Stands of C. arvense were found in various counties and examined for insects from May through October of each year. Two main sites, located in Brookings and Moody Counties, were examined 2 or 3 times per week during this period.

The Brookings County site is located on the Johnson farm, approximately 4¼ miles N and 1½ miles W of Brookings. The soil type is Estelline silt loam, nearly level-medium to fine-textured. This site is in a tree-sheltered area, at an elevation of 1646 ft., and had a thick stand of thistles. This is the same site used by Schaber (1973) for a release of A. carduorum in 1971-1972.

The second site, in Moody County, was situated on the Durland farm, 1 mile S of the Big Sioux River on County road #21, on Lamour silt loam, at an elevation of 1580 ft.

Specimens were collected from each location by slowly walking through the thistle stands and examining the plants for insects. During each visit to the various sites, 1-2 hours were spent examining

plants and collecting insects. Collections were made by hand, aspirator, D-vac insect collecting apparatus, or by sweep net. Notes were made, whenever possible, on insect numbers observed, the location of the plant where the insects were collected, and whether feeding damage was observed.

At the Johnson farm site, 8 pitfall traps, made from ½ pint jars, were placed on the periphery of the field cages containing A. carduorum. The traps were uniformly arranged in a circle, 10 ft. in diameter, around the field cages. Collections of carabid predators and other insects were made from the traps at weekly intervals during June through September in 1971 and 1972.

All collected specimens were killed using K.A.A.D. (a mixture of kerosene, ethyl alcohol, glacial acetic acid, and dioxane) and stored in 4 dram vials containing 70 percent ethyl alcohol until identifications could be made. To aid in identification, immature stages were occasionally brought back to the laboratory, placed in environmental chambers and reared to adults on thistle bouquets.

Identifications were made to the lowest possible taxon using available keys and the South Dakota State University Insect Collection. The keys used for the identifications were by the following authors: Blatchley (1910,1926), Blatchley and Leng (1916), Borror and DeLong (1970), Bowing and Craighead (1931), Cole (1969), Crumb (1956), DeLong (1948), DeLong and Knull(1945), Essig (1926), Field (1971), Forbes (1923), Gates and Peters (1962), Hatch (1971), Helfer (1953), Holland (1905), Johnson (1972), Medler and Ghosh (1969), Metcalf

et. al. (1962), Nielson (1968), and Peterson (1960, 1962). Specimens which could not be identified locally were sent to specialists at the Systematic Entomology Laboratory, U. S. Department of Agriculture, Beltsville, Maryland, for determinations.

Releases of C. litura.--Controlled releases of C. litura were made in eastern South Dakota during the summers of 1972-1973. The release site was located on the Durland farm in Moody County. The site consisted of approximately ½ acre of fenced pasture, heavily infested with Canada thistle and with some incidence of bull thistle. An unusually wet summer produced a thick stand of thistles ranging from 5-6 feet in height.

Prior to the release of the weevils, a field cage measuring 8' x 8' x 16', screened with 16 mesh screen, was constructed over a dense stand of thistles on the site (Fig. 1). One-fourth of the cage was partitioned off to provide for a check area. Doors were placed on each end of the cage.

On July 12, 1972, 32 adult C. litura weevils of German origins, were received from the U. S. Department of Agriculture, Biological Control of Weeds Laboratory, Albany, California. The weevils (Fig. 2) were transferred to fresh thistle bouquets and held in an environmental chamber until they were released on the morning of July 13. A second release of 64 adults was made in the field cage on August 2, 1972. Observations on the number of beetles observed were made twice a week until October 1972. The following spring, observations were continued to determine the survival of the beetles.

Fig. 1.--Release site and field cage in Moody County, South Dakota.

Fig. 2.--Adult Cnutorhynchus litura on thistle.

In 1973, another release of 100-150 C. litura adults was made at the Durland site on July 19. This time, the release was made in the control area of the field cage.

Rearing Studies of C. rubiginosa.--Attempts were made to establish a laboratory colony of C. rubiginosa from stocks received from the Pennsylvania Department of Agriculture, Harrisburg, Pennsylvania (Fig. 3). Adult, larval and pupal stages were field collected from Canada thistle in Pennsylvania during July, 1971-1973, and shipped to South Dakota. In 1971, about 50 adults and larvae were received; 50 adults and 86 larvae and pupae were received on July 10, 1972; and 608 adults, larvae and pupae were received on July 11, 1973.

The technique used for rearing the beetles was essentially the same as the one used by Schaber (1973) in rearing A. carduorum. Ten to 20 adult beetles or larvae were placed in ½ gallon plastic ice cream containers. The central portion of the lid was removed and a piece of plastic wrap was placed over the container and the lid snapped into place. The plastic was perforated with holes using a small tweezers to allow gaseous exchange and prevent condensation. A circular piece of foam, ½ inch in width, was placed on the bottom of the container to absorb excess moisture.

Bouquets of cut Canada thistle were made by inserting thistle foliage into a 6 dram-snap-cap vial, filled with water. The plant bouquet was held upright by wrapping the stem base with cotton and inserting it through a hole in the plastic cap. During the summer months, field-cut thistle was used for the bouquets. In the winter,

Fig. 3.--Adult Cassida rubiginosa on thistle leaf.

bouquets were obtained from a greenhouse supply of approximately 400 plants.

The containers were placed into a Percival environmental chamber, Model PT-80. The growth chamber was kept at a daytime temperature of 18.3°C, 16 hours of daylight, and 8 hours of darkness, with the RH near 70% during the summer months. In the fall, the daylight hours and temperatures in the chamber were lessened to correspond with natural hours and temperatures.

Fresh bouquets were replaced in the containers at least three times per week, or as needed. Adults were transferred from the original bouquets to fresh ones by hand or with an aspirator. Transfer of the larval and pupal stages was done with a camelhair brush.

The leaves of original bouquets were examined carefully for eggs. Generally the eggs were laid on the underside of the leaves near the base. Bouquets with eggs were replenished with water, placed in separate containers, and observed for egg hatching.

RESULTS AND DISCUSSION

Insect Survey.--A total of 121 taxa, representing 9 insect orders, 64 families, 103 genera and 118 species were collected from Canada thistle during the survey period 1970 through 1973. The list of native insects collected with ecological and other pertinent collecting data is shown in Table 1. Table 2 shows the numerical data of the various taxa collected during the study.

Phytophagous insects.--The most common phytophagous insects found feeding on Canada thistle were the four-lined leaf bug, Poecilocapsus lineatus (F.); the painted lady or thistle butterfly, Cynthia cardui (L.); the artichoke plume moth, Platyptila carduidactyla Riley; the thistle head midge, Dasyneura gibsoni Felt; the flea beetle, Systena elongata (F.); and the aphid, Dactynotus sp.

The leaf bug, P. lineatus (Fig. 4), was frequently found attacking the leaves of thistle at both the Durland and Johnson sites during 1972 and 1973. The heaviest infestations occurred in May and June, however, this insect could be found and collected throughout the summer. A survey at the Durland site during June, 1973, showed an average of 3-4 bugs per plant. P. lineatus occurred mainly in thistle stands located near sheltered tree areas. Very few specimens were collected from thistles found in open pasture or grassland areas.

Larvae of the painted lady butterfly, C. cardui, were commonly found feeding on thistle (Fig. 4). A heavy larval infestation occurred during the summer of 1973 throughout the state. At the Durland site during June, as many as 4-5 larvae per plant were found.

Fig. 4.--Larva of the painted lady butterfly, Cynthia cardui, (right) partially covered by a leaf and an adult leaf bug, Poecilocapsus lineatus, (center). Note feeding damage on leaves caused by the leaf bug.

Many of the thistles were stripped of their leaves, however, most recovered from the injury.

The larvae of the artichoke plume moth, P. carduida tyla, frequently were found to infest and injure the heads and stems of Canada thistle, mainly during May and June. The larvae feed and mine through the head and bore out through the upper stem of the plant. At one eastern site, during 1972, it was noted that 10-15 percent of the heads of thistle were infested with this insect.

The thistle head midge, D. gibsoni, was often found infesting the heads of thistle during the early summer months. The minute, pinkish-white larvae suck the juices from the young akenes in the heads. As many as 5-6 larvae were found per head in the field.

Adult flea beetles, S. elongata, frequently were found feeding on thistle leaves during August and September, 1972. Beetle numbers ranged from 1-4 per plant at one thistle infested pasture site in Brookings County. Heavy feeding damage to the leaves of young thistle was noted in this area; however, the overall effect on the thistle could not be determined.

The aphid, Dactynotus sp., was abundantly found feeding on thistle stems and leaves at various locations during the summer months in 1972 and 1973. Peak infestations generally occurred during June and July; however, specimens were collected in late August. A large, damaging population of these aphids occurred on thistles in the screened field cage at the Durland site. The screen used for the construction of the cage prevented the natural coccinellid enemies

from entering and enabled the aphid population to increase unchecked. As many as 100-200 aphids per plant were noted during June-July, 1973. This attack, plus a large infestation of leaf bugs, P. lineatus, and possibly stem damage by C. litura larvae, caused death to most of the thistle stand in the cage.

Although the above insects caused various degrees of damage to Canada thistle during severe infestations, they failed to control the weed below the economic level. A review of the life histories of the insects revealed that all are considered general feeders and are not host specific to Canada thistle.

Various other miscellaneous species were found to feed, on occasion, on Canada thistle (Table 1.). A review of their life histories showed that most of these are incidental feeders on thistle.

Entomophagous insects.--A total of 37 species of entomophagous insects were collected from or found associated with Canada thistle. The most abundant species were in the orders Coleoptera, Hemiptera and Diptera.

Coleoptera: The most common insect predators found were the carabid species, Evarthrus alternans Casey, Harpalus pennsylvanicus DeGeer, and Lebia viridis Say; the coccinellids, Coleomegilla maculata Timberlake, Cycloneda munda Say, and Hippodamia convergens Guerin.

The majority of the carabids were collected from the 8 pitfall traps located at the Johnson farm site, during 1971-1972. The ground beetles are considered highly beneficial and most feed extensively

on other insects. Schaber (1973) noted that the predator, L. viridis, readily fed on the larvae of the introduced beetle, A. carduorum, during his field study in South Dakota. Also implicated in the decline of the Altica population was predation by H. pennsylvanicus.

The coccinellid predators prey on aphids and other small insects. Larvae and adults of the three main species collected could commonly be found on the foliage of thistle throughout the summer and early fall.

Hemiptera: Three common Hemiptera predators, the flower bug, Orius tristicolor (White); and nabids, Nabis ferus (L.), and N. roseipennis Reuter, were commonly collected from thistle. O. tristicolor frequently was found in the heads of thistle where reportedly it feeds on plant lice and other soft-bodied insects. N. ferus and N. roseipennis are known to feed on various small insects.

Diptera: Many dipterous predators were collected from thistle. The frit fly, Thaumatomyia glabra Meigen was commonly collected from thistle leaves. Larvae of this insect are reported to prey on root aphids. Other predaceous species which were occasionally collected are shown in Table 1.

Table 1.--A list of native insects collected from Canada thistle, Cirsium arvense (L.) Scop., in South Dakota, with notes on their occurrences, ecological role, and biology.

Classification	Habitat or biology observed or reported in the literature	Frequency in collections[a]	Stages[b]	General feeding habit[c]	Month	Year	How obtained[d]	Feeding noted[e]	Location on plant[f]
ORTHOPTERA									
Acrididae									
Melanoplus angustipennis (Dodge)	Generally found on grasslands (Helfer 1955)	R	A	Phyt.	Aug	1972	S.N.	-	L
Melanoplus femurrubrum (DeGeer) redlegged grasshopper	Adults feed on a variety of plants and grasses (Helfer 1953)	O	N	Phyt.	Jun Aug	1972	S.N.	-	L
Gryllidae									
Oecanthus nigricornis Walker black-horned tree cricket	Found on tall weeds, shrubs and young trees (Helfer 1953)	R	A	Phyt.	Aug	1972	A.H.	-	L
Tettigoniidae									
Orchelimum vulgare Harris common meadow katydid	Found on grasslands (Helfer 1953)	O	A	Phyt.	Aug	1972	A.H.	+	L
THYSANOPTERA									
Thripidae	Most members of this group are plant feeders (Borror and DeLong 1970)	O	A	Phyt.	Jun Jul	1972	A.H.	-	H

[a] C = Common; O = Occasionally; R = Rare

[b] A = Adult; L = Larvae; N = Nymph

[c] Phyt. = Phytophagous; Pred. = Predator; Para. = Parasite; Poll. = Pollen; Scav. = Scavenger or saprobe

[d] A.H. = Aspirator and/or hand; D.V. = Devac; S.N. = Sweep net; P.T. = Pitfall trap

[e] + = Feeding damage noted; - = No damage noted

[f] H = Head; L = Leaf; S = Stem

Table 1. (Continued)

Classification	Habitat or biology observed or reported in the literature	Frequency in collections[a]	Stages[b]	General feeding habit[c]	Month	Year	How obtained[d]	Feeding noted[e]	Location on plant[f]
HEMIPTERA									
Anthocoridae									
Orius tristicolor (White)	Lives in or on heads of various flowers; feeds on plant lice and other soft-bodied insects (Blatchley 1926)	C	A	Pred.	Jun Aug	1972	S.N. A.H.	-	H
Corimelaenidae									
Corimelaena pulicaria (Germar)	Occurs on a variety of weeds and cultivated plants; sucks juices (Blatchley 1926)	O	A	Phyt.	Aug	1970	A.H.	-	L
Coreidae									
Leptocoris trivittatus (Say) boxelder bug	Sucks juices of leaves of boxelder tree and has been reported to damage various fruits (Blatchley 1926)	C	A,N	Phyt.	Jun Jul Sept	1972	A.H.	-	L
Miridae									
Hercias dislocatus (Say)	Often occurs in numbers on the great ragweed (Blatchley 1926)	C	A	Phyt.	Jun	1973	D.V.	-	
Miris dolabratus (L.) meadow plant bug	Feeds on bluegrass, timothy and other forage grasses (Blatchley 1926)	O	A	Phyt.	Jun	1973	D.V.	-	

Table 1. (Continued)

Classification	Habitat or biology observed or reported in the literature	Frequency in collections[a]	Stages[b]	General feeding habit[c]	Month	Year	How obtained[d]	Feeding noted[e]	Location on plant[f]
Lygus lineolaris (Beauvois) tarnished plant bug	Feeds on buds and flowers of plants. Cause loss in alfalfa seed production (Gates and Waters 1962)	C	A	Phyt.	Sept	1972	A.H.	+	L
L. rutilans Horvath	Occurs on weeds and grasses (Blatchley 1926)	O	A	Phyt.	Aug	1972	S.N.	+	
L. shulli Knight		O	A,N	Phyt.	Aug	1972	S.N.	+	
Lygus sp.		C	A,N	Phyt.	Jun Jul Aug Sept	1972	A.H.	+	L
Poecilocapsus lineatus (F.) four-lined leaf bug	Feeds particularly on currants and gooseberries; inserts eggs into stems of plants (Borror and DeLong 1964)	C	A,N	Phyt.	May Jun Jul Aug	1972 1973	A.H D.V.	+	L,S
Nabidae									
Nabis ferus (L.)	Preys on small insects (Blatchley 1926)	C	A,N	Pred.	Jun	1972	A.H.	-	L
N. roseipennis Reuter	Feeds on grass- and herb-inhabiting insects (Blatchley 1926)	C	A	Pred.	Aug Sept	1972	A.H.	-	L
Pentatomidae									
Euschistus euschistoides (Vollenhoven)	Occurs on foliage and flowers of various kinds of plants (Blatchley 1926)	O	N	Phyt.	Aug	1972	A.H.	-	L

Table 1. (Continued)

Classification	Habitat or biology observed or reported in the literature	Frequency in collections[a]	Stages[b]	General feeding habit[c]	Month	Year	How obtained[d]	Feeding noted[e]	Location on plant[f]
E. trianguus (Say)	Found on flowers and foliage of weeds along roadsides and in open woodlands (Blatchley 1926)	O	A	Phyt.	Jun	1972	A.H.	-	L
Phymatidae									
Phymata wolfii Stal	Occurs on flowers and foliage of Compositae and other weeds (Blatchley 1926)	O	A	Pred.	Jun	1972	A.H.	-	L
Reduviidae									
Sinea diadema (F.)	Found especially on thistles and asters; feeds on aphids and other insects (Blatchley 1926)	O	A	Pred.	Jun	1972	A.H.	-	L
HOMOPTERA									
Aphididae									
Dactynotus sp.	Sucks juices of a variety of plants	C	A,N	Phyt.	Jun Jul Aug	1972 1973	A.H.	+	L,S
Capitophorus eleagni (Del Guercio)	-	C	A,N	Phyt.	Jun Jul	1972 1973	A.H.	+	L
Cicadellidae									
Agallia quadripunctata (Provancher)	Occurs abundantly in moist open woodland areas (DeLong 1948)	O	A	Phyt.	Jun	1973	D.V.	+	

Table 1. (Continued)

Classification	Habitat or biology observed or reported in the literature	Frequency in collections[a]	Stages[b]	General feeding habit[c]	Month	Year	How obtained[d]	Feeding noted[e]	Location on plant[f]
Ambyselius curtisii (Fitch)	Common species in bluegrass meadows and pastures, also in grains and legumes (DeLong 1948)	O	A	Phyt.	Jun	1973	D.V.	-	
Membracidae									
Campylenchia latipes (Say)	A common grass and alfalfa feeding species (Gates and Peters 1962)	R	A	Phyt.	Jul	1973	A.H.	-	L
Publilus modesta Uhler	-	O	A	Phyt.	Jul	1970	A.H.	-	L
NEUROPTERA									
Chrysopidae									
Chrysopa occulata Say	Both adults and larvae are predaceous, chiefly on aphids (Borror and DeLong 1970)	O	A,L	Pred.	Jun Jul	1970 1972	A.H.	-	L
COLEOPTERA									
Cantharidae									
Podabrus punctulatis LeConte	Larvae are carnivorous; feeds on eggs of grasshoppers, maggots and other small insects (Arnett 1960)	O	A	Pred.	Jun	1972	A.H.	-	L
Carabidae									
Agonum placidum Say	-	O	A	Pred.	Aug	1972	P.T.	-	
Agonoderus lecontei Chaudoir	Species does some damage to seed corn and sorghum planted in wet soils (Gates and Peters 1962)	R	A	Phyt.	Aug	1973	A.H.	-	L
Chlaenius platyderus Chaudoir	Feeds largely upon other insects (Blatchley 1910)	O	A	Pred.	Jun	1972	P.T.	-	

Table 1. (Continued)

Classification	Habitat or biology observed or reported in the literature	Frequency in collections[a]	Stages[b]	General Feeding habit[c]	Month	Year	How obtained[d]	Feeding noted[e]	Location on plant[f]
Dicaelus sculptilis Say	Found usually in dry open woods. Feeds wholly on insects (Blatchley 1910)	O	A	Pred.	Jun	1972	P.T.	-	
Evarthrus alternans Casey	Highly beneficial; feeds mainly on other insects (Blatchley 1910)	C	A	Pred.	Jun Jul Aug Sept	1971 1972	P.T.	-	
Harpalus pennsylvanicus DeGeer	Feeds on ragweed and other seeds; also on caterpillars and other insects (Blatchley 1910)	C	A	Pred.	Jun Jul Aug Sept	1972	P.T.	-	
Lebia viridis Say	Occurs on foliage of plants where they feed on plant lice and other insects (Blatchley 1910)	C	A	Pred.	May Jun Jul	1970 1971 1972	A.H.	-	L
Chrysomelidae									
Diabrotica longicornis (Say) northern corn rootworm	Adults found on silk and leaves of ripening corn and on flowers of wild sunflower and goldenrod (Blatchley 1910)	O	A	Phyt.	Jul	1972	A.H.	-	L
D. undecimpunctata howardi Barber southern corn rootworm	Occurs on foliage of many plants including corn and goldenrod (Blatchley 1910)	O	A	Phyt.	Jun Jul	1972	A.H.	-	L
D. virgifera LeConte western corn rootworm	Adults feed on cornsilk	O	A	Phyt.	Jun Aug	1972	A.H.	-	L

Table 1. (Continued)

Classification	Habitat or biology observed or reported in the literature	Frequency in collections[a]	Stages[b]	General feeding habit[c]	Month	Year	How obtained[d]	Feeding noted[e]	Location on plant[f]
Epitrix cucumeris Harris potato flea beetle	Occurs on a wide variety of field and garden products including the leaves of potatoes (Blatchley 1910)	O	A	Phyt.	May	1973	A.H.	-	L
Metriona purpuata (Boh)	-	R	A	Phyt.	Jun	1972	A.H.	-	L
Pachybrachis sp.	Adults are found on the leaves of a variety of plants (Arnett 1960)	O	A	Phyt.	Jun	1970 1972	A.H.	-	L
Systena elongata (F.)	Adults feed on leaves of a variety of plants (Arnett 1960)	C	A	Phyt.	Aug Sept	1972	A.H. S.N.	+	L
Cleridae									
Phyllobaenus humeralis (Say)	-	R	A	Pred.	Jun	1972	A.H.	-	L
P. lecontei (Wolcott)	Both larvae and adults are predaceous on other insects (Arnett 1960)	O	A	Pred.	Jun	1972	A.H.	-	L
Coccinellidae									
Brachyacantha ursina F.	Occurs especially on the leaves and flowers of milkweed (Blatchley 1910)	C	A	Pred. Poll.	Jun	1972	A.H.	-	L
Coleomegilla maculata Timberlake	Both larvae and adults feed on plant lice and other insects (Blatchley 1910)	C	A	Pred.	May Jun	1972	A.H.	-	L
Cycloneda munda Say	-	C	A	Pred.	Jun Aug	1970 1972	A.H.	-	L
Hyperaspis binotata (Say)	-	O	A	Pred.	Jul	1971	A.H.	-	L

Table 1. (Continued)

Classification	Habitat or biology observed or reported in the literature	Frequency in collections[a]	Stages[b]	General feeding habit[c]	Month	Year	How obtained[d]	Feeding noted[e]	Location on plant[f]
Hippodamia convergens Guerin-Meneville	Feeds on various insects and pollen of grasses and Compositae (Blatchley 1910)	C	A,L	Pred. Poll.	Jul Aug	1970 1972 1973	A.H.	-	L
Curculionidae									
Apion sp.	Occurs on a wide variety of plants (Arnett 1960)	O	A	Phyt.	Jun	1972	A.H.	-	L
Brachyrhinus ovatus L. strawberry root weevil	Especially damaging to strawberries but also attacks other plants (Hatch 1971)	O	A	Phyt.	May	1972	A.H.	-	L
Coeliothynchus marginatus Paykull	Found on lettuce and reared from buds of dandelion (Blatchley and Leng 1916)	O	A	Phyt.	Jun	1970	A.H.	-	L
Hyperodes sp.	-	O	A	Phyt.	Sept	1972	A.H.	-	L
Idiostethus sp.	Found frequently on various flowers (Blatchley and Leng 1916)	O	A	Phyt.	Jun	1972	A.H.	-	H,L
Notaris puncticollis (LeConte)	Has been recorded attacking (Blatchley and Leng 1916)	R	A	Phyt.	Jun	1972	A.H.	-	H,L
Elateridae									
Dalopius pallidus Brown	Elaterid larvae are vegetarians, or feed on both animal and plant matter (Arnett 1960)	R	A	Phyt.	Aug	1972	P.T.	-	

Table 1. (Continued)

Classification	Habitat or biology observed or reported in the literature	Frequency in collections[a]	Stages[b]	General feeding habit[c]	Month	Year	How obtainted[d]	Feeding noted[e]	Location on plant[f]
Hemicrepidius memnonius (Herbst)	-	R	A	Phyt.	Aug	1972	P.T.	-	
Languriidae									
Languria sp.	The larvae are stem borers and feed in stems of a variety of plants, especially Compositae and Leguminosae (Arnett 1960)	R	L	Phyt.	Aug	1973	A.H.	+	S
Meloidae									
Epicauta fabricii (LeConte)	Adult meloids are phytophagous (Arnett 1960)	O	A	Phyt.	Jun	1972	A.H.	-	L
E. pennsylvanica (DeGeer)	Occurs especially on goldenrod, also on other weeds (Blatchley 1910)	O	A	Phyt.	Aug	1972	A.H.	-	L
Melyridae									
Collops quadrimaculatus F.	Found in flowers; larvae and adults are predators, feed on eggs, larvae and small insects (Blatchley 1910)	O	A	Pred.	Jun	1972	A.H.	-	H
Nitidulidae									
Glischrochilus quadriguttatus F.	Adults feed on sap of decayed fruit (Blatchley 1910)	O	A	Scav.	Jun	1973	D.V.	-	
Pedilidae									
Pedilus elegans Hentz	Adults live on leaves and flowers of plants (Arnett 1960)	C	A	Phyt.	Jul	1972	A.H.	-	L

Table 1. (Continued)

Classification	Habitat or biology observed or reported in the literature	Frequency in collections[a]	Stages[b]	General feeding habit[c]	Month	Year	How obtained[d]	Feeding noted[e]	Location on plant[f]
Pedilus sp.	-	O	A	Phyt.	Jul	1972	A.H.	-	L
Phalacridae									
Olibrus tufipes LeConte	Larvae of this family live principally on flowers, especially those of Compositae (Blatchley 1910)	C	A	Phyt.	May Jun	1972	A.H.	-	H
Scarabeidae									
Trox sonorae LeConte	-	R	A	Scav.	Jun	1971	A.H.	-	
Staphylinidae									
Staphylinus maxillosus L.	Feeds upon decaying organic matter (Blatchley 1910)	R	A	Scav.	Jun	1971	A.H.	-	
Ontholestes cingulatus Gravenhorst	Found in dung (Arnett 1960)	R	A	Scav.	Jul	1972	P.T.	-	
LEPIDOPTERA									
Amatidae									
Scepsis fulvicollis (Hubner) yellow-collared scape moth	Moths frequent the blossoms of goldenrod in late summer (Holland 1905)	O	A	Phyt.	Jun	1970 1973	A.H.	-	L
Arctiidae									
Apantesis sp.	-	O	L	Phyt.	Jul	1972	A.H.	-	L
Halisidota harrisii Walsh sycamore tussock moth	-	R	L	Phyt.	Sept	1970	A.H.	-	L
Isia isabella Abbot and Smith	Larvae feed freely upon a wide variety of herbaceous plants (Holland 1905)	O	L	Phyt.	Aug	1970 1973	A.H.	-	L

Table 1. (Continued)

Classification	Habitat or biology observed or reported in the literature	Frequency in collections[a]	Stages[b]	General feeding habit[c]	Month	Year	How obtained[d]	Feeding noted[e]	Location on plant[f]
Geometridae									
Erranis sp.	Geometrid larvae feed chiefly on foliage of many native and cultivated plants (Peterson 1962)	O	L	Phyt.	Jun	1972	A.H.	+	H
Noctuidae									
Amathes sp.	Noctuid larvae feed largely on leaves of many kinds of wild and cultivated plants (Peterson 1962)	O	L	Phyt.	Jun	1972	A.H.	+	H
Autographa precationis (Guenee)	Larvae feed on sunflower, thistle, dandelion and other plants (Crumb 1956)	O	L	Phyt.	Jun	1972	A.H.	-	L
Peridroma saucia (Hubner) variegated cutworm	Larvae damage alfalfa and other vegetable, field, and fruit crops (Gates and Peters 1962)	R	L	Phyt.	Jun	1970	A.H.	-	L
Plathypena scabra F. green cloverworm	Feeds chiefly on foliage of legumes, especially clover; also attacks many other plants (Peterson 1962)	O	L	Phyt.	Sept	1972	A.H.	+	L
Polia adjuncta (Boisduval)	Feeds on buttercup, wild currant, elder and other wild plants (Crumb 1956)	O	L	Phyt.	Sept	1972	A.H.	+	L

Table 1. (Continued)

Classification	Habitat or biology observed or reported in the literature	Frequency in collections[a]	Stages[b]	General feeding habit[c]	Month	Year	How obtained[d]	Feeding noted[e]	Location on plant[f]
Polia sp.	-	O	L	Phyt.	Sept	1972	A.H.	-	L
Nymphalidae									
Cynthia cardui (L.) painted lady butterfly	Larvae feed on leaves of many weeds, especially sunflower, hollyhock, burdock, and thistles (Gates and Peters 1962)	C	A,L	Phyt.	Jun Jul Aug	1970 1972 1973	A.H.	+	H,L
Vanessa atlanta (L.) red admiral	Larvae feed principally on nettles (Borror and DeLong 1970)	O	A,L	Phyt.	Jul Aug	1972	A.H.	+	L
Pterophoridae									
Platyptilia carduidactyla Riley artichoke plume moth	Larvae feed upon cultivated artichoke and many types of thistle. Attacks floral heads (Peterson 1962)	C	L	Phyt.	Jun Jul	1970 1972 1973	A.H.	+	H
Satyridae									
Euptychia cymela (Cramer) little wood satyr	The larvae of this family feed on grasses (Borror and DeLong 1970)	O	A	Phyt.	Jun	1973	A.H.	-	L
Tortricidae									
Argyrotaenia velutinana (Walker)	Larva is a leaf roller on many different plants (Forbes 1923)	O	L	Phyt.	May Jun	1972	A.H.	+	H
Argyrotaenia sp.	-	O	L	Phyt.	Jul	1972	A.H.	+	L

Table 1. (Continued)

Classification	Habitat or biology observed or reported in the literature	Frequency in collections[a]	Stages[b]	General feeding habit[c]	Month	Year	How obtained[d]	Feeding noted[e]	Location on plant[f]
DIPTERA									
Anthomyiidae									
Paraprosalpia silvestris (Fallen)	-	R	A	Scav.	Jun	1973	D.V.	-	
Asilidae									
Leptogaster murinus Loew	Prey upon plant lice and midges (Cole 1969)	R	A	Pred.	Aug	1972	A.H.	-	L
Calliphoridae									
Phaenicia mexicana (Macquart)	-	O	A	Scav.	Jun	1973	D.V.	-	
Cecidomyiidae									
Dasyneura gibsoni Felt	Larvae feed on developing seeds in the heads of Canada thistle (Detmers 1927)	C	L	Phyt.	May Jun	1970 1972 1973	A.H.	+	H
Chloropidae									
Thaumatomyia glabra Meigen	Larvae have been reported as predators on root aphids (Cole 1969)	C	A	Pred.	Jun Jul	1972 1973	A.H. D.V.	-	L
Dolichopodidae									
Condylostylus caudatus (Weidemann)	Preys upon small soft bodied insects such as, mosquitoes and midges (Cole 1969)	O	A	Pred.	Jun	1973	D.V.	-	L
Dolichopus bifractus Loew	Preys upon small insects. (Cole 1969)	O	A	Pred.	Jun	1973	D.V.	-	L
D. dakotensis Aldrich	Predaceous on small insects (Cole 1969)	C	A	Pred.	Jun	1973	D.V.	-	

Table 1. (Continued)

Classification	Habitat or biology observed or reported in the literature	Frequency in collections[a]	Stages[b]	General feeding habit[c]	Month	Year	How obtained[d]	Feeding noted[e]	Location on plant[f]
Drosophilidae									
Drosophila sp.	Generally scavengers; larvae live on yeasts (Cole 1969)	O	A,	Scav.	Jun	1973	D.V.		
Micropezidae									
Rainieria sp.	Adults usually found in marshes or moist woods, on leaves and stems of plants and on tree trunks (Cole 1969)	R	A	Scav.	Jun	1972	A.H.	-	L
Rhagionidae									
Chrysopilus quadratus (Say)	Both larvae and adults are predaceous on a variety of small insects (Borror and DeLong 1970)	O	A	Pred.	Jun	1973	D.V.	-	
Sarcophagidae									
Sarcophaga kellyi Aldrich	Parasite of grasshoppers (Cole 1969)	R	A	Para.	Jun	1973	D.V.	-	
Scatophagidae									
Cordilura sp.	Adults of some species are known to be predaceous (Cole 1969)	O	A	Scav.	Jun	1973	D.V.	-	
Sciomyzidae									
Tetanocera nanciae Brimley	The adults of this family live in moist places, the larvae are aquatic (Cole 1969)	R	A	Phyt.	Jun	1973	D.V.	-	
Trypetoptera canadensis (Macquart)	-	R	A	Phyt.	Jun	1973	D.V.	-	

Table 1. (Continued)

Classification	Habitat or biology observed or reported in the literature	Frequency in collections[a]	Stages[b]	General feeding habit[c]	Month	Year	How obtained[d]	Feeding noted[e]	Location on plant[f]
Sepsidae									
Sepsis violacea Meigen	The flies are generally scavengers (Cole 1969)	O	A	Scav.	Jun	1973	D.V.	-	
Stratiomyidae									
Actina viridis (Say)	Adult stratiomyids visit flowers of various plants (Cole 1969)	O	A	Scav.	Jun	1971	A.H.	-	L
Nemotelus canadensis Loew	-	R	A	Scav.	Jul	1970	A.H.	-	
N. kansensis Adams	-	R	A	Scav.	Jul	1970	A.H.	-	
Syrphidae									
Allograpta sp.	Most species are aphis feeders (Cole 1969)	O	A	Pred.	Jun	1972	A.H.	-	L
Mesograpta marginata (Say)	Larvae feed on aphids (Cole 1969)	R	A	Pred.	Aug	1972	S.N.	-	
Toxomerus sp.	The larvae are aphis feeders (Cole 1969)	O	A	Pred.	Jun	1973	D.V.	-	
Tachinidae									
Lewisiomma simplex (Fallen)	The tachina flies are internal parasites of many kinds of caterpillars and other insects (Gates and Petera 1962)	O	A	Para.	Jun	1973	D.V.	-	
Lydina aeros (Walker)	-	O	A	Para.	Jun	1973	D.V.	-	

Table 1. (Continued)

Classification	Habitat or biology observed or reported in the literature	Frequency in collections[a]	Stages[b]	General feeding habit[c]	Month	Year	How obtained[d]	Feeding noted[e]	Location on plant[f]
Tephritidae									
Facaeantha culta (Wiedemann)	Larvae of most tephritids feed on plants and fruits; adults frequent flowers (Borror and DeLong 1970)	O	A	Phyt.	Aug	1972	A.H.	-	L
HYMENOPTERA									
Apidae									
Bombus griseocollis (DeGeer) bumble bee	Very beneficial as pollenators of plants (Borror and DeLong 1970)	C	A	Poll.	Jul Aug	1972 1973	A.H.	-	H
Apis mellifera L. honeybee	Beneficial as pollenators.	C	A	Poll.	Jul Aug	1972 1973	A.H.	-	H
Braconidae	Most braconids are parasites on other insects (Borror and DeLong 1970)	O	A	Para.	Jun	1973	D.V.	-	
Cimbicidae									
Cimbex americana Leach	The larvae feed chiefly on elm and willow (Borror and DeLong 1970)	O	L	Phyt.	Jun	1972	A.H.	+	L
Formicidae									
Camponotus sp.	-	R	A	Phyt.	Jun	1971	A.H.	-	L
Ichneumonidae	Most ichneumons are internal parasites of the immature stages of other insects (Borror and DeLong 1970)	O	A	Para.	Jun	1973	D.V.	-	

Table 1. (Continued)

Classification	Habitat or biology observed or reported in the literature	Frequency in collections[a]	Stages[b]	General feeding habit[c]	Month	Year	How obtained[d]	Feeding noted[e]	Location on plant[f]
Platygasteridae									
Inostemma sp.	Most of the platygasterids are parasitic on the larvae of Cecidomyiidae (Borror and DeLong 1970)	R	A	Para.	Jul	1973	D.V.	-	
Scelionidae									
Trimorus sp.	The scelionids are small insects that are parasitic in insect or spider eggs (Borror and DeLong 1970)	R	A	Para.	Jun	1972	A.H.	-	L
Tenthredinidae									
Dolerus sp.	Most of the larvae are external feeders on foliage (Borror and DeLong 1970)	O	L	Phyt.	Jun	1972	A.H.	-	L
Pachynematus extensicornis (Norton) grass sawfly	-	O	A	Phyt.	Jun	1972	A.H.	-	L

Table 2.--Numerical summary of insect taxa collected from Canada thistle, in South Dakota, and their ecological roles.

	No. of taxa in category					Ecological role		
	Families	Genera	Species	Total Taxa	Phytophagous[a]	Predator	Parasite	Scavenger
Orthoptera	3	4	4	4	4			
Thysanoptera	1			1	1			
Hemiptera	8	11	16	16	11	5		
Homoptera	3	6	6	6	6			
Neuroptera	1	1	1	1		1		
Coleoptera	15	36	41	41	22	15		4
Lepidoptera	8	15	17	17	17			
Diptera	17	23	25	25	4	9	3	9
Hymenoptera	8	8	8	10	6		4	

[a]Pollen and nectar feeders are included.

Releases of C. litura.--The thick stand of Canada thistle in the field cage at the Durland release site made it difficult to observe the small C. litura adults, following the release during July and August, 1972. Only 1 or 2 beetles could be observed at any one time on the thistle during the remainder of the summer months. Zwölfer and Harris (1966) reported that in Switzerland, adult C. litura appear to leave their host plants and find hibernation sites before mid-summer. Apparently this was the case with the weevils in the field cage. The last adult observation was made on September 5, 1972, when one adult was found feeding on new thistle growth.

The first indication of overwintering success occurred on April 23, 1973 when one adult weevil was found on newly emerged thistle. Another adult was observed on thistle on May 14, however, no beetles could be found in the cage after this date. By June, a thick stand of thistles had developed in the field cage (Fig. 5).

During June and July, 1973, a large buildup of aphids, Dactynotus sp., and leaf bugs, Poecilocapsus lineatus (F.) occurred on thistle in the cage. These populations fed heavily on the thistle until August. Observations made on July 10-11, showed that many of the thistle plants were lodged and falling over. The leaves of the thistles turned brown and the plants appeared to be dead. Stalk examination showed internal feeding and burrowing damage in about 1/3 of the plants examined. One curculionid larva, probably a Ceutorhynchus, was found inside the stalk near the base on July 11. Burrowing damage and a larva of the stem borer, Lamaria sp., was

Fig. 5.--Canada thistle stand inside field cage, June, 1973.

found in one stalk on August 18.

The thistle stand in the cage continued to decline and by August 15, most of the plants had either died or were severely lodged, (Fig. 6). Thistles in the control area were subjected to the same insect feedings but failed to lodge or die as quickly as in the release area. Likewise, the thistles surrounding the field cage did not die or show any lodging damage.

The cause of the thistle decline in the field cage is difficult to assess. Symptoms of lodged plants, leaves turning brown and eventual death to the weed are similar to those caused by attacks of C. litura; however, no adult weevils were observed during the summer, and only one larva, thought to be C. litura, was found in the stalks examined. The combined stresses of heavy feedings by the aphid, Dactynotus sp., and the leaf bug, P. lineatus, along with internal stalk feeding by possibly C. litura larvae may explain the thistle decline.

A similar pattern developed in the field colony of C. litura which were released during July, 1973. The adults disappeared in the control area and were not observed again until August 30, 1973. At that time 4 adults were found feeding on new thistle growth near the release site.

Rearing Studies of C. rubiginosa.--Attempts to establish a laboratory colony of C. rubiginosa were not successful. The beetles fed readily on the thistle bouquets; however, adult mortality was high and the colonies died out each fall. Even more difficulty was

Fig. 6.--Damaged thistle inside field cage, August, 1973. Note healthy thistle outside of the cage.

experienced in rearing the larval and pupal stages with only a few being reared to adults.

Mating and oviposition occurred on the bouquets each year, with the peak egg-laying period occurring during late August and early September. Eggs were laid generally in groups of 2-4 on the underside of the basal leaves near the midvein. In September 1971, 15 eggs hatched and 11 larvae were successfully reared to adults. The adults, however, failed to mate or oviposit and eventually died.

The colonies received during 1972 and 1973 experienced the same general mortality and decline. In the 1972 colony, the last beetle died on December 1. Oviposition occurred but the eggs failed to hatch.

Bouquets with eggs were kept in the growth chamber for a period of 3-4 weeks. After this period, the foliage on the bouquets had completely dried out or had become moldy. The eggs on the leaves changed color, from light to dark brown and appeared to be dead. In one experiment, the freshly laid eggs were placed on moist cotton in a covered petri dish, but these also failed to hatch.

The lack of sufficient literature on the life history of C. rubiginosa made these rearing attempts more difficult. Possible explanations for the failure of the eggs to hatch are that a diapause stage is needed or that the foliage of the bouquets did not last long enough to complete a life cycle.

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SUMMARY AND CONCLUSIONS

A survey of the native insect fauna found on Canada thistle in South Dakota was conducted from May through October in 1970 and 1973.

A total of 121 insect taxa, representing 9 orders, 64 families, 103 genera and 118 species was found associated with Cirsium arvense. The most common phytophagous insects found feeding on the weed were: the leaf bug, Poecilocapsus lineatus; the plume moth, Platyptila carduidactyla; the head midge, Dasyneura gibsoni; the flea beetle, Systena elongata; and the aphid, Dactynotus sp. All these species are polyphagous and all failed to control the thistle below the economic level.

The common entomophagous insects found were the carabids, Bembidion alternans, Harpalus pennsylvanicus, and Lebia viridis; the coccinellids, Coleomegilla maculata, Cycloneda munda, and Hippodamia convergens Guerin; the clerid, Phyllobaenus lecontei; the flower bug, Orius tristicolor; the nabids, Nabis ferus and N. roseipennis; and the frit fly, Thaumatomyia glabra.

Based on this survey, little or no feeding competition could be expected between the native phytophagous insects and the introduced thistle parasite, Ceutorhynchus litura. The biology of C. litura precludes any significant predation from occurring by the common entomophagous found associated with Canada thistle.

Field releases of the introduced weevil C. litura, were made in Moody County, South Dakota during 1972 and 1973. A total of 99 adults was released during July and August, 1972, into a field cage placed

on a thistle infested permanent pasture. Initial overwintering success was indicated when 2 adults were found in the cage in April and May 1973. The thistle stand in the cage died out during July and August, 1973. This decline probably was due to damage caused by heavy infestations of the aphid, Dactynotus sp.[1], the leaf bug, P. lineatus, and possibly by the weevil C. litura. The lack of natural predators in the field cage permitted the large population of aphids to develop. Approximately 150 adult C. litura were released on the same site during August 1973. Field observations thus far indicate that C. litura could become established in South Dakota. Further studies would be warranted.

Attempts to establish a laboratory colony of the tortoise beetle, Cassida rubiginosa, were not successful. Adult beetles readily fed on the thistle bouquets, mated, and oviposited on the leaves. However, the eggs failed to hatch. Further studies should be conducted on this insect to determine its host plant range, and if field release should be made in South Dakota.

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[1]Following the completion of this manuscript, this aphid was identified as Dactynotus cirsii (L.) by Miss Louise M. Russell, Systematic Entomology Laboratory, Agricultural Research Service, U. S. Department of Agriculture. Her comment states this is a new United States record.

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