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Some aspects of natural control of the European corn borer, Ostrinia nubilalis (Hubner), in Massachusetts.

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Some Aspects of Natural Control of the European Corn Borer, *Ostrinia nubilalis* (Hübner), in Massachusetts

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SOME ASPECTS OF NATURAL CONTROL OF THE EUROPEAN CORN BORER, _OSTRINIA NUBILALIS_ (HBN.), IN MASSACHUSETTS

A Thesis

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Introduction

Due to the often spectacular early successes of modern synthetic insecticides, much of the applied entomological research of the past 25 years has been devoted to these compounds. However, numerous problems associated with the use of insecticides, such as insect resistance, residues in food, and environmental contamination have become apparent. As a result there has been a search for alternative methods of insect control, both through the reëvaluation of older methods and the development of new techniques. One of the areas of renewed interest is the natural control of insects, and particularly the biotic components of natural control, since these are considered to be more subject to manipulation by man.

In Massachusetts, an obvious candidate for the study of its natural control is the European corn borer, *Ostrinia nubilalis* (Hübner). The original site of infestation of this pest in North America is in Massachusetts. This state was also one of the areas of a concentrated effort on the part of the United States Department of Agriculture to control this pest through the release of its imported parasites. Although the corn borer has remained an economic pest in Massachusetts, the U.S.D.A. program was eventually discontinued. For this and other reasons, natural control of this pest in Massachusetts has not been systematically studied since 1947. This study was intended to reveal the current status of parasites, predators, and diseases of the European corn borer in Massachusetts.

Review of Literature -- Natural Control of the European Corn Borer

1. Climatic Factors

It has been proposed that there are two races or strains of the European corn borer present in the United States. One is a univoltine strain, and the other a multivoltine strain (Arbuthnot 1944). The strain present in Massachusetts is multivoltine, and varies from one to two generations per year (Arbuthnot 1949). The presence of a summer flight of moths and the concomitant damage is controlled by temperature and photoperiod (Beck and Apple 1961). Manipulation of photoperiod to induce a fall flight of moths and a consequent reduction of the overwintering larval population has been accomplished experimentally (Hayes *et al*. 1970).

Winter mortality of larvae in New England varied with the severity of the winter and with the type and condition of the plants in which the borers overwintered. However, winter mortality did not exceed 10 per cent during the two years of the study (Barber 1924). Temperature accumulations may be used to predict the date of emergence of a given per cent of the moths, but not the size of the flight (Jarvis and Brindley 1965). Chiang and Hodson (1972) concluded that, at Waseca, Minnesota, corn border populations reach economically significant levels whenever temperatures become favorable. Temperatures below 60°F at night practically inhibit oviposition (Barber 1925a). Heavy rains and winds adversely affected moth survival, oviposition, and larval establishment in New England (Barber 1926a).

Canadian workers concluded that average rainfall per day was the most important climatic factor, and temperature secondary, in determining the number of first generation borers (Barlow et al. 1963). Everett et al. (1958) stated that if June temperatures and rainfall or both were low, the first generation would be light. Barlow and Mutchmor (1963) showed that insufficient drinking water reduced fecundity and lowered adult survival. Also, Kira et al. (1969) stated that available drinking water for adult females was necessary to insure good hatchability of borer eggs.

The size of the second generation is not as easily predictable as the first, possibly because the period of flight is more extended than the first, resulting in less precise evaluation of environmental factors (Barlow 1963). Sparks et al. (1967) were able to correlate both first and second brood populations with the amount of rainfall during the emergence, oviposition, and larval establishment periods, and also with the number of days having wind speeds over eight miles per hour at 10 P.M.

2. Parasites

In their review paper Baker *et al.* (1949) listed both native and exotic parasites of the corn borer in the United States, summarizing their biology and parasitization levels. The importation, release, and recovery records through 1947 were also given. Seven exotic parasites were listed as established: *Lydella thompsoni* Hert. (Tachinidae), *Horogenes punctorius* (Rom.) and *Macrocentrus grandii* Boid. (Braconidae), *Chelonus annulipes* Wesm., *Phaogenes nigridens* Wesm. and *Zaleptopygus flavo-orbitalis* (Cam.) (Ichneumonidae), and *Sympiesis viridula* (Thoms.) (Eulophidae). *P. nigridens* is a pupal parasite, while the remainder attack the larval stage. A review of the status of exotic parasites of the European corn borer in Canada was compiled by McLeod (1962).

The status of exotic corn borer parasites in the United States has been reviewed several times since 1949 (Arbuthnot 1950, Arbuthnot 1953, York 1955). These surveys indicated that *M. grandii*, with parasitism levels of 20 to 30 per cent, was the most important parasite in New England. *C. annulipes* was of importance only in certain areas of southern New England. *H. punctorius* was considered established on the Atlantic coast and in the Midwest, although *L. thompsoni* was most important in the latter area.

Exotic parasites have also been surveyed at the state level. At East Hartford, Connecticut, *L. thompsoni*, *C. annulipes*, *H. punctorius*, and *M. grandii* were present, with *H. punctorius* being displaced by *M. grandii* as the most effective parasite (Arbuthnot 1955). With the exception of *H. punctorius*, these parasites were also recovered in

Delaware where L. thompsoni was by far the most numerous (McCreary and Rice 1949, Milliron 1953). After its initial success in Delaware, Lydella disappeared and was subsequently reintroduced (Van Denburgh et al. 1962). In Maryland, L. thompsoni was reported widely distributed and abundant, and M. grandii was considered established (Cory et al. 1952). L. thompsoni, H. punctorius, and S. viridula were recovered in Ohio. Although widely distributed in Ohio, Sympiesis was of little importance (Rolston et al. 1958). In Indiana Arbuthnot and Wright (1951) found both L. thompsoni and S. viridula to be widely distributed, but only the former was present at significant levels, while Blickenstaff et al. (1953) found a similar situation in Iowa. In Georgia a species of Lixophaga (Tachinidae) and a species of Campoletis (Ichneumonidae) have been reared from corn borer larvae (Miller 1971). S. viridula has recently been recovered for the first time in Quebec (Hudon 1965).

L. thompsoni was released on Guam, along with several other borer parasites. It soon reached parasitism levels of 50 to 100 per cent, but had to be reintroduced within 15 years, with no apparent success (Peterson 1955). Eighteen species of tachinids, with L. thompsoni the most important, parasitize the corn borer in the Union of Soviet Socialist Republics (Chao 1961). In the region near Zemun, Yugoslavia, H. punctorius was the major parasite, with L. thompsoni and Campoplex alkae (Ell. and Sacht.) also causing some reduction in the corn borer population (Bjegović and Lazarević 1963).

Although L. thompsoni is often listed, particularly in midwestern surveys, as the most effective parasite of the European corn borer, it is poorly synchronized with its host. In Iowa it emerges too early to parasitize the corn borer, so one generation is carried out on the common stalk borer, Papainema nebris (Guen.) (Noctuidae), and two subsequent generations are carried out on O. nubilalis (Jarvis and York 1961). In Minnesota Lydella can produce four generations per year if P. nebris is present and three generations if it is not (Hsiao and Holdaway 1966). Larviposition by L. thompsoni is stimulated by a metabolic product in the frass of several lepidopterous larvae (Hsiao et al. 1966). Lydella is attracted to the corn borer first by its preference for a particular corn hybrid and only secondarily to borer larvae (Franklin and Holdaway 1966). Jarvis and York could not correlate the population fluctuations of these two insects with each other. Chiang and Hodson (1972) stated that this fly is no longer found in the north-central states.

S. viridula has also been reared from the common stalk borer (York et al. 1955). Most records of this insect indicate that, although it is widely distributed, it rarely reaches significant levels of parasitism. A study has shown that the probable reason for its lack of efficiency is that, while the majority of suitable corn borers are found in the corn plant below the ear shank, the female parasite's host-searching is generally limited to that portion above the ear shank (Showers and Reed 1969).

Of the other exotic parasites considered established in the U.S. by Baker et al. (1949), P. nigridens and Z. flavo-orbitalis were not subsequently recovered. Also no further work, other than survey reports, has been published on C. annulipes, H. punctorius or M. grandii.

There are no recent references to parasites of European corn borer eggs in North America, although some work has been conducted in this area in eastern Europe. In that area egg parasitism by *Trichogramma evanescans* West. (Trichogrammatidae) has reached a reported maximum of 75 per cent, and levels of 50 per cent or more are common (Birova 1962, Perju 1959). Artificial releases of trichogrammatids have resulted in reductions in borer damage up to 71.9 per cent (Guseva 1962, Tkalich 1961).

3. Diseases

a. Bacteria

Metalnikov and Chorine (1928) reviewed the early work with the bacteria associated with the corn borer and described three new species. Husz (1928) gave the first report of _Bacillus thuringiensis_ Berliner being highly pathogenic to _O. nubilalis_. Chorine (1929) confirmed this finding while reporting five additional species as being pathogenic. _B. thuringiensis_ spores withstood temperature extremes well and gave up to 50 per cent reduction in corn borer damage in preliminary field trials (Husz 1929). A number of other attempts have been made to employ _B. thuringiensis_ as a microbial insecticide, including Hudon (1963) and Raun and Jackson (1966). Other studies of the relationship between _B. thuringiensis_ and the corn borer have treated effects on borer developments (Sutter and Raun 1966), environmental factors affecting pathogenicity (Raun _et al_. 1966), and histopathology (Sutter and Raun 1967).

Further work on bacterial infections affecting the borer in the field has been carried out (Beers _et al_. 1959, Raun and Brooks 1963). Nesbitt and Zimmack (1968) found reduced fecundity in females reared from borer eggs sprayed in the laboratory with suspensions of _Serratia marcescens_ Bizio and _Escherichia coli_ (Migulo). Esterline and Zimmack (1972) described the histological effects of these two species on the borer.

b. Fungi

Metalnikov and Toumanoff (1928) reported several species of entomophilic fungi, including _Beauveria bassiana_ (Bals.) Vuill. as being pathogenic to the European corn borer. Toumanoff (1928) showed the routes of infection of the corn borer by *Aspergillus flavus* Link and *Spicaria farinosa* (Fron.) to be through the integument, but noted no special temperature or humidity requirements. The route of infection of *O. nubilalis* by *Metarrhizium anisopliae* (Metch.) is also through the integument (Wallengren and Johansson 1929).

Lefebvre (1934) made a histological study of the infection of the corn borer by *B. bassiana*. Bartlett and Lefebvre (1934) conducted field trials with *B. bassiana* against the corn borer, with promising results. These early attempts to employ *B. bassiana* as a microbial insecticide were discontinued due to difficulties in obtaining sufficient spores (Clausen 1956). York (1958) found the maximum effectiveness of *B. bassiana* to be equivalent to that of chemical insecticides, but noted personal physical debilitation from handling the spores. *M. anisopliae* and *B. bassiana* were compared as to their effectiveness against the corn borer in the laboratory and in the field. They were of equivalent pathogenicity in the laboratory, but *B. bassiana* gave superior control in field trials (Smith 1961). These two species, along with *Aspergillus parasiticus* Speare, were the most pathogenic of twelve fungal species isolated from corn borer larvae collected in Iowa (Brooks and Raun 1962). One species of *Cephalosporium* has been found infecting corn borer larvae in the field. No cytological change in either cells or tissue was found in the borers at the time of death (Baird 1954).

c. Nematodes

Kotlán (1928b) described the first nematode, *Diplogaster brevicauda*, associated with the corn borer, and stated that the relationship was possibly parasitic. Hergula (1930a) reported a species of Mermis parasitizing less than 0.1 per cent of a borer population in Yugoslavia. Clark (1934) found Hexamermis meridionalis Steiner parasitizing the corn borer in Japan. It was found only in a small area, but parasitization there reached 31 per cent. The corn borer has also been shown to be quite susceptible to a species of Neoaplectana isolated from the codling moth, Laspeyresia pomonella (L.) (Olethreutidae) (Dutky and Hough 1955). This nematode, referred to as DD 136, was used in field tests against several vegetable crop pests. The best control by this nematode was against the corn borer (Welch and Briand 1961), although reduction in borer damage was not comparable to that obtained with chemicals (Briand and Welch 1963).

d. Protozoa

Three protozoan species have been described from the European corn borer. Paillot (1927) described Leptomonas pyraustae as a rare flagellate with different morphologic forms found in the Malpighian tubules, the midgut, and the haemolymph. He also described Perezia pyraustae, a microsporidan found in the silk glands and Malpighian tubules of the larvae. Kotlán (1928a) described a similar species, Nosema pyraustae, from the larval muscle tissue. It has been suggested that these two are the same species (Steinhaus 1949); and Weiser (1961) has placed P. pyraustae in the genus Nosema, although the original nomenclature has been retained in most subsequent literature.

Hall (1952) studied the morphology and life cycle of a microsporidan found in diseased larvae from Iowa. He reported it to be P. pyraustae, and that his was the first record of this parasite in the

United States. Kramer studied the morphology and life cycle of *P. pyraustae* (1959c) and discussed size and shape variations among the spores (1960). A larger form which invades adipose tissue, suggesting another variety or species, has also been reported (Suranzi 1955).

P. pyraustae lowers the growth and survival rates of borer larvae (Kramer 1959b; Zimmack *et al*. 1954). Kramer (1959a) also reported that the disease interacts with temperature to cause mortality in host populations in the field. It is found in the Malpighian tubules and reproductive structures of the adults, its presence causing reduced life span of this stage (Kramer 1959b; Zimmack *et al*. 1954). Infected adult females lay fewer egg masses containing fewer eggs, of which no less than one half are infected (Kramer 1959b; Zimmack and Brindley 1957). This infection is transovarial, the eggs being contaminated both internally and externally (Kramer 1959b; Paillot 1928; Zimmack and Brindley 1957). There is a tendency for borers reared on borer-resistant inbred lines of corn to have lower percentages of *P. pyraustae* infections than those reared on borer-susceptible inbred lines (Yamamota 1956). *P. pyraustae* raises oxygen consumption slightly in larvae, pupae, and adults (Lewis *et al*. 1971).

The presence of *P. pyraustae* makes laboratory rearing of borers difficult. Various methods have been used to eliminate microsporidiosis from laboratory colonies, including heat (Raun 1961) and drugs (Lewis and Lynch 1969, 1970; Lynch and Lewis 1971).

Raun *et al*. (1960) described a quantitative method to determine rates of infection, and gave rates and incidence of microsporidiosis in corn borer samples from eight different states. Similar data were reported from Delaware by Van Denburgh and Burbutis (1962), while Hill *et al*. (1967) and Frye (1971) gave further data from some of the north-central states.

There have been several attempts at field application of *P. pyraustae*. Zimmack *et al*. (1954) conducted inconclusive field tests. Decker (1960) stated that diseased borers had been artificially distributed in certain areas in Illinois, and that the disease had become one of the major factors keeping the borer populations in check in these areas. Dresner (1958) reported the importation of *P. pyraustae* into Indonesia for use against cane and rice borers.

e. Viruses

One virus has been found in the corn borer. The virus manifests itself in the fifth larval instar and affects the fat body and gut walls of the insect (Raun 1963). Electron microscope studies revealed the virus to be of the noninclusion type, similar to *Moratorvirus lamellicornium*, found in *Melolontha* spp. (Scarabaeidae) (Adams and Wilcox 1965).

4. Predators

There have been a number of studies of European corn borer egg predators, although few of these have been quantitative in nature. Froeschner (1950) found 34.2 per cent of the egg masses sampled in Iowa showing signs of predation. He observed Chrysopa oculata Say and C. plorabunda (Fitch) (Chrysopidae), Coleomegilla maculata (De Geer) and Hippodamia 13-punctata (L.) (Coccinellidae), and Orius insidiosus (Say) (Anthocoridae) feeding on eggs. Bartholomai (1954) found the level of egg predation in Indiana to be 8.7 per cent on the first generation and 37.8 per cent on the second generation. He recorded Adalia bipunctata (L.), Coccinella 9-notata Herbst, Cycloneda sanguinea (L.) and Hippodamia parenthis (Say) (Coccinellidae), and Trombidium fuliginosum Koch (Acarina, Trombidiidae), as well as undetermined mites, thrips, nabids, and reduviids in addition to the egg predators mentioned by Froeschner. T. fuliginosum larvae were observed to have eaten 16 per cent of the corn borer eggs in an experimental field in Yugoslavia (Hergula 1930b). Conrad (1959), by sampling for the presence or absence of adult fecal pellets in Delaware, found that 15.3-16.5 per cent of observed egg masses were fed on by C. maculata. In addition, Beard (1943) listed Nabis ferus L. as feeding on corn borer eggs in Connecticut.

Orius insidiosus, a small pirate bug, sometimes becomes quite abundant on corn. It has often been observed feeding on corn borer eggs, but only at times when pollen is not abundant (Dicke and Jarvis 1962). Barber (1926b) stated that this insect had been recorded as attacking 22 species of insects, and discussed its biology in depth.

A method of evaluating the intensity of predation on borer larvae through predator exclusion was first described by Chiang and Holdaway (1955). They listed C. maculata, C. plorabunda, H. convergens, H. 13-punctata, O. insidiosus, and Sphaerophoria cylindrica (Say) (Syrphidae) as larval predators. Sparks et al. (1966) reported results of evaluating predation on corn borer larvae in several midwestern states over several years. Predation was a major factor controlling borer populations in some locations in some years. They added A. bipunctata, C. 9-notata, Coccinella trifasciata (L.), H. parenthis, and Chrysopa cornea Stephens to the list of larval predators. Frye (1972b) reported similar data for North Dakota, and added C. oculata to the list of corn borer larval predators.

A study of the relationship between the corn borer and Glischrochilus quadrisignatus (Say) (Nitidulidae) revealed that 80 per cent of the dead 3rd, 4th, and 5th instar borers were associated with this fungus beetle. It is believed that borer larvae were mechanically injured through contact with the beetles in the tunnels. Weakened and dead borers were then attacked by these scavengers. Eight per cent total reduction of the larval borer population was attributed to this interaction in Iowa (McCoy and Brindley 1961).

Additional insects reported as preying on corn borer larvae include elaterids (Zwölfer 1928), Podisus placidus Uhler (Pentatomidae) and Sinea diadema Fab. (Reduviidae) (Caffrey and Worthley 1927); Podisus maculiventrus (Say) and O. insidiosus (Say) (Barber 1926a); Chrysopa vulgaris Schneider (Paillot 1928); and Heliothis zea (Boddie) (Vinal and Caffrey 1919). In Europe, ants of the genus Lasius and the ant Tetramorium caespitum Latreille are known to prey on hibernating larvae and pupae (Kotlán 1929, Paillot 1928, Zwölfer 1928). Hergula (1930b) observed the ants Lasius emarginatus Oliver and Myrmica laevinodis Nylander attacking and killing, but not eating, young and full grown larvae. A Canadian worker also listed ants as predators of the larvae (Caesar 1925).

Few vertebrates are known to feed on corn borer larvae. A shrew, Crocidura leucodon Hermann, was observed feeding on borers in Europe (Zwölfer 1928). Barber (1926a) in New England observed several species of mice feeding on overwintering borers. Birds, particularly Dendrocopos pubescens (Swainson) and D. villosus (L.), however, do become a significant reductive force at certain times in certain locations. Barber (1925b) found maximum winter avian predation levels of 84 per cent in New England, reporting, in addition to D. pubescens, Parus atricapillus (L.), Sturnus vulgaris L., Euphagus carolinus Müller, and Quisculus quiscula (L.). Average predation was 18 per cent. In a follow-up to Barber's work, Baker et al. (1949) found avian predation levels averaging 15 per cent in Ohio and 30 per cent in Indiana. They observed an additional five species of birds (Agelaius phoeniceus (L.), Corvus brachyrhynchos Brehm., D. villosus (L.), Phasianus colchicus Gmelin, and Turdus migratorius (L.)) feeding on corn borers. Weekman (1956) in Iowa found that woodpeckers caused a 31 per cent reduction in an overwintering borer population. Stoltenow (1968) in North Dakota found that bird predation was influenced by levels and distribution of borer damage, and also by the habitat types found around the corn fields. Frye (1972a), in the same state, concluded that bird predation has a significant effect on borer populations during the fall, winter, and spring. The effect of bird predation on winter borer populations in Arkansas has also been studied (Wall and Whitcomb 1964); and further qualitative observations on avian predation of *O. nubilalis* were offered by Fankhausen (1962) and Kohl (1960).

Barber (1926a) made the only observations on predation on borer adults. He considered avian predation unimportant, but reported *Asilus erythrocnemius* Hine and *Asilus sericeus* Say (Asilidae) as moth predators.

Table 1. Summary of European corn borer predators included in this review of literature

Classification of predators	Reference	Locality	Stage attacked
Class Insecta			
Order Thysanoptera			
Misc. spp.	Bartholomai (1954)	Ind.	eggs
Order Hemiptera			
Family Anthocoridae			
Orius insidiosus (Say)	Froescher (1950)	Iowa	eggs
	Chiang and Holdaway (1955)	Minn.	young larvae
Family Nabidae			
Nabis ferus L.	Beard (1943)	Conn.	eggs
Misc. spp.	Bartholomai (1954)	Ind.	eggs
Family Reduviidae			
Sinea diadema Fab.	Caffrey and Worthley (1927)	U.S.	larvae
Misc. spp.	Bartholomai (1954)	Ind.	eggs
Family Pentatomidae			
Podisus maculiventrus (Say)	Barber (1926a)	New England	larvae
Podisus placidus Uhler	Caffrey and Worthley (1927)	U.S.	larvae
Order Coleoptera			
Family Elateridae			
Misc. spp.	Zwölfer (1928)	Europe	larvae
Family Nitidulidae			
Glischrochilus quadrisignatus (Say)	McCoy and Brindley (1961)	Iowa	larvae

Table 1 (continued)

Classification of predators	Reference	Locality	Stage attacked
Family Coccinellidae			
Adalia bipunctata (L.)	Bartholomai (1954)	Ind.	eggs
	Sparks *et al*. (1966)	Midwest	larvae
Coccinella 9-notata Herbst	Bartholomai (1954)	Ind.	eggs
	Sparks *et al*. (1966)	Midwest	larvae
Coccinella trifasciata (L.)	Sparks *et al*. (1966)	Midwest	larvae
Coleomegilla maculata (De Geer)	Froeschner (1950)	Iowa	eggs
	Chiang and Holdaway (1955)	Minn.	larvae
Cycloneda sanguinea (L.)	Bartholomai (1954)	Ind.	eggs
Hippodamia convergens Guérin-Méneville	Chiang and Holdaway (1955)	Minn.	larvae
Hippodamia parenthis (Say)	Bartholomai (1954)	Ind.	eggs
	Sparks *et al*. (1966)	Midwest	larvae
Hippodamia 13-punctata (L.)	Froeschner (1950)	Iowa	eggs
	Chiang and Holdaway (1955)	Minn.	larvae
Order Neuroptera			
Family Chrysopidae			
Chrysopa carnea Stephens	Sparks *et al*. (1966)	Midwest	larvae
Chrysopa oculata Say	Froeschner (1950)	Iowa	eggs
	Frye (1972)	N. Dak.	larvae
Chrysopa plorabunda (Fitch)	Froeschner (1950)	Iowa	eggs
	Chiang and Holdaway (1955)	Minn.	larvae
Chrysopa vulgaris Schneider	Paillot (1928)	Europe	larvae
Order Lepidoptera			
Family Noctuidae			
Heliothis zea (Boddie)	Vinal and Caffrey (1919)	Mass.	larvae

Table 1 (continued)

Classification of predators	Reference	Locality	Stage attacked
Order Diptera			
Family Asilidae			
Asilus erythrocnemius Hine	Barber (1926a)	New England	adults
Asilus serviceus Say	Barber (1926a)	New England	adults
Family Syrphidae			
Sphaerophoria cylindrica (Say)	Chiang and Holdaway (1955)	Minn.	larvae
Order Hymenoptera			
Family Formicidae			
Lasius emarginatus Oliver	Hergula (1930b)	Europe	larvae
Lasius spp.	Paillot (1928)	Europe	larvae
Myrmica laevinodis Nylander	Hergula (1930b)	Europe	larvae
Tetramorium caespitum Latreille	Zwölfer (1928)	Europe	larvae
Class Arachnida			
Order Acarina			
Misc. spp.	Bartholomai (1954)	Ind.	eggs
Family Trombidiidae			
Trombidium fuliginosum Koch	Bartholomai (1954)	Ind.	eggs
Class Aves			
Order Galliformes			
Family Phasianidae			
Phasianus colchicus Gmelin	Baker *et al.* (1949)	U.S.	larvae
Order Piciformes			
Family Picidae			
Dendrocopos pubescens (Swainson)	Barber (1925b)	New England	larvae
Dendrocopos villosus (L.)	Baker *et al.* (1949)	U.S.	larvae

Table 1 (continued)

Classification of predators	Reference	Locality	Stage attacked
Order Passeriformes			
Family Corvidae			
Corvus brachyrhynchos Brehm.	Baker *et al.* (1949)	U.S.	larvae
Family Paridae			
Parus atricapillus (L.)	Barber (1925b)	New England	larvae
Family Turdidae			
Turdus migratorius (L.)	Baker *et al.* (1949)	U.S.	larvae
Family Sturnidae			
Sturnus vulgaris L.	Barber (1925b)	New England	larvae
Family Icteridae			
Agelaius phoenicius (L.)	Baker *et al.* (1949)	U.S.	larvae
Euphagus carolinus (Müller)	Barber (1925b)	New England	larvae
Quisculus quiscula (L.)	Barber (1925b)	New England	larvae
Class Mammalia			
Order Insectivora			
Family Soricidae			
Crocidura leucodon Hermann	Zwölfer (1928)	Europe	larvae
Order Rodentia			
Family Muridae			
Misc. spp.	Barber (1926a)	New England	larvae

Materials and Methods

1. Parasite Survey

Fifth instar borers were collected at various localities (listed in Table 3) throughout Massachusetts from both overwintering and first generation populations during the period from October, 1971 through July, 1973. Individual larvae were placed in separate vials (4 drams) which were stopped with cotton.

The borer-containing vials from the 1971 collection were kept in closed containers, along with moistened paper towels, at room temperature. All other collections were placed in a growth chamber set with 16L:8D photoperiod, 80°F day and 70°F night temperatures, and 90% relative humidity.

After parasite emergence, the percentage of borers parasitized by each species was recorded, as was the total per cent parasitization of the borers in each collection. In collections taken from the first generation populations, the total per cent of borers parasitized was adjusted for the fraction of borers which had already pupated at the collection site at the time the collection was made. This was done in order to give a better idea of the overall parasitization level in that areas.

In the case of *Macrocentrus grandii*, by far the most abundant and important parasite, the sex and number of the adults of this polyembryonic insect in each colony were observed. If adult wasps failed to emerge, the number of larvae or pupae were recorded.

Only one collection of borer pupae was made (May 1972) and this was treated in the same manner as a larval collection. A number of pupae were inspected in the field for the oviposition scars that are characteristic of pupae parasitized by *Phaogenes nigridens*.

Finally, several hymenopterous and dipterous pupae were found associated either with a borer head capsule, a borer tunnel or both. These were also collected and treated in a manner similar to that described above for the borers. In all but the case of *Sympiesis viridula*, each of these was counted as emerging from a collected borer and included in per cent parasitization figures.

2. *Perezia pyraustae* Survey

Collections of 50 borers each were taken from 12 localities in Massachusetts which represented all the mainland counties except Suffolk. The collections from Berkshire and Franklin Counties and the Amherst locality in Hampshire County were taken from borer populations in field corn. The remaining collections were all taken from sweet corn populations.

The method used to determine *P. pyraustae* infection levels in the collected borers was essentially that of Raun *et al*. (1960). Each borer was weighed to the nearest mg. and then placed in a 40 ml. tissue grinder. To this was added 0.1 ml. of distilled water for each 3 mg. of body weight of the specimen. The borer was then homogenized and some of the homogenate was transferred with a Pasteur pipette to the counting chamber of an Improved Neubauer hemacytometer. A cover slip was then placed over the chamber and the four smallest squares at each corner plus the four smallest squares in the center of the chamber were examined microscopically for *P. pyraustae* spores. Spore counts from the 1972 collections were made at 600X (phase contrast) with a Wild M 11 compound microscope. Counts from the 1973 collections were made with the same model of microscope at 1500X (bright field).

Spore counts for the 20 squares were then multiplied by 6,666 to obtain the number of spores per mg. of body weight. This result was multiplied by the total body weight of each infected borer to obtain the total number of spores per borer. At the dilution rate given above, Raun *et al*. state that this method is accurate to ±6,000 spores per mg.

of body weight. Average spore count per mg. of borer body weight and average spore count per mg. of infected borer body weight were also computed for each collection.

3. Quantitative Predation Studies

The predator exclusion studies were conducted during August and early September of 1972, in a manner similar to that reported by Sparks *et al*. (1966).

Six rows were randomly selected in each of two fields of sweet corn in the green tassel stage in Holyoke, Massachusetts. Within each row, two groups of three corn plants each were randomly selected. Each plant was artificially infested with approximately 60 borer eggs obtained from the USDA Corn Borer Laboratory at Ankeny, Iowa. One of the two groups of plants in each row was then cleared of predacious insects and enclosed with a cage. The cages were six feet tall and three feet square; they were constructed from one by one-half inch wood strips and standard mesh aluminum screen. The uncaged plants were checked periodically for native egg masses. When the borers reached the fifth instar, the number of borers surviving in the caged plants was compared to the number surviving in the uncaged plants in the same row. An index of predation intensity was arrived at through the following formula from Sparks *et al*. (1966):

$$\text{I (index)} = \frac{(\text{No. of borers/caged plants} - \text{No. borers/uncaged plants}) \times 100}{\text{No. borers/caged plants}}$$

Results and Discussion

1. Parasite Survey

a. Exotic parasites

Of the seven imported species of insects parasitic on *O. nubilalis* considered established in the United States by Baker *et al.* (1949), only three, *Sympiesis viridula*, *Horogenes punctorius*, and *Macrocentrus grandii* were recovered in Massachusetts. *Chelonus annulipes* was not recovered, although it has been considered established in southeastern Massachusetts (Arbuthnot 1950) and established and on the rise in the Hartford, Connecticut area (Arbuthnot 1955). Most conspicuous by its absence was *Lydella thompsoni*, once considered the most important of the corn borer parasites and most recently reported by York (1955) to be consistently present in low numbers on the East Coast.

Sympiesis viridula (determined by B. D. Burks), hitherto unreported from Massachusetts, was recovered, but not in significant numbers. Three overwintering pupae were found in Amherst on March 30, 1972, and two were found in West Bridgewater on May 18, 1972. These results are consistent with this insect's reputation for wide distribution with low levels of parasitization.

Horogenes punctorius (determined by P. M. Marsh) also was recovered in only limited numbers at two localities. In a collection of 60 borers made in Waltham on July 30, 1973, five specimens were found, a per cent parasitization of 8.3. In a collection of 11 corn borers made on July 24, 1973 in Danvers, one specimen was found parasitized by *H. punctorius*. Arbuthnot (1953) reported that this species was declining on the East Coast, and apparently this trend has continued.

Arbuthnot also reported that *M. grandii* had become a quite important parasite in southern New England. This is still the case. Of the 12 collections of corn borers examined for parasites, *M. grandii* (determined by P. M. Marsh) was found in all. A total of 1498 borers were examined, and of these 334 or 22.4 per cent were killed by *M. grandii*. Percentages of parasitization ranged from 6.3 in Bridgewater to 60 in West Bridgewater, and are summarized in Table 1. Baker *et al*. (1949) stated that the heaviest populations of *M. grandii* were centered around Bridgewater, Massachusetts, and reported a maximum parasitization of 56.3 per cent. It is interesting to note that the highest parasitization encountered in this survey (60 per cent) was also found in the Bridgewater area. York (1955) stated that *M. grandii* had established equilibrium in southern New England at parasitization levels of 20 to 30 per cent. This situation appears unchanged after nearly 20 years.

Parker's (1931) extensive studies of *M. grandii* included morphology, development, laboratory behavior, and phenology in Europe. He reported 71 male colonies to average 24.0 individuals, 54 female colonies to average 16.2, and 75 mixed-sex colonies to average 20.9. In the Massachusetts survey 98 male colonies averaged 19.3 individuals, 111 female colonies averaged 18.0, and 21 mixed-sex colonies averaged 29.0. These figures are similar except for the number of mixed-sex colonies, Parker finding 39.4 per cent mixed colonies while in Massachusetts only 9.1 per cent of the colonies were mixed. Wishart (1946) gave data for

80 field-collected colonies of M. grandii which are more similar to those for Massachusetts. Only 7.7 per cent of the colonies were mixed, averaging 23.8, while male and female colonies averaged 20.9 and 17.9 individuals respectively.

One possible reason for the discrepancies in percentages of mixed colonies might be differences in host populations. Over half of the mixed colonies in Massachusetts came from one collection made at a farm in West Bridgewater with high borer populations (discussed below in the section on N. pyraustae). Unfortunately data for the borer populations from which Wishart and Parker collected are not available. Another aspect is the fact that Parker was working with the European strain of M. grandii, which can develop only on univoltine borers (Wishart 1946). This strain, along with the oriental strain which does not require a host diapause for development (Wishart 1946), were introduced into Massachusetts. Both Massachusetts and Ontario, the area in which Wishart collected, are predominantly populated by multivoltine borers. Most of the M. grandii from these areas, therefore, are probably of the oriental strain, thus providing a possible explanation for the above discrepancies.

The mixed-sex colonies are of interest because in most cases one sex dominates in numbers of individuals in a colony. Of Wishart's 134 laboratory-reared mixed colonies, 6.7 per cent had equal numbers of sexes, whereas four per cent of Parker's mixed colonies and none of the Massachusetts mixed colonies had equal numbers. A student's t-test comparing sex numbers in Parker's mixed colonies and also those from Massachusetts yielded a t-value of .054 with 190 degrees of freedom, indicating that neither sex may be expected to dominate the numbers of a colony. This is contrary to Wishart's conclusion that, in mixed colonies, females outnumber the males in the majority of instances. When the numbers of the majority sex were tested against the numbers of the minority sex, the t-value was 17.4, indicating that one sex can be expected, with 99 per cent confidence, to dominate the numbers in a mixed-sex colony. Since, according to Parker, usually only one or two eggs are deposited in the borer host, and since only one sex is derived from an egg, the above can probably be best explained by larvae from the first-hatched egg out-competing those hatching later.

One problem encountered in this survey that Parker did not experience was failure of the M. grandii colonies to reach adulthood. This occurred in 27.8 per cent of the colonies reared from the borers. This should not affect survey data, but could become a problem if the parasite were being reared for release. According to Wishart (1946), M. grandii larvae need to be confined when they emerge from the host in order to form a normal cocoon mass. This was not done with the Massachusetts collections and this neglect may have been the cause of the high mortality. However, the number of individuals in unemerged colonies averaged little more than half that of an average adult colony. Such a difference in numbers may indicate that a disease or some nutritional factor may be involved.

Judging from its wide distribution and steady and occasionally high percentages of parasitization over the years in Massachusetts, it would seem that M. grandii would be a prime candidate for inclusion in any program of biological control directed at the corn borer in this state. Furthermore, both host (Reed *et al*. 1972) and parasite (Wishart 1946) have been reared in the laboratory, which indicates that mass rearing may be feasible. Also encouraging is the fact that another member of the same genus, *M. ancylivorus* has already been used with some degree of success in biological control programs against the Oriental fruit moth, *Grapholitha molesta* (Busck) (Olethreutidae) (Clausen 1956). Very little is known about the field biology of *M. grandii*, however, and an intensive study of this area is essential. Such a study would reveal and perhaps remedy any factors limiting the parasite's effectiveness. Also of importance is the current status of the two strains of *M. grandii* and their relationships to uni- and multivoltine borers in Massachusetts.

Table 2. *Macrocentrus grandii* reared from *Ostrinia nubilalis* collected in Massachusetts, 1971-73.

Locality	Date	Number of borers	Number of male colonies--average number of individuals	Number of female colonies--average number of individuals	Number of unemerged colonies--average number of individuals	Per cent parasitization
Barnstable Co.						
(E. Sandwich)	VII-23-73	60	1--22.0	1--26.0	16--15.9	30.0
Essex Co.						
(Danvers)	VII-24-73	11	1--48.0	0-- 0	0-- 0	9.1
(Ipswich)	VII-12-73	60	3--21.7	2-- 8.5	1--18.0	25.0[a,b]
(Waltham)	VII-30-73	60	0-- 0	0-- 0	3--21.0	11.7[a]
Franklin Co.						
(S. Deerfield)	X- 1-71	300	33--16.7	40--16.2	4-- 7.3	25.7
Hampden Co.						
(Holyoke)	VIII- 4-72	60	2--26.5	3--17.3	0-- 0	8.3
Hampshire Co.						
(Easthampton)	VII-28-72	60	2--11.5	7--20.9	0-- 0	15.0[c]
Norfolk Co.						
(Attleboro)	VII-16-73	60	8--28.1	6--19.8	3-- 6.7	28.3
Plymouth Co.						
(Bridgewater)	VII-30-73	32	0-- 0	0-- 0	0-- 0	6.3[a]
(W. Bridgewater	VIII- 3-72	60	1-- 7.0	4--25.0	1--12.0	10.0[c]
	X-15-72	675	42--17.2	39--16.4	54-- 8.3	21.0[d]
	VII-20-73	60	5--34.8	9--28.4	10--12.7	60.0[e]
Total		1498	98--19.3	111--18.0	92--10.5	22.4[a,f]

a) Percentage includes colonies observed in field, not reared from collected borers.
b) Included are two mixed-sex colonies, averaging 22.5 adults.
c) Not a true figure as colonies encountered while collecting were not recorded.
d) Included are seven mixed-sex colonies, averaging 22.9 adults.
e) Included are 12 mixed-sex colonies, averaging 33.7 adults.
f) Included are 21 mixed-sex colonies, averaging 29.0 adults.

b. Native parasites

Three different native tachinid parasites were recovered from corn borers during the Massachusetts parasite survey. The first, *Aplomya caesar* (Aldrich) (determined by C. W. Sabrosky), was found parasitizing one per cent of 300 borers collected from South Deerfield on October 1, 1971. It was also found parasitizing 0.7 per cent of 675 borers collected in West Bridgewater on October 15, 1972, and 3.3 per cent of 60 borers collected on August 4, 1972 in Holyoke. According to Baker *et al*. (1949), this insect was the most abundant of the native larval parasites of the corn borer, but it never reached significant levels of parasitization in the United States. In Ontario one collection of borers was found to be 26 per cent parasitized by *A. caesar* (Wishart 1945).

Secondly, a species of *Lixophaga* (determined by C. W. Sabrosky) emerged from 8.3 per cent of 60 borers collected in Holyoke on August 4, 1972. In the same collection were six dipterous puparia very similar in appearance to those of the *Lixophaga*. Adults failed to emerge from these, but if they were the same species the total parasitization by *Lixophaga* in this collection would have been 18.3 per cent. Baker *et al*. (1949) reported the collection of several *Lixophaga* puparia from borer-infested plants, and Miller (1971) found a *Lixophaga* species parasitizing one of eight borers collected in Georgia.

In addition, two unidentified tachinids were reared, in each instance both host and parasite pupae being formed. One was found in a collection of 11 borers made on July 24, 1973 in Danvers, and one in a collection of 60 borers from Attleboro made on July 16, 1973.

As can be seen from Table 3, when the performances of all species are compared, in only two instances was the level of parasitization by *M. grandii* equaled or surpassed by other species. In one of these cases the sample consisted of only 11 borers and was thus not representative. In the other case native tachinids combined to kill about twice as many borers as did *M. grandii*. Of the grand total of 1498 borers examined, 24.2 per cent were parasitized. Of these, 92.0 per cent were killed by *M. grandii*. This is further evidence of the importance of this insect as a natural enemy of the European corn borer.

Table 3. Parasites reared from <u>Ostrinia nubilalis</u> in Massachusetts, 1971-73

Locality	Date	No. of borers	Per cent *M. grandii*	Per cent *H. punctorius*	Per cent *A. caesar*	Per cent *Lixophaga* sp.	Per cent unidentified tachinids	Total per cent parasitization
Barnstable Co.								
(E. Sandwich	VII-23-73	60	30.0	-	-	-	-	30.0
Essex Co.								
(Danvers)	VII-24-73	11	9.1	9.1	-	-	9.1	27.3
(Ipswich)	VII-12-73	60	25.0	-	-	-	-	25.0
(Waltham)	VII-30-73	60	11.7	8.3	-	-	-	20.0
Franklin Co.								
(S. Deerfield)	X- 1-71	300	25.7	-	1.0	-	-	26.7
Hampden Co.								
(Holyoke)	VIII- 4-73	60	8.3	-	3.3	8.3 or 18.3[a]	0.0[a] or 10.0	30.0
Hampshire Co.								
(Easthampton)	VII-28-72	60	15.0	-	-	-	-	15.0
Norfolk Co.								
(Attleboro)	VII-16-73	60	28.3	-	-	-	1.7	30.0
Plymouth Co.								
(Bridgewater)	VII-30-73	32	6.3	-	-	-	-	6.3
(W. Bridgewater	VIII- 3-72	60	10.0	-	-	-	-	10.0
	X-15-72	675	21.0	-	0.7	-	-	21.7
	VII-20-73	60	60.0	-	-	-	-	60.0
Overall		1498	22.4	0.4	0.7	0.3 or 0.7[a]	0.1[a] or 0.5	24.2

a) If six dipterous puparia from which adults failed to emerge were <u>Lixophaga</u>.

2. *Perezia pyraustae* Survey

Although previously unreported from Massachusetts, *P. pyraustae* was found in 11 of 12 collections of 50 corn borers made throughout the state in 1972 and 1973. Kramer (1959a) indicated that this protozoan probably occurs in all states in which populations of the European corn borer are found.

The per cent infection of *P. pyraustae* in *O. nubilalis* in the 12 collections ranged from practically zero in Barnstable County to 78 in Plymouth County. The overall infection of the 600 borers examined was 19 per cent. There appeared to be no geographical differences in per cent infection, although such a pattern might become apparent if a larger set of samples were taken over a short period of time. Unfortunately borer populations in the fields sampled were not estimated. This is a parameter with which per cent infection might be correlated; the collection from Plymouth County was taken from a farm which consistently has had 75 per cent stalk infestation over the past four years. No other field sampled had a population approaching this level; no other collection had an infection level above 28 per cent.

The percentages of infection of *P. pyraustae* in *O. nubilalis* do not seem unusual in comparison with those reported in the literature. In 11 collections representing eight states, Raun *et al*. (1960) found infection levels ranging from two per cent in Wisconsin and Hall County, Nebraska to 66 per cent in Delaware. Kansas, Minnesota, and Pennsylvania all had 20 per cent infection, quite close to the average for Massachusetts. Hill *et al*. (1967) reported levels of infection that, over a number of years, ranged from zero to 82 per cent in Boone County, Iowa; from zero to 100 per cent in Cuming County, Nebraska; and from zero to 44 per cent in Hall County, Nebraska. These workers felt that the high infection levels reported from Boone County for 1964 might have combined with adverse weather conditions to produce a greater reduction in fall borer populations than could have been expected from the weather conditions alone. Kramer (1959a) conducted a four-year study of infection levels in fifth instar borers in Illinois and found the percentages of infection to average 19 in the spring and 52 in the fall. Finally, Frye (1971) reported levels of infection in North Dakota which varied from zero to 100 per cent.

The highest total number of spores found in any Massachusetts borer was approximately 134,446,000 in a pupa from Bristol County. This figure is nearly twice that of the next highest total. The average total spores for all infected borers was approximately 15,677,000, and the range was from 1,074,000 at the Ipswich locality in Essex County to 27,155,000 for the collection from Bristol County. It should be noted that this latter figure includes the single exceptional spore total reported above. However, since borers from all instars including the pupal stage were collected, spore counts per mg. of body weight of infected borers seems to be a more valid figure for comparisons than total spore counts and is used here. Converted to these terms the above total spore counts range from 48,000 to 306,000 approximate average spores per mg., with the 12-collection average being 231,000. No geographical pattern was evident for spore counts per mg. nor did there appear to be a relationship between spore counts per mg. and per cent infection. Such patterns might appear with further investigation. One might also attempt, as with per cent infection, to correlate spores per mg. with borer populations. The second highest average spores per mg. was found in the Plymouth County collection which was taken, as mentioned above, from a heavily populated field. The highest average spores per mg. was, as noted, distorted by one exceptionally high count.

There are no average spore counts per mg. of infected borer available from the literature for comparison. Frye (1971) included total spores per infected larva with his data but weights of the infected borers were not given. Raun et al. (1960) reported total spores per infected larva but also did not provide the weights of infected borers. These authors did make it possible to compute the approximate spores per mg. for all borers in a collection. The average spores per mg. of body weight computed from their data ranged from approximately 770 in Wisconsin to 308,000 in Boone County, Iowa, with an overall average of about 77,000. The Massachusetts figures ranged from zero in Barnstable County to 239,000 approximate average spores per mg. in Plymouth County, with an overall average for the 12 collections of about 51,000. Data from Massachusetts samples are within the extremes of spore counts per mg. of body weight reported previously.

In conclusion, the *P. pyraustae* survey in Massachusetts has revealed a situation similar to those found in other states. The parasite is present in the state, but varies widely in per cent and intensity of infection. Actually, the data presented here have little meaning. It is necessary to learn what effect the different intensities of infection reported have on various functions such as fecundity, adult longevity, and survival that the parasite is known to affect in the corn borer. Such information would help assess the impact of this organism on field populations of borers and the necessity and feasibility of artificially encouraging *P. pyraustae* in this state.

Table 4. Infection levels of _Perezia pyraustae_ in _Ostrinia nubilalis_ in Massachusetts.

Locality of collection site (percentage refers to pupation)	Date(s) of collection	Per cent infection (50 specimens per collection)	Average weight in mg. (all borers)	Approximate average spores per mg. (all borers) × 1000	Average weight in mg. (infected borers)	Approximate average spores per mg. (infected borers) × 1000
Barnstable Co. (E. Sandwich)	VII-23-73	0	102.8	0	0	0
Berkshire Co. (Sheffield)	VII-22-72	8	27.3	22	36.0	218
Bristol Co. (Attleboro--32%)	VII-16-73	16	82.6	53	88.6	306
Essex Co. (Conford)	VII-10-73	18	41.5	41	54.7	174
(Ipswich)	VII- 5-73	18	26.5	7	22.3	48
Franklin Co. (S. Deerfield)	VII-25-72 (30 borers) X- 1-72 (20 borers)	8	62.5	8	38.5	169
Hampden Co. (Holyoke)	VII-17-72	18	33.5	29	39.0	204

Table 4 (continued)

Locality of collection site (percentage refers to pupation)	Date(s) of collection	Per cent infection (50 specimens per collection)	Average weight in mg. (all borers)	Approximate average spores per mg. (all borers) × 1000	Average weight in mg. (infected borers)	Approximate average spores per mg. (infected borers) × 1000
Hampshire Co. (Amherst)	IX-22-72 (10 borers) IX-23-72 (10 borers) X-28-72 (30 borers)	8	59.1	7	50.0	103
(Easthampton--32%)	VII-27-72	28	64.5	59	100.6	145
Norfolk Co. (Franklin)	VII-18-73	6	68.5	2	41.7	61
Plymouth Co. (W. Bridgewater --38%)	VIII- 3-72	78	86.7	239	92.6	287
Worcester Co. (Westboro)	IX-24-72	24	54.3	40	35.0	258
Total (600 borers)		19	59.2	51	68.0	231

3. Predation Studies

Considerable difficulties were encountered while conducting predation intensity studies. Problems were found with both weather and coordination of experimental activities with the normal activities of the farmers in whose fields the cages were placed. As a result, data were obtained from only two replications in one field in Holyoke in 1972. Sparks _et al_. (1966) established that a minimum of six replications were necessary before the index of predation intensity could have significance, so little credence can be placed with our results. However, the average index of predation intensity for the two replications was 55.2. This is lower than the averages reported by Frye (1972b), but higher than most of those reported by Sparks _et al_. (1966).

Summary and Conclusions

1. Summary of Literature Review

A review of the literature shows that the multivoltine strain of the European corn borer is commonly present in Massachusetts. The appearance of the second generation and damage are controlled primarily by temperature and photoperiod. Temperature has been used to predict emergence dates, and in some areas it is felt that temperature is the major factor controlling corn borer population levels. Rainfall also has been considered to be a primary factor influencing first generation size. Climatic factors affecting corn borer oviposition include temperature and evening wind speed.

Parasites, diseases, and predators also affect corn borer populations, and these have also been reviewed. Seven exotic parasites were considered established at the termination of a USDA program which involved the importation of 26 species. Of these *Lydella thompsoni* became most widespread and abundant, but later disappeared. *Horogenes punctorius* and *Sympiesis viridula* became established outside of New England, but never achieved much importance. *Macrocentrus grandii* was considered the most important parasite in New England. Native parasites have been reported, but none appear to have caused any significant reduction.

Several species of bacteria have been isolated from the corn borer, although most emphasis has been placed on the use of *Bacillus thuringiensis* as a control for the borer. As with bacteria, several fungi have been isolated from O. nubilalis. Several attempts have been made to employ Beauveria bassiana as a control measure with some encouraging results. The corn borer has also been shown to be quite susceptible to the nematode DD 136, but control attempts with this nematode have not attained the reductions in borer populations provided by chemical insecticides.

Other diseases reported from the corn borer include a virus and two protozoans. The virus and Leptomonas pyraustae did not appear to be of any importance. The other protozoan, Perezia pyraustae, is thought to occur wherever populations of the corn borer are found. An obligate, intracellular parasite of the corn borer, P. pyraustae lowers growth and survival rates of larvae, while raising oxygen consumption. It also reduces the adult life span and fecundity, and interacts with temperature extremes to produce host mortality. A quantitative method to measure the incidence and intensity of P. pyraustae infections has been devised and the results of several surveys have been reported.

Numerous qualitative studies have been conducted on corn borer predators. There are records of all life stages being attacked, with most predators being either insects or birds. Several quantitative studies of egg predators have been reported. Larval predators have been studied quantitatively by using a predator exclusion technique, and through direct observations on birds feeding on overwintering borers.

2. Summary of Results and Conclusions

Of the seven exotic parasites once considered established, three, *H. punctorius*, *M. grandii*, and *S. viridula* were recovered in Massachusetts during this survey conducted from the fall of 1971 through the summer of 1973. Only *M. grandii* appeared in significant numbers. This polyembryonic, braconid parasite was present in all collections, with levels of parasitization ranging from 6.3 to 60 per cent and an overall percentage of 22.3. Several species of native tachinids were also recovered which combined with the exotic parasites to kill 24.2 per cent of the 1498 borers examined. However, *M. grandii* killed 92.0 per cent of the parasitized borers examined.

The sizes of the adult colonies of *M. grandii* reared were similar to those reported in the literature, except that the percentage of mixed-sex colonies was much lower than reported from Europe (but similar to that reported from Ontario). It was shown that one sex may be expected to dominate in numbers in a mixed-sex colony of *M. grandii*. This parasite obviously should be considered for any biological control program directed against the European corn borer in Massachusetts.

P. pyraustae, a microsporidian parasite of European corn borer, was found in Massachusetts for the first time and was present in 11 of 12 collections. *P. pyraustae* varied greatly in percentage and intensity of infection, a situation similar to those reported for other states. Percentages of infection and spore count appear to have little meaning so far because little is known about what effect different titres of the parasite have on the host.

Preliminary predation studies were conducted in 1972. However, due to various practical problems the results were not conclusive.

During the course of this study we failed to recognize any indications of appreciable corn borer mortality due to pathogenic fungi, bacteria, viruses, or nematodes. Neither did we observe any signs of either egg or pupual parasites.

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