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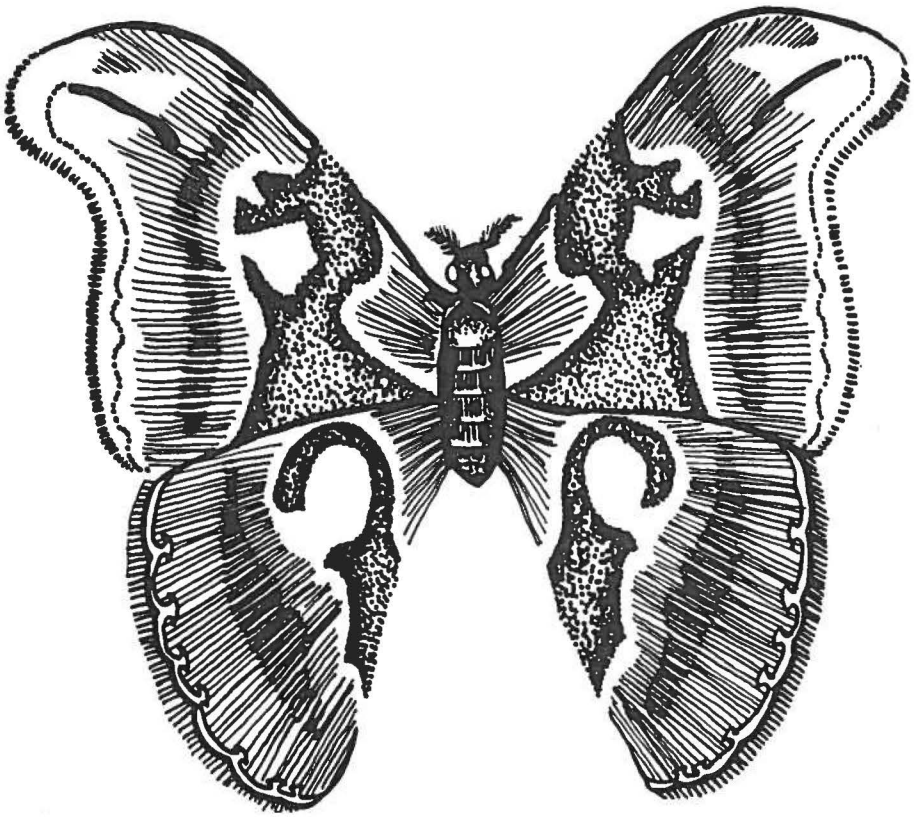

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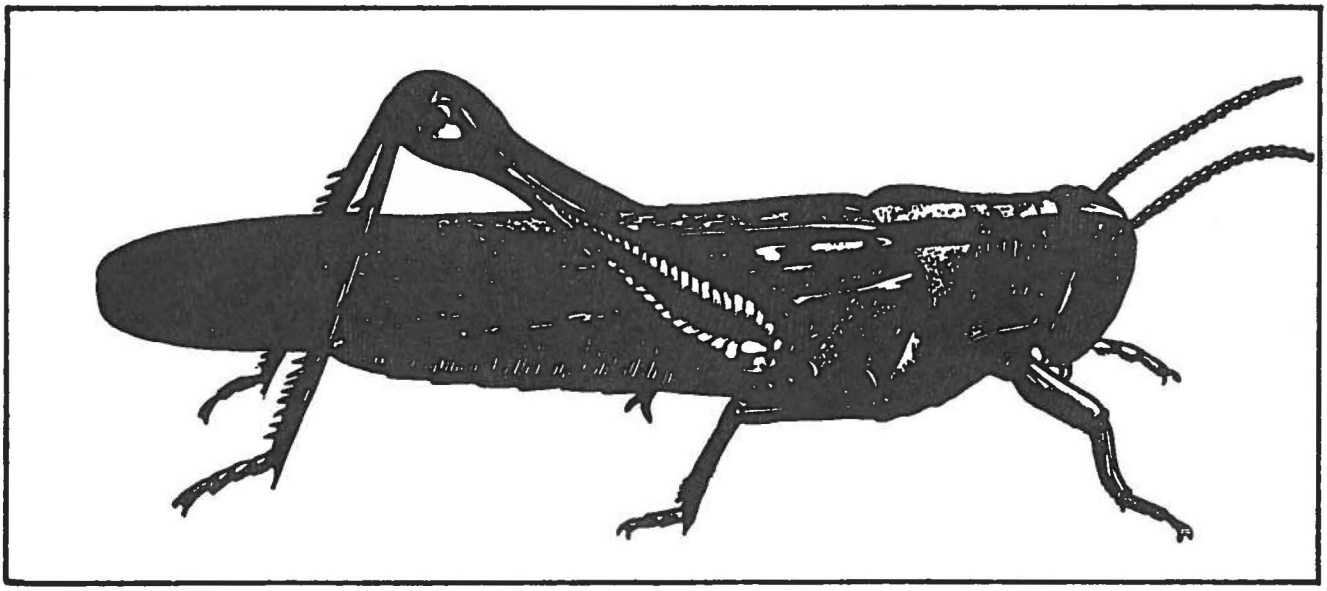

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THE MANITOBA ENTOMOLOGIST

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THE MANITOBA ENTOMOLOGIST

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THE MANITOBA ENTOMOLOGIST

An official publication of the Entomological Society of Manitoba, an organization to foster the advancement, exchange and dissemination of entomological knowledge

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ECONOMIC ENTOMOLOGY IN WESTERN CANADA: NOSTALGIA AND CONCERN

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Economic Entomology! Today that descriptive phrase may ring rather strangely in many ears. Some still use the term but such usage is being replaced slowly by more prestigious terms such as 'Pest Control' and 'Pest Management'. In yester-year we could find an active 'American Association of Economic Entomologists', while we in this region were keen participants in the annual meetings of the 'International Great Plains Conference of Entomologists'.

Where are these associations? *Why* are they gone? *What* has replaced them? *When* was their usefulness no longer appreciated, nor desired, and, therefore, were they replaced by, or metamorphosed into, something seemingly relevant? *Who* was no longer present to represent the 'old order' and thus made change a matter of progress?

The foregoing sounds like the scenario for a new TV program of W5! Perhaps it should be, but today I merely want to share with you a few memories of economic entomology in western Canada, and especially in Manitoba and the Canadian Great Plains. Perhaps I will also have some time to evaluate the present situation and express a few personal concerns.

What is economic entomology? There undoubtedly is a precise definition for the term but to me it is the science of that which Metcalf and Flint called "Destructive and Useful Insects". The destructiveness and the usefulness of insects have been known for many centuries but the exact science of such knowledge has been one of evolution. We have to begin with entomology *per se*.

J. Alston Moffat, in 1902, said: "Entomology is the science that gives to insects long names, short lives and a pin through the middle"[1]. Thus economic entomology must include something else, such as the costs of giving long names to insects; the evaluation of research, and the time expended in ensuring that noxious insects have short lives; and using more than mere pins through the middle to gain mastery over an elusive foe or a reluctant friend.

In western Canada, before we knew much about this country of ours, the concern about insects occurred only when man was bothered by them. Such was the experience of Captain John Monck in 1619 when he set foot upon a spit of land near the place where Churchill, Manitoba stands today. He was greeted by a hostile land and by the "gnats" with which they "were extremely pester'd"[2]. Others who followed in his wake, the explorers and the traders, all had similar unsavoury expletives to offer. There was James Knight of the Hudson's Bay Company's York Factory, who selected the Monck site on which to build the mightiest and most formidable fortress in colonial America, Fort Prince of Wales. When he landed there in July of 1717, he "was wellcom'd by such a quantity of musketos . . . that fixed their stings like great wasps [and left their flesh in] knotts and bumps"[3].

Samuel Hearne who followed as Governor of Fort Prince of Wales, suffered stoically from the stings of the mosquitoes during his explorations down the Coppermine River to the Arctic Ocean in the years 1769-72. In fact David Thompson, when in northern Saskatchewan near Lake Wollaston in 1796, reported that the deer had been driven out of

[1] Moffat, J. A., 1902. 33rd. Ann. Rept. Ent. Soc. Ont., p. 117.

[2] An account of a most dangerous voyage performed by the famous Captain John Monck, in the years 1619 and 1620. An excerpt from: A collection of voyages and travels . . . London, printed by assignment from Messrs. Churchill, for J. Walthose, Vol. 1, p. 487-514. 1732.

[3] Speck, G., 1963. Samuel Hearne and the Northwest Passage, p. 82.

the bush and were standing in the water to escape the flies. However, northern biting flies were only one of the many Orders of insects that were recognized by man.

Alexander Henry, in 1800, was one of the first to report the presence of locusts lying in a windrow nine inches deep on the shores of Lake Winnipeg. Later he was plagued by wood ticks and fleas in the old Pembina Fort, but mosquitoes were his worst foes. To ward off the pests he had to carry large kettles, kept constantly smoking, in his boat while he paddled up the Red River. However, after six years he had learned to live with the biting flies but he had also learned to use defensive measures. He wore a tight-fitting mask of thin, dressed caribou hide to cover his face. What the native Indians thought of when they saw this apparition, or how they responded, I leave to your imagination.

There were others who had similar experiences: Daniel Harmon and the locusts near Canora, Saskatchewan on the Assiniboine River in 1802; John McLean who encountered bark beetles in the Peace River region in 1836; A. J. Thibodo driven to a near panic by horse flies along the Souris in 1859; and James Carnegie, the Earl of Southesk almost overwhelmed by the sand flies and blackflies near Battleford in 1859. Their collective adventures with entomology can be summed up in the words of Carnegie: "Mosquitoes on the wet ground, sand-flies on the dry, bulldogs in the sunshine, bugs in the oakwoods, ants everywhere – it is maddening"[4].

These were the itinerants, the people who were just passing through the land. Their life was made more torturous by the presence of pain-inflicting and annoying insects, but this did not stop nor deter them. They recognized the pests for what they were and they defended themselves against attack as best they could, even as they would against hostile Indians or dangerous wild animals. It was an age of stoicism, of stubborn determination to reach their objective. The best they did with the insects was to avoid them for they did not stay to fight. They were merely passing through.

But there were other men, men with strange ideals or visions, men with dreams, men with courage and willing to take a chance. There were the entrepreneurs among whom we can place the fur traders of the Hudson's Bay Company and the North West Company. They were placed in charge of specific out-of-the-way places or stations. In these semi-permanent locations they had to live with everything that surrounded them. Examine the records and find the names and the locations of many of the fur-trading posts: Fort Garry, Fort Dufferin, Fort Ellice, Norway House, Cumberland House, Edmonton House, Fort Qu'Appelle, Fort Carlton, Fort Saskatchewan, Fort Calgary – just to name a few. In charge were the skilled entrepreneurs, the Factors, like John Rowand, John P. Pruden, Donald McKenzie, and others.

Under orders from the Company, each Fort was to become as self-sufficient as possible. A garden was planted to provide vegetables to complement the wild game, the fish, and the pemmican. But soon the turnips, beets, and radishes were damaged by maggots, the cabbages routed by cabbage worms while the potatoes and the carrots were scarred by wireworms. The presence of insects was duly noted – and tolerated. Even when invading swarms of locusts darkened the sky, as they did repeatedly on the Great Plains, man did nothing more than pray that the coming devastation would be less than the previous one.

Real settlement of western Canada started in 1812 by Lord Selkirk and his Red River settlers who staked out a home just a few miles from the place in which we are assembled today. That story of settlement is well known to all of you, but let us not forget the insects: the biting flies, the vegetable insects, and the invading locusts that nearly spelled doom for the settlement on more than one occasion. For eight years the locusts ravaged the land and in 1821 – lo! the pest was no more. The outbreak had been terminated by nature and the well-known fungus disease, *Entomophthora grylli*. Man played no role in the demise of the locust.

On this occasion the insects had given men pause to think. Perhaps there was more to this co-existence with insects than mere tolerance; men could take the offensive. Perhaps

[4] Innis, M.Q., 1956. Travellers West. p. 29.

here we witness the birth of the embryo economic entomologist. The "Grasshopper Governor", Alexander Macdonell advised the farmers that

> . . . notice should be taken where they deposit their eggs that no cultivation may be attempted there the next season, and persons should be sent to different places to discover where the grasshoppers have not appeared or deposited eggs; and men and horses ought to be sent there in the autumn to plough as much as possible in preparation for the following summer, at all events even in the spring fresh ground may be ploughed for potatoes, and if ploughed deep and the turf is well turned in, even wheat and barley may be grown enough to preserve a succession of fresh seed.[5]

Here we have, for the first time in western Canada, some sage advice and some guidelines for the control of an economic insect pest. Macdonell, as an economic entomologist, and perhaps as an extension entomologist, included in his remarks several practices that are still adhered to today. He mentioned surveys of insect abundance, cultural methods, and the use of resistant varieties of crops. Not bad for a start!

Alas, these good words were soon forgotten for the plague faded and the locusts did not reappear until 35 years later. However, settlements expanded and the farmers continued to seed and harvest in the Red River valley and westward along the Assiniboine. They took evasive action against the insects whenever possible. They swatted, smoked, and swore at the biting flies but generally did nothing more than co-exist with the insects that affected their crops, their homes, their bodies, and their livestock.

During these 35 years much of the territory between the Red River and the Rockies remained in a pristine condition. The Cree still roamed at will in a seemingly empty place, a place that few white men had seen or wanted to venture into. However, the Government of Canada was economically minded. It had all that space of endless prairie, land that might be used for better things. Two expeditions were sent out in 1857 to investigate the West. The one, headed by S. J. Dawson and Henry Y. Hind and commissioned by the Canadian government, was to find out all they could about the resources of the land, with agriculture and colonization in mind. The other, sponsored by the British government, was led by Captain James Palliser who was also assigned to determine the agricultural possibilities of the land, and to seek a southern railroad pass through the mountains.

Both parties encountered locusts, saw the destruction, and warned of the consequences of their invasions. Hind's descriptions[6] of the swarms remain as some of the most vivid that were ever written about the Rocky Mountain Locust. Although Palliser wrote off the Canadian Great Plains as being unfit for settlement and agriculture, Dawson and Hind were of the opposite opinion but had reservations. Consequently settlement was slow in expanding. It seemed to be a process of populating singular and insular areas surrounding a Fort, followed by a line of settlement connecting these. Thus we find a thin line of settlers stretching along the waterways westward from Fort Garry, along the Assiniboine to Fort Ellice, up the Qu'Appelle to Fort Qu'Appelle, and west along the Saskatchewan Rivers to Prince Albert and Edmonton. The ten-year locust war of 1864-74 did little to promote further expansion westward.

In the 1870s both the provincial and federal governments launched vigorous drives for colonists. In Manitoba, the East and West Reserves were established for the Mennonites on both sides of the Red River, and at Gimli for the Icelanders. When the CPR went west in the 1880s settlement appeared to have no bounds. All of the southern prairies were soon swarming with people wielding ploughs and farming equipment. The whole of the pristine west was suddenly in a turmoil.

The delicate balance of nature that had been kept near a quiescent equilibrium was suddenly disrupted. Indigenous insects that had for many millenia eked out a precarious

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[5] Oliver, E. H., 1914. The Canadian north-west, its early development and legislative records. *In* Vol. I. Alexander Macdonell-Memorandum of guidance as agent for Selkirk's executors, 1821.

[6] Hind, H. Y., Vol. I, Can. Red River Expedition 1857.

grassland existence were faced with disaster. They had been viciously disturbed and routed from their routine. They fought back. They launched an attack at the invading humans, an attack that left nothing to the imagination for they attacked on all fronts: crops, body, soil, livestock, and the homes. Man had to go on the offensive to survive!

There was no one at hand who could advise the farmers and settlers about the control or elimination of noxious insects. The only resource most of them had was to write to Ottawa and hope that help could come from there. A sufficient number of complaints reached the political incumbents so that some action was made necessary. The Minister of Agriculture, J. H. Pope said:

> An acquaintance with the practical result of entomological science is a matter of such necessity to every tiller of soil, that I deemed it necessary to take some measure by which the attention of those whose interests were materially affected, could be called to it. With this purpose in view, a Dominion Entomologist, entirely an honorary position, was appointed by me.[7]

The appointment was made on June 1, 1884; the appointee was James Fletcher. Not only did this action launch Canada into the field of professional entomology, the position was one that called for the expertise of an economic entomologist. Up to that time there were many 'amateur' entomologists in Canada, many of whom were naturalists and collectors and often regarded as "queer" people. Most of them had given little, if any, thought to the control of insects. Fletcher's appointment was to change all that, as well as to do something more. The appointment was an honourary one; it was the great Canadian experiment to test the value of insect investigations or entomological research. It was the test of an idea, a test of a man's ability, a test to determine if it was possible to erase the blurred image of an entomologist as conceived by the general public, and change it from 'harmless idiot' to 'essential scientist'.

James Fletcher passed the test with 'Honours'. He set up an intelligence unit of 400 reporters across Canada who soon flooded his office with information concerning noxious insects and suggested remedies whereby they might be controlled. The results were immediate. Acton Burrows, the Deputy Minister of Agriculture for Manitoba, sent samples of injurious cutworms to Fletcher in July of 1884. They were identified and control measures were suggested. This information was printed by the Manitoba government as one of their crop bulletins, thereby getting suggestions for practical control of cutworms into the hands of the farmers within the year.

However, most of the flood of inquiries came not from western Canada. Because of limited agricultural activity in the region there was only a limited activity on the part of the insects. For the next ten years James Fletcher was not totally taken up in giving advice and answering inquiries, he could do some basic biological investigations. Insects that were of concern included: the diamondback moth on cabbages from the Pacific to Winnipeg, in 1890; the oak looper in Victoria, in 1887; the fall cankerworm on ash-leaved maple in Winnipeg, in 1891; the redbacked cutworm from Ottawa to Calgary, in 1891; and the red turnip beetle from Saskatoon to Minnedosa, from 1885 to 1893. In 1893, the Colorado potato beetle invaded Manitoba across the 49th parallel; Paris green came into use!

On July 5, 1895, James Fletcher captured the first adult wheat stem sawflies near Indian Head, Saskatchewan. A year and 32 days later, on August 6, 1896, some larvae were taken from wheat stems at Souris, Manitoba. A new pest was at hand; an indigenous insect which was surviving well in spite of man, was soon to spread over much of the prairies and become Insect Enemy No. 1 some forty years later. There were other pests: the wheat stem maggot in Manitoba in 1896, and then the return of the 'Hateful Locust', the notorious *spretus,* in 1897. The Rocky Mountain Locust made its last return together with its brethren the three or four indigenous species of grasshoppers, to ravage the fields

[7] Lowe, John, 1885. Report of the Minister of Agriculture for the Dominion of Canada for 1884. p. 14.

of farmers for the next six years. Then, in 1902, it was gone; it had passed into oblivion and extinction.

During these critical end-of-the-century years when new insect pests seemed to rise with vigorous regularity, who was there to help the Dominion Entomologist? Who in this vast 'Great Lone Land' was qualified to take on the duties of an economic entomologist? A kindly Providence must have smiled down on Canada for Fletcher found help in many quarters.

In Alberta, in the Blackfaulds area near Lacombe, a group of dedicated biologists had banded together in 1898 to form the North West (Canada) Entomological Society. Under the watchful eye and guiding hand of its president, Percy B. Gregson, men like F. H. Wolley-Dod and Norman B. Sanson joined forces to help settlers in their fight against economic insect pests. These were the men who travelled, held meetings, lectured to school children, and set up entomological displays at local fairs. They identified insects for farmers, ranchers, and urbanites, and advised them of the control of many pests including mosquitoes at Banff, bedbugs in lumber camps, and cutworms at Taber. Without their expert advice, even though they were not paid professionals, Fletcher would have been hard pressed to keep abreast of current entomological awakenings in the West.

In Saskatchewan there was T. N. Willing, the Game Guardian and Weed Inspector of the Territorial government, who acted as the chief entomological 'vizer' for many years. Later, in 1915, he became the first Professor of Natural History at the University of Saskatchewan. He was aided by other sincere men who kept a watchful eye on noxious insects, men like G. D. Fitzgerald of Grenfell, and Joseph Smith and Thomas Copland of Saskatoon.

In Manitoba James Fletcher found a ready comrade-in-arms in Hugh McKellar, the Chief Clerk and later, Deputy Minister, of the Manitoba Department of Agriculture. For about 20 years, and until 1904 when he left for Moose Jaw as editor of a farm paper, McKellar saw to it that Manitoba remained as free of insect pests as it was possible to be. However, the amateur collectors of the province were of material aid in this endeavour. There was L. E. Marmont of Rounthwaite, H. W. Boger of Brandon, and E. Firmstone Heath of Cartwright, just to name three. The latter lived on a homestead named 'The Hermitage', a very apt name for a place that Fletcher described as "six miles across the prairie from Cartwright, which is almost like six miles from nowhere".[8]

James Fletcher met a man in 1900 who proved to be an invaluable aid to him in economic entomology. This was a soft spoken, well mannered but reserved poet. He was a philosopher in rhyme:

> "Pure thoughts as pure flowers they soon fade away,
> They come as the sunrise and pass as the day;
> Each has its period of glory and power
> And may live for a season, or fade in an hour."[9]

This man was a naturalist at heart; he was Norman Criddle whose achievements and contributions to entomology in western Canada are so well known to all of you that a re-telling of even a small part of the Criddle story would not only be redundant, but vastly inadequate. Let it suffice to say that Norman Criddle was an economic entomologist and that there was, and probably still is, none better. At the start of the century and for the remaining years of Fletcher's life, Criddle remained an unpaid aide, a non-professional entomologist, merely a behind-the-scenes scientist who was gaining momentum and expertise wherewith to serve the public in later years.

At about this time an important national political event took place that established entomology and insect control on a firm basis in Canada. This was the passing of a bill, 'An Act to protect Canada against the introduction of the insect pest known as the San

[8] Fletcher, J., 1896. Letterbook, Pub. Arch. Can., R.G. 17, Vol. 2341, p. 148.

[9] Norman Criddle, 1917. From a private collection and by kind permission of Miss Alma Criddle, Winnipeg.

Jose Scale' in the Parliament of Canada on March 16, 1898. This was the first anti-insect legislation passed in the Dominion and it signified the intent of the government, as advised by the entomological experts, to keep Canada as free of insect pests as possible.

The result of such legislation was the establishment of fumigation houses at convenient border points where consigned shipments of vegetative material could be inspected, fumigated with HCN gas, and sent on to the consignees. The Vancouver Station was operated by Tom Wilson and the first superintendent at Winnipeg was A. K. Leith. Although the greatest danger of infestation and ruin was to British Columbia's fruit crops, the 'Inspectors of Fruit Pests', an official position authorized under the B.C. Horticultural Board Act in 1892, now had extra help to keep the west-coast province pest free. In fact it was primarily due to the efforts of J. R. Anderson, R. M. Palmer, and Thomas Cunningham, an indefatigable trio of energetic, devoted, and knowledgeable men who made entomology their business and public service their motto, that kept British Columbia free of insect pests.

The fledgling science of economic entomology in Canada was severely shocked in 1908 when James Fletcher died suddenly on November 8th. His one-man era of leadership had been highly successful and fears were expressed that his successor would do less. This was not the case for the new Dominion Entomologist, C. Gordon Hewitt dedicated his energies to entomology with the same zeal and devotion as had Fletcher.

One of Hewitt's first acts was to have legislation passed to strengthen Canada's defence against foreign insects. The 'Destructive Insect and Pest Act' of 1910 guaranteed that action would be taken against all pests, not only the San Jose Scale. It also served another very useful purpose, namely, it provided money; funds to enforce the Act. For Hewitt, as well as for many of his successors, these monies were used to expand entomological services by hiring additional people to do the job.

Hewitt used the funds with extreme skill. He had Arthur Gibson as an assistant since 1899, but now he started to expand his staff. With uncanny ability he picked the right men: J. M. Swaine, to head the investigation of forest insects; J. D. Tothill, to direct insect parasite investigations; W. A. Ross, to guide fruit insect work; and R. C. Treherne to take charge of a new western laboratory at Agassiz in the Lower Fraser Valley. Of course, Hewitt did not neglect or overlook the expertise he had elsewhere on the Prairies. By 1913 he had enmeshed Norman Criddle in the folds of the federal entomological net with duties that included studies and control of white grubs, Hessian flies, and the wheat stem sawfly.

But, as mentioned earlier, the insects were not passively submitting to the take-over of their domain by man; they were fighting back. The cutworms, including the variegated, the army cutworm, the redbacked, and the pale western, had increased their attacks on field and garden crops starting in 1911. By 1913 their ravages on the southern Canadian prairies had reached epidemic proportions. The cries for assistance could not be ignored by the entomological authorities. Once more Hewitt chose wisely and well, and as Fate decreed the right man was available. Edgar H. Strickland was appointed in 1913 to head the third entomological field station in western Canada. This one was established in Lethbridge, the second having been built at Aweme with Norman Criddle in charge.

Economic entomology was firmly entrenched in western Canada by the time the dark clouds of World War I loomed on the far eastern horizon. The entomological needs of the region were in the capable hands of a dozen dedicated entomologists who saw things through the next four years of the war. What happened after the war?

A quick assessment of the situation seemed to indicate that settlement had indeed interfered with, or changed, the ways of insects on the prairies. Man had encroached upon virgin territory and had upset a stabilized ecosystem by tillage. Some sections of land were now being grazed continuously by domestic livestock instead of being short cropped on an occasional basis by itinerant herds of buffalo. Furthermore, the method of settlement, as instituted by the government may have had a bearing on the rapidity with which insects became pests, and therefore, the relative rapidity with which economic entomology rose to prominence on the prairies.

Let me digress for a moment and explain my phrase 'method of settlement'. In 1873 the federal government adopted a revised version of the American method of land division, i.e. the Section-Township-Range system. The land was divided into one-square-mile sections, grouped into 'townships' of 36 sections and allowed for roadways at one-mile intervals. Each odd-numbered section was given to the Railroad Company, two sections (11 and 29) were school sections; and two (8 and 26) were left with the Hudson's Bay Co. Even-numbered sections were available for homesteading, but only the NE and the SW quarters thereof. The other two quarter sections (NW and SE) were 'pre-emption' quarters and available to the adjacent homesteader if he could pay cash for them.

In effect this permitted the tillage or farming of 16 sections out of every 36, assuming that each homesteader exercised his pre-emption rights. Initially then, the interference to a stabilized ecosystem was exercised on a portion, or all, of 16 sections per township, an amount equivalent to about 45% or less of the land in western Canada. This was not a complete upsetting of the natural biological equilibrium but it was a very disturbing movement. Although some insects turned to the new foods being offered to them in the form of domestic grains, there were many species that remained on their native habitat and bothered no one. It was because of those who began to encroach upon the farmers crops that the call for help first went out. This occurred during the initial whirl of settlement when James Fletcher was first called upon to do something about it. Then followed the great influx of settlers after the turn of the century, causing greater disturbance to the grassland prairies and followed by increased insect activity. More land was being cultivated and the contiguity of farmed fields with native grassland made it easier for the quick dispersal and movement of noxious insects. Again this called for more action by the government and resulted in the acquisition of more entomologists, notably Criddle, Strickland, and Treherne in western Canada.

During World War I and in the 1920s settlement intensified, more land was purchased, and arable agriculture expanded. Insects that were pests on 45% of the land became more widespread and occupied correspondingly more acreage and more damage ensued. The 'domino effect' called for more action on the part of the entomologists. In Manitoba Norman Criddle worked unceasingly to ferret out information concerning the 95 or more insect species that he had to deal with at one time or another. E. H. Strickland, back after the war, re-opened the cutworm investigation work and fought a renewed grasshopper outbreak. A. E. Cameron had been appointed in 1916 to investigate thrips in B.C. but by 1918 he was in Saskatchewan investigating biting flies and helping Criddle to limit the grasshopper outbreak.

The increased activity of insects did not only demand the presence of more entomologists in the field, but it also created a shortage of trained personnel, and thus directly affected the Universities. I am sure that most of you will recall what that effect was in western Canada. A. V. Mitchener was appointed as a biologist to the Manitoba Agricultural College (later the University of Manitoba) in 1919. E. H. Strickland went to the University of Alberta in 1921, founded the Entomology Department and ran a one-man show for 32 years, till 1954. A. E. Cameron accepted a teaching position at the University of Saskatchewan in 1921 and was succeeded by L. G. Saunders in 1925. These were the men who had seen action in the field as economic entomologists. Now they were entrusted with the task of teaching others to be their equal, or their peers.

The practical side to entomology was not neglected. C. Gordon Hewitt died in 1919, the victim of the 'Great Flu', and was succeeded in 1920 by Arthur Gibson. The latter continued the expansionist policy of the Division of Entomology by appointing H. L. Seamans in 1921, to head the Lethbridge Laboratory and K. M. King to take on similar duties in Saskatoon in 1922. Now it was up to these six men to educate the masses, create the experts, learn about all the noxious insects, devise effective control measures, and, above all, show an economic benefit as a result of their endeavours. This was to be another 'test', one as an economic entomologist to determine if he could make the job pay to the satisfaction of the politicians, to industry, the rural and urban people, and to the science of entomology. We did not have to wait very long to find out.

In Alberta, 'Hod' Seamans assembled his associates: George Manson, Larry Jacobson, Reg Salt and Chris Farstad. K. M. King was joined by Robert Glen, Lorne Paul, Arni Arnason, Harold McMahon, Howard McDonald, Ellis McMillan, N. J. Atkinson, V. L. Berg, Bill Fox, and Harry Williamson. Norman Criddle gained the services of Dick Handford, R. M. 'Sam' White, Dick Painter; and after Criddle's death Ralph Bird, Herman Moore, Willard Allen and Seyward Smith joined the Brandon staff. These, and others that I have not space nor time to mention, were the field men, western Canada's economic entomologists and front line specialists who stood firm against the insects that plagued the settlers of the plains. The men of the Universities were loners, playing a one-man game of educating the students in all aspects of the science of entomology. It will be forever to their credit that they not only undertook to teach all the courses but they also had time to do some practical work and turned out some of the nations' best qualified entomologists.

The causes of the 'Dirty Thirties' have been attributed to a wide variety of factors, not the least of which have been the agronomic practices of the landowners. Land that had been deeded to the railroads and the Hudson's Bay Company had long since been grabbed up by land companies and most of it was sold to farmers. When most of the land was under full cultivation it represented a state of near-maximum disturbance of a huge macro-ecosystem. Insect species could scarcely find an 'original' home except on the native pastures and along the road allowances. For some of them this type of a 'reservation' was good enough and they adhered to it. To many more they were strangers in their own land. It was now a world of man and not merely of nature; a new set of rules had to be established.

The economic entomologists of the pre-Second World War era were making the rules whereby the insects were to live. It is impossible to detail here all the work that was done by these men in order to arrive at the rules that were to be imposed. Many of the concepts and regulations had to be changed or discarded because of the findings of their research or the advances in technology. Some brief examples may be cited: a) the advent of surface tillage implements required the discarding of the mouldboard plough, b) the appearance and use of the combine harvester hastened the harvest operation and decreased the necessary manpower, c) extensive drought and wind created new methods of cultural practices, d) studies of the life history and habits of insects demanded changed baiting procedures for cutworms that did not feed above ground.

The work of the economic entomologists was to refine the ecological aspects of those factors that had an influence on insect life. As a result of this concern more and more attention was given to insect ecology.

We need only examine the record of performance of K. M. King and his associates at Saskatoon where they initiated studies to assess the abiotic and biotic inter-relationships of soil-inhabiting arthropods. Or, we can examine the efforts of Bird, Handford, Moore, Allen and Smith in gathering information on the Intensive Study Blocks at Arnaud and Lyleton so as to better fathom the intricacies and inter-relationships of grasshopper behaviour, fecundity, and outbreak probabilities. In the same breath I can mention J. J. DeGryse, appointed in 1923 and sent to Indian Head to study shelterbelt insects, replaced in 1925 by K. E. Stewart who in turn was replaced by L. O. T. Peterson in 1939. DeGryse did some intense ecological studies of defoliators in Ontario and when he took over the Division of Forest Insects in 1934 these studies were expanded to Winnipeg and left in the capable hands of H. A. Richmond and his staff.

No matter where one looked at entomology in western Canada just prior to World War II, all entomologists were concerned about, and busily engaged in, insect control. The latter was geared to insect ecology not because it was the fashionable thing to do but because economic entomologists at that time knew enough about the insect's biology to realize that control lay not in eradication but in suppression. The chemicals used were short-term, often stop-gap control devices, while long-range control involved subtle techniques aimed at the 'inner' insect, the unknown vulnerable points of its biology or constitution. The entomologists were just beginning to realize the complexity of insect biology and ecology when war broke out again. All things went into a HOLD position.

It may sound strange but the insects, by this time, had also sorted out their priorities. They had adapted to a near-total agricultural concept and perhaps they had learned how to live with man and with the changed ecosystem habitats that had evolved on the prairies. It seems as though the insects had reached an uneasy but stable position relative to their capacity to cause damage or be called pests. After the war many things happened but for economic entomology everything suddenly became very complicated.

The war brought new discoveries and new techniques. Man was given instruments that could probe to unimaginable micro levels of both form and function, viz. the mass spectrometer, computers, electron microscopes and a host of electronic gear that could work miracles. It also gave us DDT, the miracle insecticide that would eliminate the need for economic entomologists. With the new instruments on hand all that was necessary was to train specialists to probe into the inner workings of all things at the micro level. In the ten years following the war, entomology *per se* included specialists in nutrition and metabolism, insect blood, diapause, cold hardiness, insect pathology, population dynamics, and insect toxicology. The latter was a new breed of expert and in the minds of the general public they were the ones who most closely resembled the economic entomologist of the past.

Urged on by the possibilities of the new instrumentation and the new techniques, the federal government also got caught up in the expansion fever and hired a host of new scientists. By 1954 the federal agricultural entomological service had risen to 350 full-time entomologists; this from a pre-war, 1939 level, of 140.

Some of the individuals who were part of that expanded force in the post-war era are sitting in the audience before me today. Many are elsewhere, some retired, some removed from our presence – and you will remember them. There are others present also who may call themselves entomologists but their training has not been that of the stereotyped entomologist. They may think of themselves as being a physiologist, a toxicologist, or even a taxonomist. Where are the economic entomologists? You may well reply, "Who needs them?" and you may be right.

To the economic entomologist of yesterday insect control was paramount in importance because it was *insect oriented.* Today we have pest management which is *people oriented* because a pest is a people's word and not an insect one. What one may call a pest, another may call a beneficial insect. For instance, Dr. Jay would not call a swarm of bees a pest, but to the man down the street in whose apple tree the swarm alighted, the insects would be called much more than a 'pest'! Therefore, in speaking of pest management we have diverged from an insect perspective to an environmental one. This I believe is good because pest management seeks ecological balance, a concept that earlier economic entomologists too often forgot, especially in the post-World War II period when organic chemical control was an oft-used byword for good insect control.

But in seeking pest management programs that include the beneficial insects, the non-use of broad spectrum insecticides, and the many other components of a good program, have we been striving for too much? Have we progressed in our efforts at insect control to the point where eradication is often contemplated and in some instance has been achieved? Have we reached the point where we no longer want to consider the prospect of living with our pest insects and want no pests at all? We may not want to accept the practice of mere suppression of a pest population but at the same time we do insist on unblemished fruit, on disease-free and insect-free produce which demands annihilation of pest insects and other noxious organisms.

I suggest that these new rules which we have been and are trying to enforce, are too strict. Insects display remarkable recuperative powers and retaliatory behaviour patterns. Perhaps it is not unwise to consider living with the insects again, to tolerate some levels of insect activity in order to stay within the economy of our endeavours. In fact, good pest management with biological control demands that a host population not be annihilated but that a residual pest density remain. I think the term 'economic entomology' is a very relevant term to be used today because we need to emphasize the economy of our living with insects.

I would suggest a continuation of studies and research in all the sub-disciplines of entomology so that our knowledge of the insects in a changing world, such as has happened in the prairie ecosystem in the last 100 years, remains up to date. In addition we must think of control and the domination of man over insects as an encounter in which cost-benefits will play an increasingly greater role. The economic entomologists of yesterday, and perhaps today, were cost conscious, viz. Norman Criddle developing a cheap "Criddle mixture" for grasshopper control; K. M. King assessing the value of trap strips for wheat stem sawfly control; Hal Gray, trying inexpensive fumigants for stored product insect pest suppression; Gordon Bucher assaying the effectiveness of micro-organisms as insect control agents; and Wally Romanow who has to assess costs when recommending control measures to the many hundreds of callers who are seeking his advice. We today must be assessors and economic advisors.

However, I caution you, be entomologists first and economists second. L. O. Howard once said:

> "Intelligence will win out in the long run; but the human species must turn aside in its race and concentrate a great deal of its 'God-given' intelligence on its strongest rival, the insect."[10]

Do this and you win. Ignore it at your peril.

[10] Howard, L. O., 1931. Man and Insects. Ann. Rept. Smithson. Inst., p. 399.

EFFECTS OF VARIOUS SUGAR AND HONEY TREATMENTS ON THE FORAGING ACTIVITY OF HONEY BEES

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ABSTRACT: Foraging activity and weight of pollen collected by colonies of honey bees treated with two different concentrations of sugar syrup (or honey syrup) at two different times during the day were compared throughout the day; these experiments were repeated during the "pre-flow", "honey-flow", and "post-flow" periods. No significant differences in the proportions of incoming foragers, or the weights of pollen occurred within any of the treatments. The application of these data to the beekeeping industry is discussed.

INTRODUCTION

The foraging activity of a honey bee colony is influenced by many factors, such as colony population, a beekeeper's management system, and various environmental factors including weather and the attractiveness of crops. Each of these is continually changing.

Beekeepers frequently report that when they replace a full box of honey (super) with a freshly extracted (wet) super that bee activity at the hive entrance, and the number of foraging bees, appear to increase. It may be that the small amount of honey that is not removed during the extraction process stimulates the bees to fly, and possibly to forage.

This study was done to ascertain if treating colonies artificially with honey or sugar syrups, at various times throughout the season, has any effect on the foraging activity of the bees. Such a technique might provide the beekeeper with a simple means of stimulating colonies to forage more actively for nectar and/or to pollinate certain crops.

METHODS AND MATERIALS

All experiments were conducted on the University of Manitoba campus in Langstroth hives in 1972 using honey bees of a yellow strain (Starline hybrid bees, Weaver Apiaries, Navasato, Texas). Experimental and control colonies were equal, as far as possible, in adult populations, and in stores of honey and pollen. The experiments were conducted during three time periods: (1) the "honey-flow" period, i.e. the three- to four-week period in mid-summer when most of the major nectar yielding plants bloom, (2) the "pre-flow" period, i.e. the period previous to the honey-flow period when relatively few major nectar yielding plants are in bloom, (3) the "post-flow" period, i.e. the period following the honey-flow when again relatively few major nectar yielding plants are in bloom. During these experiments, colony populations were as follows: pre-flow period, 10,000-15,000; honey-flow period, 25,000-30,000; post-flow period, 45,000-50,000.

All experimental colonies received similar treatment as follows: after the lid was removed from a hive it was smoked lightly and 100 ml of either a sugar or a honey syrup were sprayed into the top box of each experimental hive with a three gallon compressed air sprayer calibrated to deliver 100 ml of sugar (or honey) syrup in 13 seconds. After treatment, the lid was replaced gently. The experimental hives were treated with either a sugar or honey solution of either high or low concentration at 1000 or 1200 h on the day an experiment was done (Table 1). The lids of control hives were removed and after the bees had been smoked lightly the lids were replaced.

Data were collected on total incoming foragers, incoming pollen foragers, and weight of pollen, from each experimental and control hive each hour of the day from 0900 or 1000 h to 1500 or 1600 h, depending on the experiment (Figures 1-6). The methods used

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Table 1. Sugar and honey syrup combinations used in experiments (1972)

Type of syrup	Ratio of sugar or honey to water by volume	% sugar	Treatment codes 1000 h	Treatment codes 1200 h
Sugar syrup (SS)	1:1 (high, H)	47.0	SS H_{10}*	SS H_{12}
	1:5 (low, L)	14.5	SS L_{10}	SS L_{12}
Honey syrup (HS)	1:1 (high, H)	46.0	HS H_{10}	HS H_{12}
	1:7 (low, L)	13.5	HS L_{10}	HS L_{12}

*SS H_{10} = Sugar syrup, high sugar concentration (47.0%), colonies treated at 1000 h.

to obtain these data, and the statistical methods used to analyse them, are described in a previous paper (Barker and Jay 1974).

Pre-flow Period

On 12 July, 15 hives were divided into five groups of three hives each. At 1000 h the first group (Group I) was treated with a high concentration sugar syrup (SS H_{10}) and a second group (Group II) was treated with a low concentration sugar syrup (SS L_{10}); the third group (Group III) was designated as a control group (C). At 1200 h the fourth group (Group IV) was treated with a high concentration sugar syrup (SS H_{12}) and a fifth group (Group V) was treated with a low concentration sugar syrup (SS L_{12}). A similar experiment, in which honey syrup was used in place of sugar syrup, was carried out on 17 July using different hives.

Honey-flow Period

The experiments outlined in the pre-flow period were repeated as follows: the sugar syrup experiments were conducted on 11 August, and the honey syrup experiments were conducted on 12 August.

An additional experiment was done to determine if the experimental treatment had a delayed effect on the foraging activities of a honey bee colony. On 17 August, the first day of the "two day experiment" nine colonies were divided into three equal groups. The hives were treated at 1200 h with honey syrup as follows: Group I was treated with a high concentration honey syrup, and Group II was treated with a low concentration honey syrup, and Group III was treated as the control group. As in the previous experiments, data were collected on forage activity and pollen weight, but only between 1100 and 1600 h on 18 August.

Post-flow Period

The experiments, outlined in the pre-flow period, were repeated on 14 September using sugar syrup. Unfavourable weather prevented completion of the experiment using honey syrup.

RESULTS

Pre-flow Period

Foraging activity of the worker bees, as measured by the proportion of total incoming foragers, incoming pollen foragers, or weight of pollen collected each hour during the experimental period, was not significantly affected by the sugar-syrup treatment (Figure 1) or the honey-syrup treatment (Figure 2).

Honey-flow Period

Again, foraging activity was not significantly affected by the sugar syrup treatment (Figure 3) or the honey syrup treatment (Figure 4). Furthermore, there was no significant

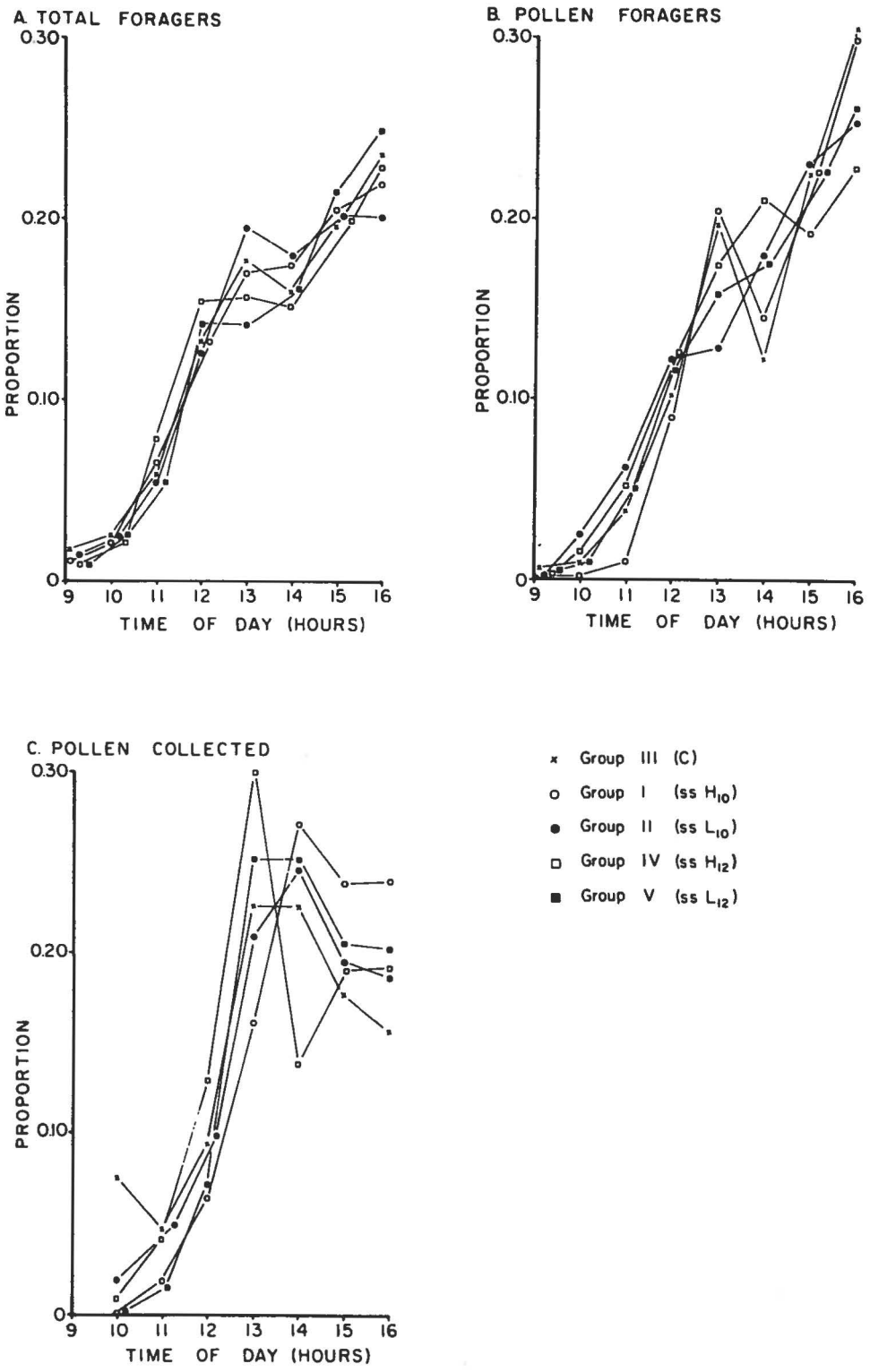

Figure 1. A comparison of group hourly proportions of total incoming foragers, incoming pollen foragers, and weight of pollen collected by colonies treated with two different concentrations of sugar syrup at two different times during the day (12 July, 1972, Pre-flow Period)

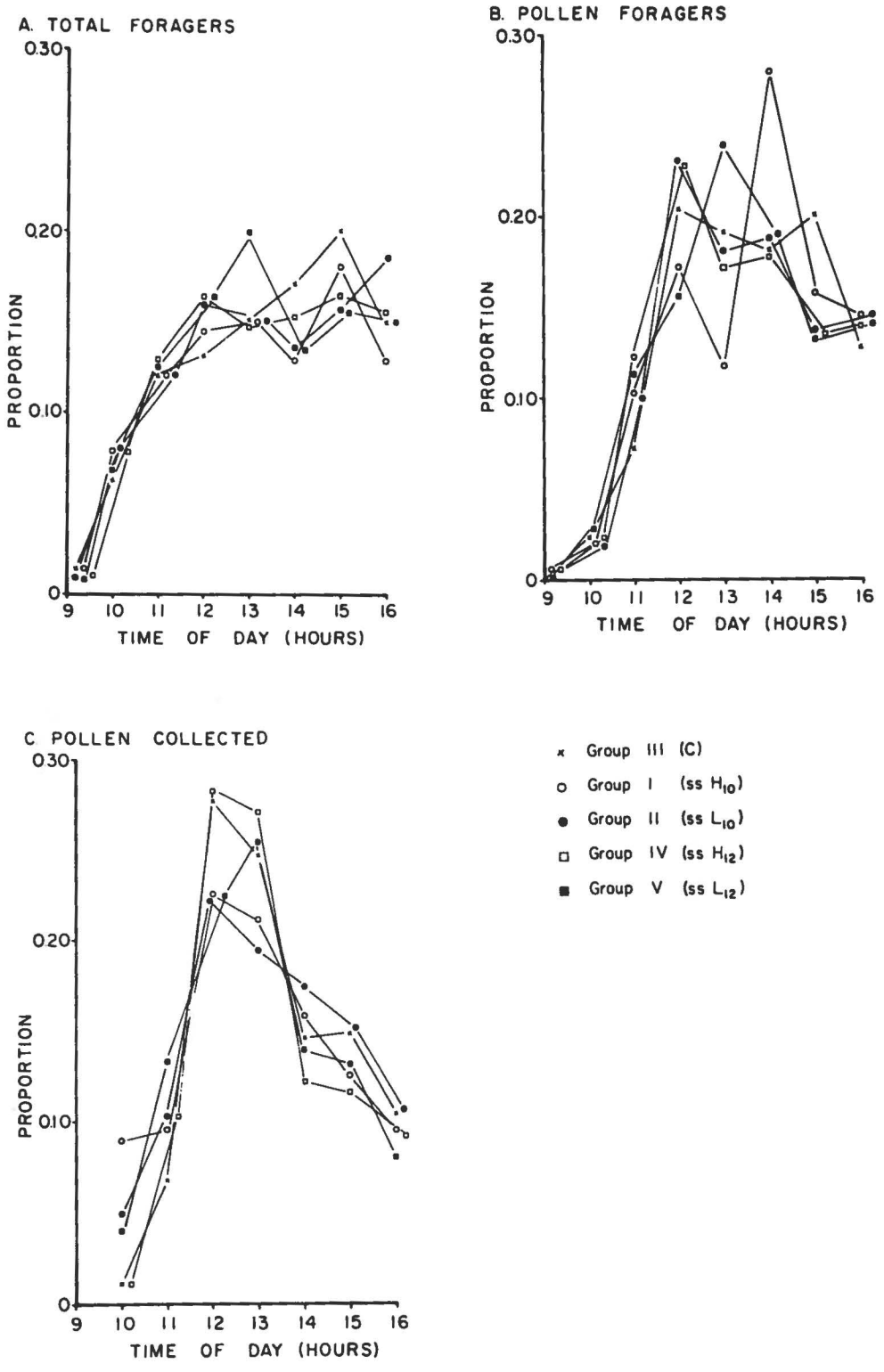

Figure 2. A comparison of group hourly proportions of total incoming foragers, incoming pollen coragers, and weight of pollen collected by colonies treated with two different concentrations of honey syrup at two different times during the day (17 July, 1972, Pre-flow Period)

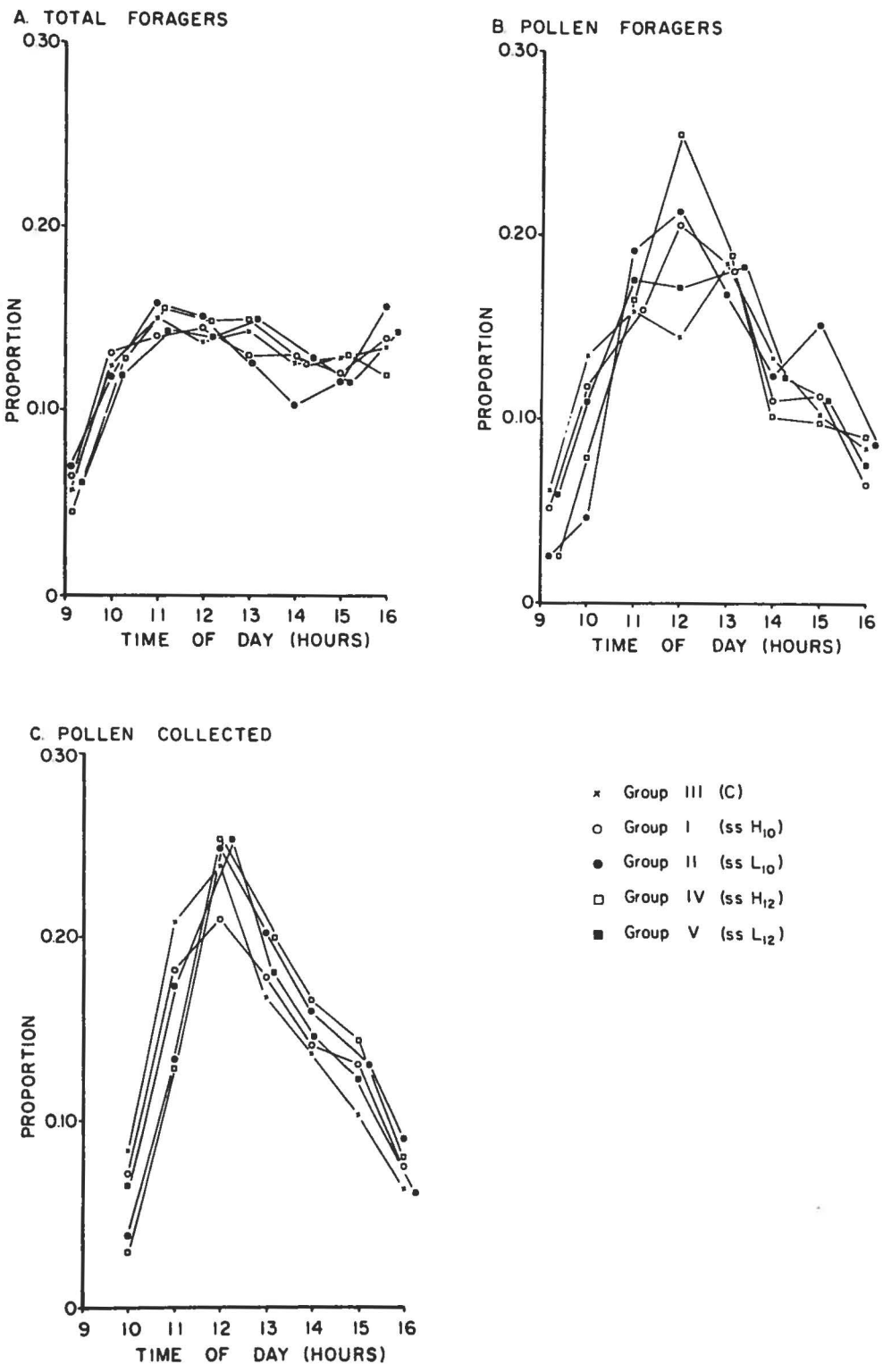

Figure 3. A comparison of group hourly proportions of total incoming foragers, incoming pollen foragers, and weight of pollen collected by colonies treated with two different concentrations of sugar syrup at two different times during the day (11 August, 1972, Honey-Flow Period)

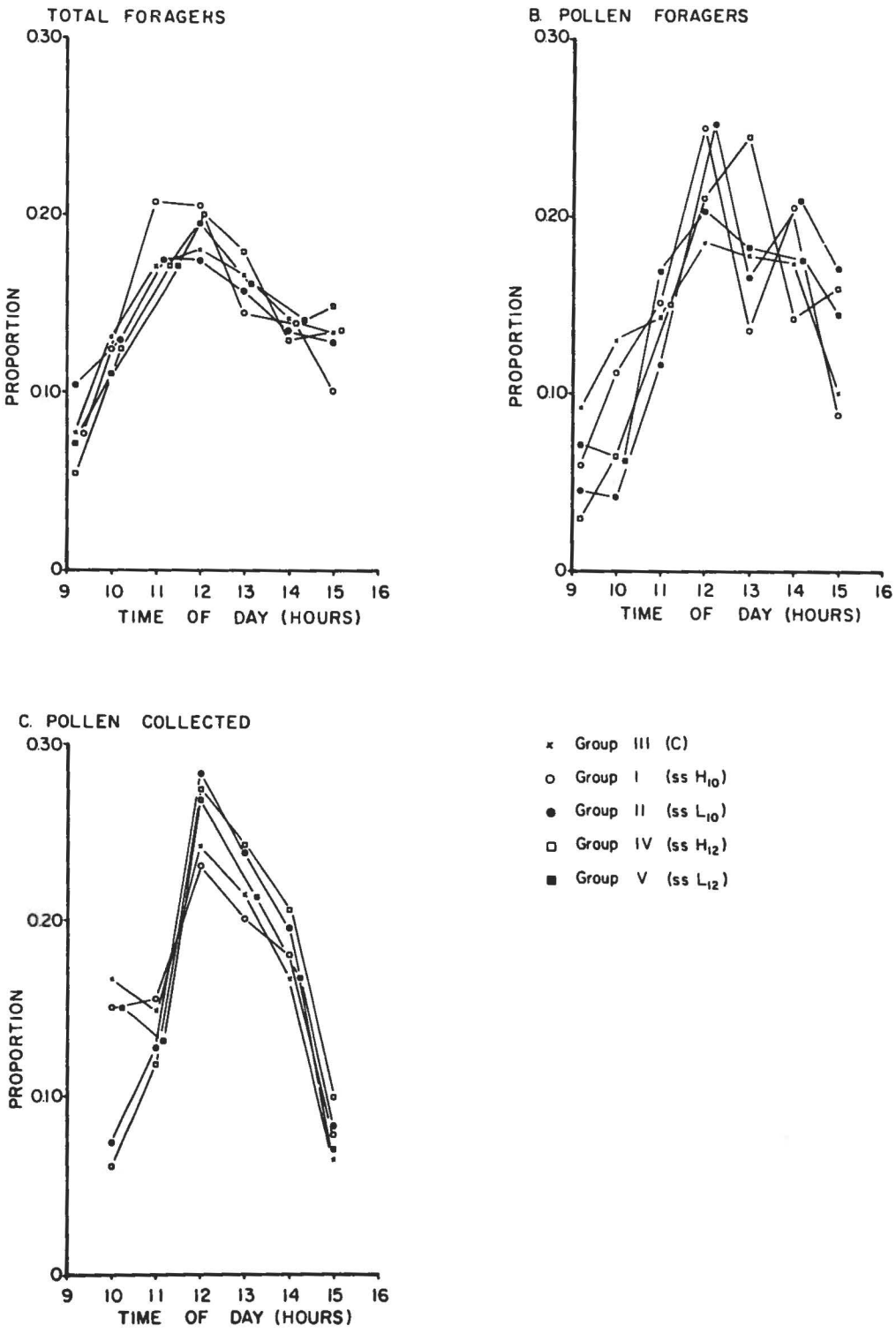

Figure 4. A comparison of group hourly proportions of total incoming foragers, incoming pollen foragers, and weight of pollen collected by colonies treated with two different concentrations of honey syrup at two different times during the day (12 August, 1972, Honey-Flow Period)

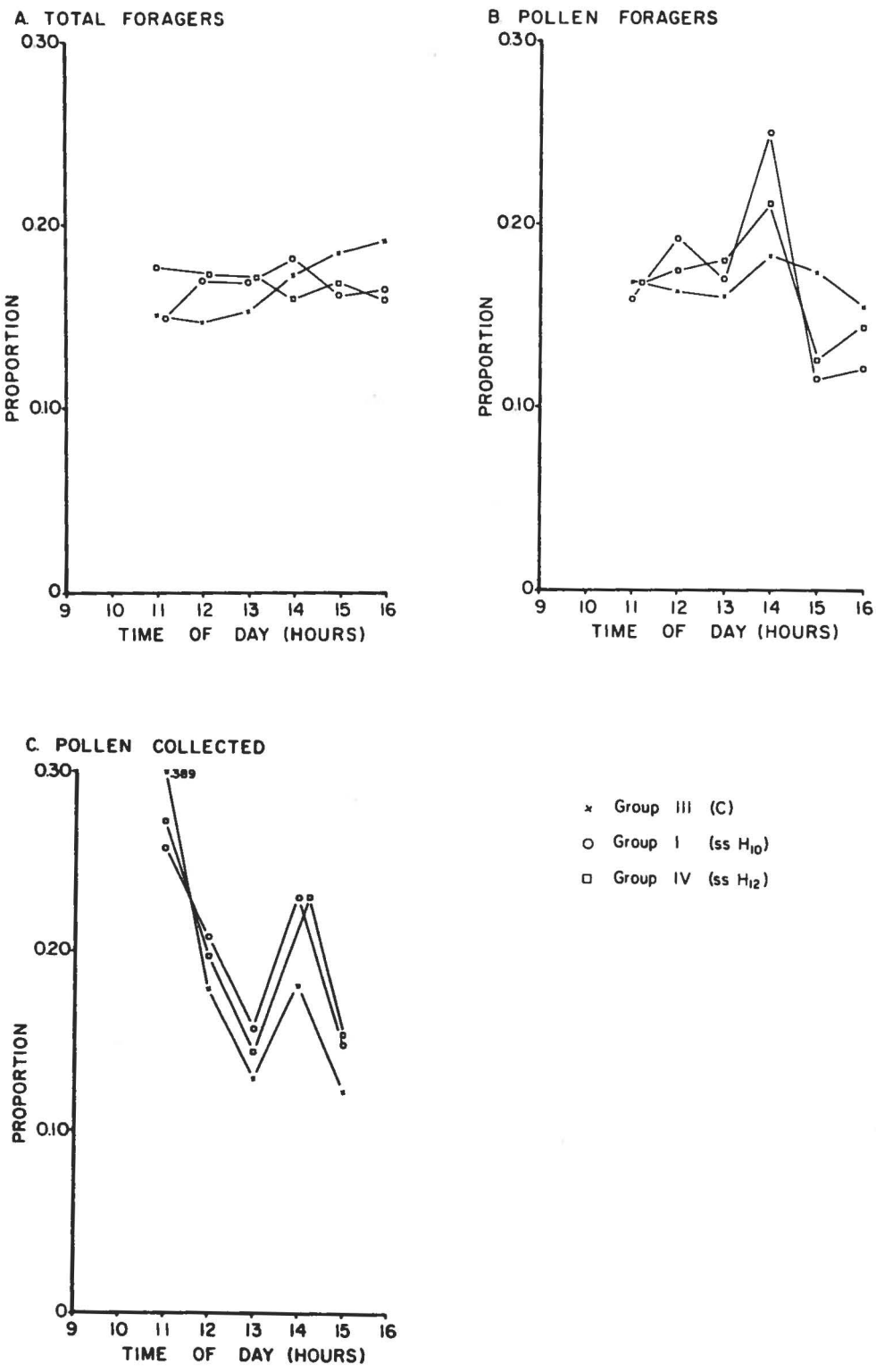

Figure 5. A comparison of group hourly proportions of total incoming foragers, incoming pollen foragers, and weight of pollen collected the day after colonies were treated with two different concentrations of honey syrup at 1200 h (18 August, 1972, Honey-Flow Period)

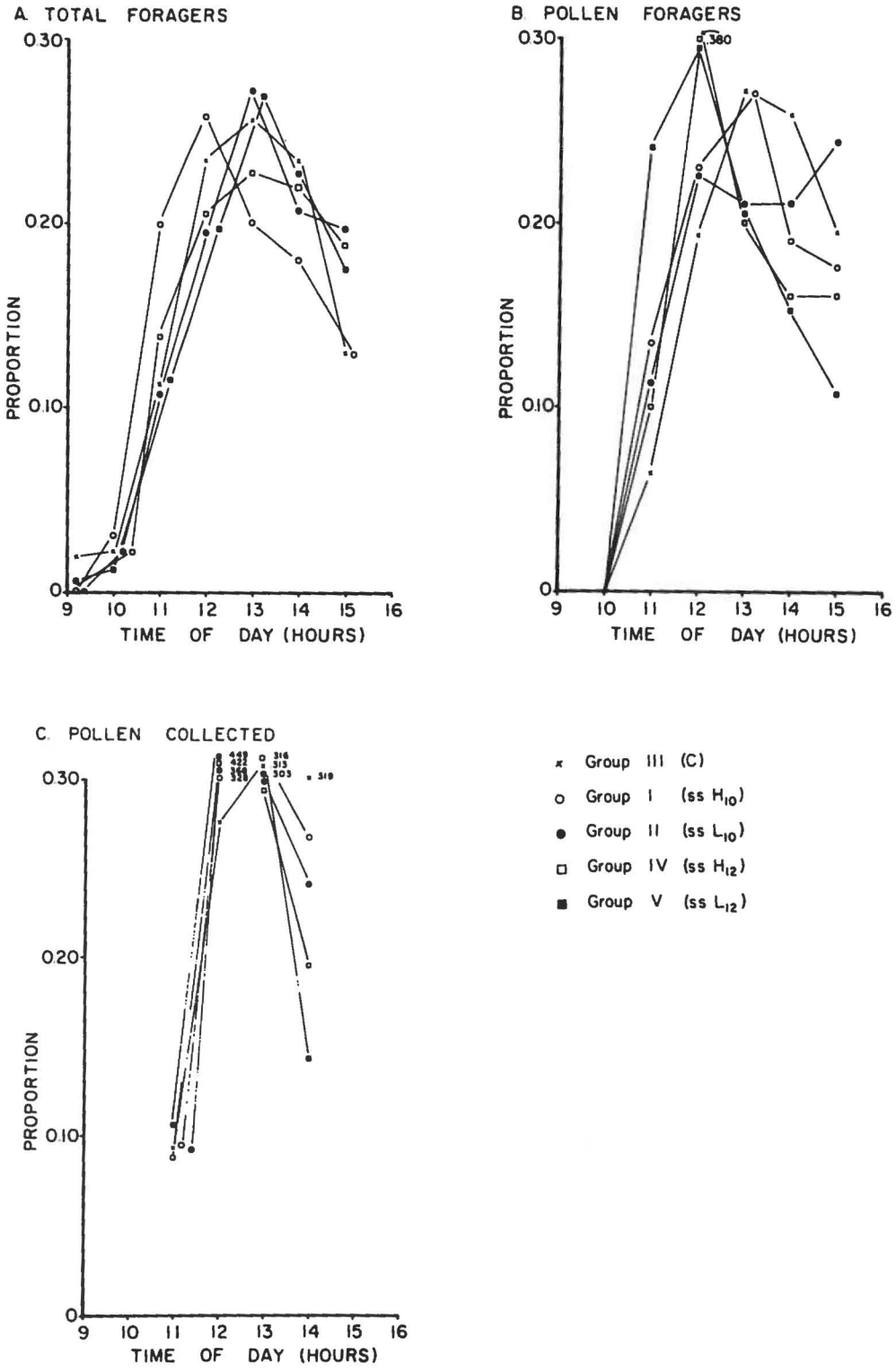

Figure 6. A comparison of group hourly proportions of total incoming foragers, incoming pollen foragers and weight of pollen collected by colonies treated with two different concentrations of sugar syrup at two different times during the day (14 September, 1972, Post-flow-Period)

change in foraging activity on the day following treatment with honey syrup. (Figure 5).

Post-flow Period

Foraging activity in the post-flow period was not significantly affected by the sugar syrup treatment even though the colony populations were larger and bloom was less. (Figure 6).

DISCUSSION AND CONCLUSIONS

The purpose of this study was to determine if sugar- or honey-syrup, sprayed into the top box of a hive, provides a quick, practical, inexpensive means of stimulating the honey bees of the colony to forage. It was found, however, that regardless of when an experiment was done during the season*, the type or concentration of syrup used, or the time of day the syrup was applied, no significant differences occurred in the proportion of total incoming foragers, incoming pollen foragers, or weight of pollen collected each hour during the experimental period. This was also true in the experiment where these data were collected on the second day. It therefore appears that the treatments had little or no effect on the foraging activities of honey bee colonies.

The increased activity of bees at a hive entrance, which has been observed by beekeepers immediately after they have placed a wet super on the hive, is probably a short term flurry of activity following stimulation by the smell and/or taste of honey, or is due to the physical disturbance of the colony by the beekeeper. Treatments, in this study, using various syrups sometimes caused brief shifts in foraging activity but there was no significant increase in the total number of bees foraging on those days.

It is interesting to note that numerous Eastern European and Russian authors (Firrsov 1951, Sovoleva 1952, Kashkovski 1954, Barskii 1956, Morozov 1959, Ragim-Zade 1966) used scented sugar syrups, while others (Leuchenko *et al.* 1954, Valyushkevich *et al.* 1958, Voskkestenkaya *et at.* 1957) used syrups in conjunction with simultaneous feedings of scented calcium chloride, to increase or direct, the foraging activity of the treated colonies. However, three authors (Blagoveshchenskaya 1955, Free 1958, 1965, Stapel 1960) concluded that, at least for improving pollination through increased or directed bee activity, the feeding of scented syrup was of little value.

During the honey flow, which is a time when beekeepers are very busy extracting honey, they will often make a special effort to restore "wet" supers quickly to the hives to provide room for incoming nectar and, as some have suggested, to stimulate the bees to forage more actively. Certainly empty supers should be returned to colonies quickly if additional space is required for incoming nectar, but returning them because one believes that the honey they contain may stimulate foraging activity does not seem valid.

What is not known is the actual effect on the foraging activity of a colony when a full honey super is replaced by an empty dry or wet super. Perhaps foraging activity is increased by a combination of one or more factors relating to this management technique, e.g. housecleaning stimuli, a large suddenly available storage place, and the dislocation of hive activity relating to full versus empty supers. This is currently under investigation.

ACKNOWLEDGEMENT

The authors thank the National Research Council of Canada for the funds to conduct this study.

*During each of the three periods when the tests were conducted, there were differences in adult bee populations, food stores, and brood levels with the hives as well as differences in environmental conditions (e.g. weather, type and amount of bloom available, etc.)

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REINTERPRETATION OF INFORMATION ON EXOTIC BROWN LACEWINGS (NEUROPTERA: HEMEROBIIDAE) USED IN A BIOCONTROL PROGRAMME IN CANADA

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ABSTRACT: A biocontrol programme for the balsam woolly aphid, *Adelges piceae* (Ratz.), in New Brunswick, Canada, during the 1930's, included release of eggs of two exotic species of Hemerobiidae, *Hemerobius nitidulus* Fabricius and *Hemerobius stigma* Stephens. Published information on these releases, which is summarized, states consistently that the species were not recovered. The two exotic hemerobiids are readily distinguishable from each other. However, *H. stigma,* which constituted most of the test-releases, could have been confused with con-specific populations endemic to the region, formerly known as *Hemerobius stigmaterus* Fitch. This taxonomic difficulty precludes a conclusive appraisal of *H. stigma* as a potential biocontrol agent on present evidence.

INTRODUCTION

Hemerobiidae are well known as predatory insects. Presently they are receiving serious consideration as potential biocontrol agents (New 1975; Neuenschwander 1976). During the 1930's, they were tested, without apparent success, in New Brunswick, Canada, in an extended programme of biological control of the balsam woolly aphid, *Adelges piceae* (Ratz.) (Clark *et al.* 1971). This note re-examines published reports which pertain to those tests, and draws attention to a taxonomic difficulty which precludes a conclusive evaluation of the one hemerobiid used most in the releases.

NATIVE AND EXOTIC HEMEROBIIDAE

The ecosystem of the balsam woolly aphid in New Brunswick includes Hemerobiidae among the endemic predators (Balch 1934; *cf.* MacAndrews 1923). In study plots near Fredericton during the years 1932-1934, *Hemerobius stigmaterus* Fitch and two undetermined species were observed (Balch 1952). Other species recorded from New Brunswick are *Hemerobius humulinus* L. (Clark *et al.* 1971) and *Hemerobius simulans* Walker (Carpenter 1940; Tjeder 1960).

The brown lacewings and other naturally occurring predators were not considered effective control agents of the balsam woolly aphid (Balch 1934). A search for other predators by the Commonwealth Bureau of Biological Control culminated in liberations which included two exotic hemerobiids, *Hemerobius nitidulus* Fabricius and *Hemerobius stigma* Stephens (Balch 1952).

Published information, summarized with respect to the test-releases of hemerobiids (Table 1), discloses that eggs of these two species were tested in three counties during the years 1935-1938. The figures are not entirely consistent but do indicate that, with the exception of 1935, *H. stigma* was employed exclusively. Despite close surveillance (McGugan and Coppel 1962), the exotic hemerobiids were not recovered (Balch 1952; Brown and Clark 1956; Smith and Coppel 1957; Balch *et al.* 1958; McGugan and Coppel 1962). One inference is that they did not survive the winter (Balch 1952).

An additional release of fifty specimens of *H. stigma,* material surplus to requirements of the New Brunswick programme, was made near Belleville, Hastings County, Ontario, in 1939 (McGugan and Coppel 1962). Again, the exotic insect was not recovered, but the liberation itself was not monitored closely (McGugan and Coppel 1962).

Table 1. Releases of Hemerobiidae in New Brunswick, Canada.
(Summarized from Balch (1952), and Smith and Coppel (1957))

Species	Releases		Number of eggs	
	Year	Location	Balch	Smith and Coppel[a]
Hemerobius nitidulus	1935	Millstream, Kings County	–	110
	1935	Fredericton, York County	810	–
Hemerobius stigma	1935	Millstream, Kings County	–	10
	1935	Long Creek, Queens County	–	220
	1935	Fredericton, York County	1331	–
	1937	Fredericton, York County	2177	423
	1938	Fredericton, York County	–	4260

[a] also recorded by McGugan and Coppel (1962: 161).

TAXONOMIC CONSIDERATIONS

The exotic hemerobiids are separable as mature larvae (Withycombe 1923; Killington 1936) and as adults (Killington 1936, 1937). A more formidable task is to separate these two exotic species, especially *H. stigma* which figured preponderantly in the test releases, from the known endemic hemerobiids.

In particular, difficulty would have been encountered due to the presence of the endemic *H. stigmaterus* which, more recently, has been rejected as a junior subjective synonym of the taxon *H. stigma* (Tjeder 1960). This synonymy is acceptable, in eastern Canada especially, because specimens for comparison were obtained in Newfoundland. Evidently, one of the released species was present already, masquerading under a spurious name.

Elucidation of the synonymy of these species-group taxa was based entirely upon a comparative study of terminalia of the adult male. Unfortunately, there is no definitive structure known in the immatures which could affirm this. For example, larval chaetotaxy is said to be constant in general plan throughout all species of hemerobiids; and, where variable, it is not specific (Withycombe 1923).

Published information on the mature, third-instar larva of *H. stigma* includes notes about the characteristic dorso-lateral bands which extend the length of the larva. Figures reveal that, in shape, these bands are similar in appearance in both the Palearctic (Withycombe 1923; Killington 1936) and the Nearctic (Smith 1923, as *H. stigmaterus*) representatives of this species. The bands become narrower posteriorly in each metamere and are discontinuous at the intersegmental boundaries. They have been described as chocolate-coloured (Withycombe 1922), dark brown (Withycombe 1923), dark brownish-red or purplish-red (Smith 1923, as *H. stigmaterus*), and reddish to purplish (Laidlaw 1936). On the basis of this information, larvae of *H. stigma* are indistinguishable regardless of their origin.

CONCLUSION

There is a serious need for taxonomic research on the identities and classification of naturally occurring predatory insects (Munroe 1971). Hemerobiidae provide an example of this need. In the Canadian experience, two species, *H. stigma* and *H. nitidulus,* were released as presumed exotic introductions. One of these, *H. stigma*, which constituted

most of the test material, was shown subsequently to be con-specific with the endemic *H. stigmaterus.* This insect is widely distributed throughout the Holarctic Region (Tjeder 1960), and taxonomic characters involving the male terminalia are variable (Nakahara 1960, 1965). The unresolved taxonomic problem with this hemerobiid appears to be to distinguish populations from different zoogeographic regions, and to document regional variability.

When the releases were made during the 1930's, the Nearctic and Palearctic populations of *H. stigma* were considered to be distinct species. Presently they are considered to be morphologically indistinguishable and taxonomically synonymous. Therefore, *H. stigma* of exotic origin, if recovered at all, could readily have been determined as the endemic *H. stigmaterus,* leaving open to question whether establishment has or has not occurred and whether such stocks have the potential to contribute to the biocontrol of the balsam woolly aphid.

ACKNOWLEDGEMENTS

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THE RESPONSES OF ELEVEN STRAINS OF *TRIBOLIUM CASTANEUM* (HERBST) TO METHYL BROMIDE[1]

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ABSTRACT: The responses of 11 strains of *Tribolium castaneum* (Herbst) to methyl bromide were studied. The LC_{50}s of the 11 strains varied from 7.05 to 8.42 mg of methyl bromide per litre of air. Some strains were tolerant to methyl bromide, one from Montreal being 1.21 times as tolerant as a standard strain. Though these differences were statistically significant, they indicate that resistance to methyl bromide has not built up in wild populations of *T. castaneum* in Canada.

INTRODUCTION

Canadian climatic conditions do not favor the increase of stored cereal insect pest populations as much as do more tropical climates. The long cold winters provide natural refrigeration for grain and reduce the number of generations of insects per year (Burges and Burrell 1964; Navarro *et al.* 1973) which leads to a reduced pace of selection for insect resistance to chemicals in Canada. The threat of accidental importation of insecticide-resistant strains, however, remains. One of the functions of the Plant Quarantine Division of Agriculture Canada is to inspect all ships and other carriers which come to Canadian ports of entry, for pests which they might bring to Canada. If pests of cereals are found, these carriers must be cleaned and fumigated (Monro 1969a); the exclusion of pests, including fumigant-tolerant strains, is a first line of defence against problems of insecticide tolerance (Popham and Hall 1958).

Ideally, ship and vehicle inspections should be complemented by the monitoring of local strains of insect pests for the emergence of tolerance to insecticides (Anonymous 1975). Tests to monitor levels of tolerance are done in laboratories, and Hoskins and Craig (1962) indicate that a high degree of precision is desirable in this sort of laboratory work.

The red flour beetle, *Tribolium castaneum* (Herbst), a stored product pest of world wide distribution, is also found in the Canadian Prairie Provinces (Liscombe and Watters 1962; Sinha 1965). This species has produced strains resistant to malathion and lindane in Australia (Champ and Campbell-Brown 1970a and 1970b). Dyte and Blackman (1970) recorded that lindane and malathion resistance was found in strains of the red flour beetle from at least 9 countries. Bhatia and Pradhan (1972) showed that a lindane-resistant strain also showed cross-resistance to eight other residual insecticides, but not to malathion or pyrethrins.

One of the fumigants most often used for the fumigation of ships and other vehicles, in Canada and other countries, is methyl bromide (Monro 1969a and 1969b). Tolerance to this fumigant is not widespread, but Monro and Upitis (1956) selected a strain of granary weevil *Sitophilus granarius* (L.) which was approximately twice as tolerant to methyl bromide as were the unselected controls. Strains of the red flour beetle may also be tolerant to methyl bromide. Experiments were therefore performed to determine the tolerance of methyl bromide of 11 strains of the red flour beetle from different geographical areas within Canada and from Texas.

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MATERIALS AND METHODS

The sources of the 11 strains of *T. castaneum* were as follows: the strain labelled Agriculture Canada (A. C.) (Table 1) has been maintained at this laboratory for many years; the strains labelled Letellier, Lethbridge, and Vancouver I and II were from elevators in the respective locations in Manitoba, Alberta and British Columbia. The Montreal strain came from a flour mill in Montreal, Quebec. The town where the Texas strain was collected is unknown. The Chatham, Paris, London and Bond strains were collected by Dr. E. Bond in Ontario, Canada.

The insects were reared on flour fortified with 5% brewer's yeast (w:w) in 3.8 litre Mason jars. Approximately 20 insects, 9 to 16 days old, from a strain were placed in each of 28 test tubes 8.5 cm long and 1.3 cm in diameter. A 0.5 x 7.0 cm strip of filter paper was placed in each of the 28 tubes to provide more surface area and reduce the density of the beetles at the bottom of the test tubes.

Three test tubes, each containing a different strain, were placed in each of 28 glass jars which were 8.0 cm long and 5.0 cm in diameter; the test tubes were thus held upright. A jar, with its three test tubes, was placed in each of the 28 sealers of 1.735 l volume. The 28 sealers were arranged at random into 7 groups of 4. One group of 4 sealers was not treated and the other groups received 6 dosages of methyl bromide which ranged from 6.1 to 8.5 mg/l. The exact quantity of methyl bromide used per jar varied from day to day because changes in the barometric pressure affected the gas burette which was used to measure the gas. The dosages of methyl bromide were equally spaced for each particular experiment. There were 6 dosages, and each dosage was repeated 4 times, providing a total of 24 points (=readings). The exposure period was 5 hours. This system had some similarities with the one used by Barker (1976).

After fumigation, the insects were placed on 8 g of clean rearing medium in vials 7 cm long and 3 cm in diameter. A snap-on cap with a hole covered with brass mesh confined the insects to the vials. Each strain was kept in separate vials. The vials with the insects were placed in incubators at 30°C and about 75% RH for 7 days. The numbers of live and dead insects were then recorded.

Logit analyses were performed on the data obtained for each strain (Ashton 1972). The standardized residuals were examined for each test; points at the 1% level were rejected because it was assumed that if aberrant points were not found in all three strains tested at one time at the same dosage, then the point in question may have been poorly recorded or may have resulted from a mishap after the test was performed. If aberrant points were found for all three strains at the same dosage, it was assumed that the amount of gas applied was not correct.

Two-way analyses of variance were performed on the LC_{50}s and LC_{95}s. Three strains of the red flour beetle were used in each analysis; repetitions of each test were considered as replicates. These repetitions took into account the variability which occurred between generations within a strain.

RESULTS AND DISCUSSION

The average response of the A.C. strain to methyl bromide varied slightly from one set of tests to another (Table 1), but there was a wider range of variation between tests within a set (Table 2). Throughout these tests the A.C. strain was the most susceptible to methyl bromide at the LC_{50} level.

Table 1. The mean LC_{50}s and LC_{95}s of 11 strains of *T. castaneum* treated with methyl bromide.

Strain	Set number	Mean LC_{50} (mg CH_3Br/l)	Mean LC_{95} (mg CH_3Br/l)
Montreal	1	8.42	11.14
Vancouver I	1	8.06	11.22
A. C.	1	7.12	9.69
L.S.D.$_{0.05}$		0.54	1.02
Lethbridge	2	7.57	9.28
Letellier	2	7.20	9.30
A. C.	2	7.07	9.31
L.S.D.$_{0.05}$		0.14	0.55
Bond	3	7.45	9.51
Vancouver II	3	7.25	8.76
A. C.	3	6.97	8.74
L.S.D.$_{0.05}$		0.07	0.45
Chatham	4	7.18	9.10
Texas	4	7.23	9.31
A. C.	4	7.05	9.02
L.S.D.$_{0.05}$		0.17	0.78
Paris	5	8.06	9.82
London	5	7.90	10.78
A. C.	5	7.06	8.89
L.S.D.$_{0.05}$		0.21	0.98

Barker (1976) examined the variability of the response of *T. castaneum* (A.C. strain) to methyl bromide and showed that not only did the LC_{50} vary from one generation to the next, but that the 95% confidence interval bands did not always overlap. In the comparison between strains, the analysis of variance took this variability into account.

The heterogeneity factors calculated for the A.C. strain ranged from 0.717 to 1.80, and the precision (Barker 1977) of the LC_{50}determinations varied from 3.3 to 6.3% (Table 2), indicating that sufficient points were used for each test and that these points were adequately distributed around the LC_{50} (Barker 1977).

In spite of the amplitude of the variations of the width of the confidence intervals, the strains Montreal, Paris, London, and Vancouver I, were more tolerant than the A.C. strain ($P<0.05$) at the LC_{50} level to methyl bromide (Table 1). Moreover, the differences were consistent and reproducible from one test to the next, in spite of the normal fluctuations of the tolerance to the fumigant.

Table 2. The LC_{50} and 95% confidence limits, heterogeneity and precision of the determination of the response of *T. castaneum* (A.C. strain) to methyl bromide.

No.	Set	LC_{50} (mg/l)	Conf. limits −95%	Conf. limits +95%	Heterog. factor	Precision (%)
1	1	7.407	7.227	7.591	1.555	4.9
2	1	7.048	6.910	7.188	1.320	3.9
3	1	7.429	7.196	7.670	1.801	6.3
4	1	6.972	6.825	7.123	1.150	4.7
5	1	6.774	6.624	6.929	0.886	4.5
6	2	6.886	6.744	7.031	0.717	4.2
7	2	7.392	7.215	7.530	1.174	4.2
8	2	6.868	6.711	7.027	1.122	4.6
9	2	7.152	7.013	7.294	0.908	3.9
10	3	6.957	6.826	7.090	0.989	3.8
11	3	6.843	6.719	6.969	1.143	3.6
12	3	7.184	7.045	7.327	1.289	3.9
13	3	6.915	6.789	7.042	0.931	3.6
14	4	7.071	6.933	7.213	0.903	3.9
15	4	7.509	7.383	7.636	0.917	3.3
16	4	6.916	6.772	7.063	1.262	4.2
17	4	7.088	6.964	7.215	0.828	3.5
18	4	6.691	6.510	6.877	1.226	5.4
19	5	7.102	6.975	7.231	0.976	3.6
20	5	7.280	7.126	7.436	0.868	4.2
21	5	7.030	6.907	7.157	1.392	3.5
22	5	6.846	6.722	6.973	0.688	3.6

The Montreal strain was the most tolerant to methyl bromide when compared to the A.C. strain (Table 1). The potency ratios between the LC_{50}s of these two strains showed that the Montreal strain was between 1.11 and 1.21 times as tolerant to methyl bromide as the A.C. strain (Table 3). These differences were small and hardly meaningful in practical terms though they were consistent and statistically significant ($P<0.05$).

A test for parallelism was performed on the data from the experiments which yielded the most widely separated LC_{50}s in the Montreal and A.C. strains. The potency ratio obtained was 1.21 with a standard error of 0.0382 (Experiment 3, Table 3). There was no conflict with the hypothesis of parallelism between the logit lines obtained (Table 4).

Based on the above experiments, however, the levels of tolerance to methyl bromide of the Chatham and Texas strains did not appear to be different from that of the A.C. strain (Table 1).

Three strains, Lethbridge, Bond, and Vancouver II showed LC_{50} levels of tolerance to methyl bromide which were intermediate between those of the Montreal and A.C. strains. The differences were consistent from one generation to the next though they were very small (Table 1).

This work has shown that 4 out of 10 strains of *T. castaneum* were more tolerant to methyl bromide than a standard susceptible strain and shows that the buildup of resistance to methyl bromide has been very slight in wild populations in Canada.

Table 3. The parameters obtained in tests for parallelism between the Montreal and A. C. strains of *T. castaneum*

Parameter	Test number				
	1	2	3	4	5
Over-all Chi-Sq.	60.38	45.04	75.26	40.58	44.47
Pooled slope	21.86	27.92	16.29	23.53	26.16
New interc. (Mtl)	−20.43	−25.32	−15.53	−20.95	−23.26
New interc. (A.C.)	−19.01	−23.68	−14.18	−19.83	−21.74
Potency ratio	1.161	1.144	1.210	1.115	1.143
St. err. pot. rat.	0.0247	0.0164	0.0382	0.0175	0.0174
St. err. slope	2.264	2.322	2.058	1.926	2.124

Table 4. Chi-square test for parallelism between the Montreal and A. C. strains of *T. castaneum* in test 3.

Source of variation	Sum of squares	d.f.	Mean square
Parallelism of regression	0.075	1	0.075
Residual heterogeneity	60.312	44	1.370
Total	60.387	45	1.342

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CONTROL OF ADULTS OF THE RUSTY GRAIN BEETLE, *CRYPTOLESTES FERRUGINEUS* (STEPHENS), WITH CARBON DISULPHIDE AT TEMPERATURES BETWEEN 6.6 AND 10°C, AND ESTIMATION OF THE DOSAGE APPLIED[1]

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ABSTRACT: The survival of adults of the rusty grain beetle in wheat treated with carbon disulphide at high and low temperatures was measured. Beetle survival was related to gas concentration, time, and temperature; 100% kill was obtained with carbon disulphide in wheat when exposure periods were 4 days or more, temperatures between 6.6 and 10°C, and fumigant concentrations more than 6 mg/l. Estimates of the original amount of fumigant applied to the wheat were obtained from a regression of $\log_{10}$ of post-treatment gas concentrations on $\log_{10}$ of time after fumigation; the intercepts calculated for day 0.33 were close to the amounts applied.

INTRODUCTION

The rusty grain beetle, *Cryptolestes ferrugineus* (Stephens), is one of the most important stored-grain pests found in empty granaries in the Prairie Provinces of Canada (Liscombe and Watters 1962) and ranks third in frequency of occurrence in samples of insects taken during routine ship inspections in Canada (Monro 1969a). This species was found by United Kingdom authorities in the after holds of ships loaded with Canadian grain which had been warmed by heat from the propeller shaft tunnels (Freeman 1968).

Adults of the rusty grain beetle undergo a process of acclimation which enables them to tolerate freezing temperatures for a few months and thus survive the Canadian winter climate (Smith 1970). Since Canadian grain is often shipped during the cold season, it is sometimes necessary to fumigate cool grain to avoid the export of an infested product.

Carbon disulphide has been an important component of liquid fumigant mixtures for more than half a century and is usually mixed with carbon tetrachloride. At the turn of the twentieth century, carbon disulphide was used in nearly pure form for the fumigation of stored corn (Hinds 1914) and cotton seed (Hinds 1915). The mixture most often sold on the market today consists of approximately 80% carbon tetrachloride and 20% carbon disulphide. Hinds (1911) recorded that an explosion was caused in a bin of corn which was heating and which has been treated with undiluted carbon disulphide. Present day mixtures contain enough carbon tetrachloride to considerably reduce fire and explosion hazards.

Burns-Brown (1944) has commented that most published toxicity data had been obtained at about 25°C, though most commercial fumigations done in England at that time were carried out at 10 to 20°C. Monro (1969b) stated that it was inadvisable to attempt fumigation of grain at temperatures below 10°C. In Canada, where grain temperatures are often below 10°C, it is necessary to evaluate the effectiveness of a fumigant at temperatures close to freezing. An evaluation of the effectiveness of carbon disulphide for the control of rusty grain beetles at very low temperatures and a method for the estimation of the amount of carbon disulphide applied are presented in this paper.

MATERIALS AND METHODS

About 25 adult *C. ferrugineus* and 8 g of wheat were placed in each of 180 vials, 7 cm high and 3 cm in internal diameter, fitted with snap-on caps. A hole, 1.5 cm diameter,

[1]Contribution No. 923, Agriculture Canada, Research Station, Winnipeg, Manitoba.

was drilled in each cap and covered with No. 60 mesh brass screen to allow gas exchange.

Six vials were attached to each of 30 nylon cords. The vials were spaced along the cords so that when suspended from the rims of steel drums, 1.90 m tall and 0.60 m diameter, the mouths of the vials were 9.3, 43.3, 74.8, 112, 145, and 175 cm from the rims of the drums.

Five cords were hung from the inside rim of each drum which was then filled with 12 bushels of wheat (327 kg, approx.). Three drums received 19.5 ml of reagent grade carbon disulphide which was poured on the grain at the centre of the grain surface. This amount coincides with the carbon disulphide content of the recommended rates of application (Monro 1969b). Lids were placed loosely on all of the drums. The crack between the lids and the drums varied from 0.0 to 0.3 cm and allowed gas loss. This was done to simulate conditions in commercial granaries, where leakage usually occurs, and to produce gradients of gas concentration. The other three drums were not treated and were used as checks. The experiments were arranged as randomized blocks with three replicates. The experiment was repeated three times (A, B, and C) under different temperature regimes (Figure 4). Temperatures ranged from 23 to 25, 7 to 13, and 3 to 11°C in experiments A, B, and C, respectively.

One cord with its attached vials was withdrawn from each treated and untreated drum according to the following schedule, after initiation of the experiments: on days 1, 2, 3, 4, and 7 for experiment A; on days 1, 2, 3, 4, and 11 for experiment B; and on days 1, 2, 4, 8, and 11 for experiment C. When the vials were taken from the drums, all adult insects were sifted from the wheat in the vials, and put in vials of fresh wheat in an incubator at 30°C and 75% R.H. One week later, the insects were examined and the numbers of live and dead individuals were recorded.

Four glass jars (1,735 l) were filled with wheat on which 19.5 ml of carbon disulphide was poured. The jars were then placed in a fume hood and examined every half hour until the liquid carbon disulphide at the bottom of the wheat had evaporated. This was done to determine the approximate time at which the highest concentration of carbon disulphide vapours could be found in the grain. The temperature was 20°C.

Small holes (2 mm diam.) were drilled into the sides of the drums at depths which coincided with the mouths of the vials. The holes were covered with aluminium foil tape which was removed while samples of air were taken, and then replaced. Carbon disulphide concentrations in each air sample was determined with a Varian 1740 model gas chromatograph fitted with a flame ionization detector. The column was packed with 3% carbowax 20 M on Chromosorb W AW-DMCS 60/80 mesh. The temperature of the oven was 154°C.

The amount of carbon disulphide applied per drum was expressed as mg CS_2/litre (assuming that the drums were empty). Regression analyses to determine the intercepts at day 0.33 were done on gas concentrations (transformed to a $\log_{10}$ base) obtained for days 2, 3, 4, 7, and 10 (also transformed to a $\log_{10}$ base) for experiment A, and for days 3, 4, 8, and 11 (also on a $\log_{10}$ base) for experiments B and C.

RESULTS AND DISCUSSION

The rates of gas loss in the three experiments were similar (Figs. 1, 2, and 3), though the temperatures of the grain were higher in experiment A (summer) than in experiments B and C (spring) (Fig. 4).

There was less survival, defined as the presence of active beetles, in experiment A than in experiments B and C (Figs. 1, 2, and 3). As the gas concentrations obtained were about the same in the three experiments, the lower survival of beetles in experiment A was probably due to the effect of higher temperature on the response of the beetles to the fumigant; the beetles were more susceptible to carbon disulphide at 22 to 25°C than at 3 to 12°C (Fig. 4). This has been shown by Shepard *et al.* (1937) who found that carbon disulphide was far more toxic to *Tribolium confusum* Du Val at 35 than at 5°C.

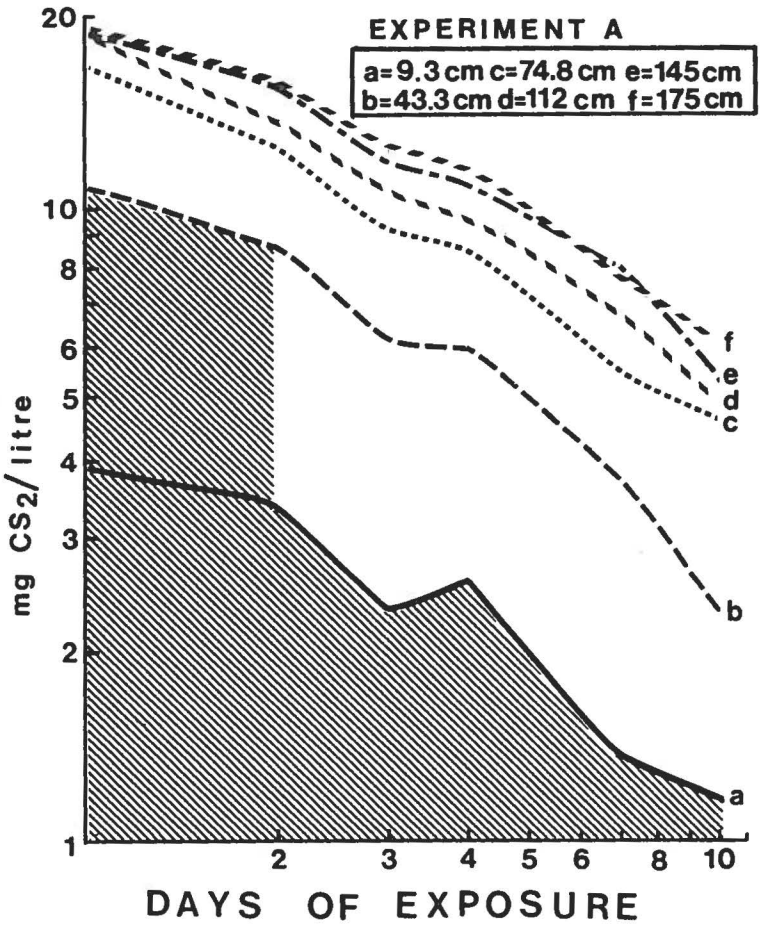

Figure 1. The survival of adults of *C. ferrugineus*, the Rusty Grain Beetle (shaded area), in relation to carbon disulphide concentrations (lines) at six depths (9.2, 43.3, 74.8, 112, 145, and 175 cms) in grain in experiment A.

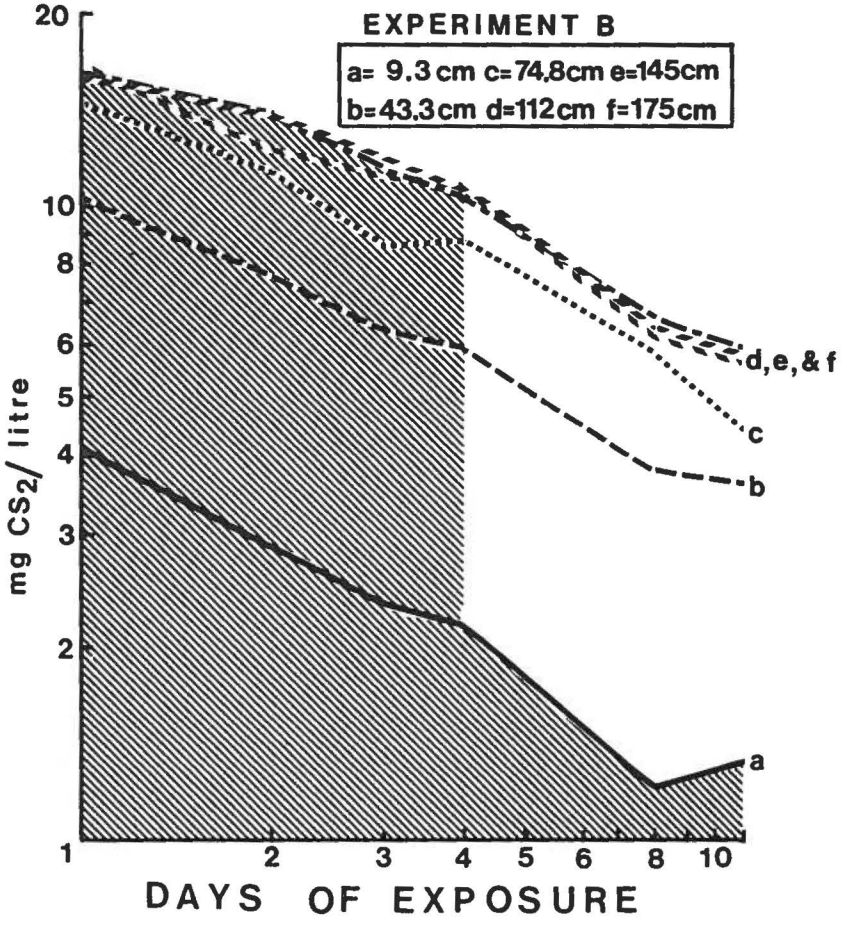

Figure 2. The survival of adults of *C. ferrugineus*, the Rusty Grain Beetle (shaded area), in relation to carbon disulphide concentrations (lines) at six depths (9.2, 43.3, 74.8, 112, 145, and 175 cms) in grain in experiment B.

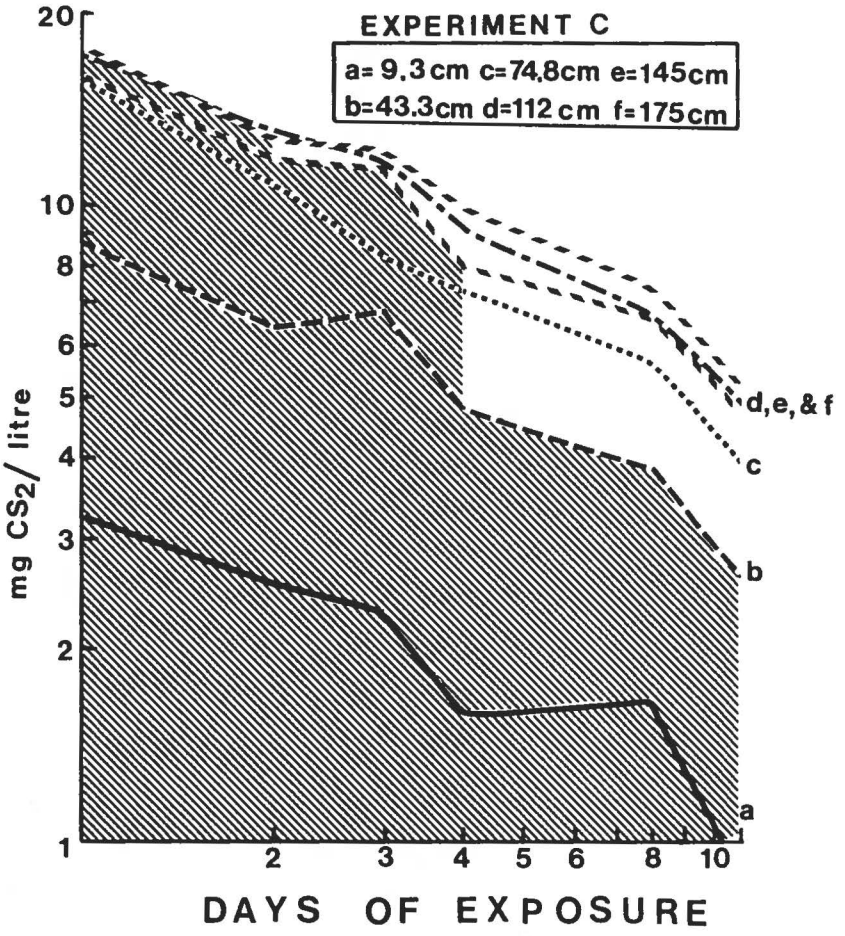

Figure 3. The survival of adults of *C. ferrugineus,* the Rusty Grain Beetle (shaded area), in relation to carbon disulphide concentrations (lines) at six depths (9.2, 43.3, 74.8, 112, 145, and 175 cms) in grain in experiment C.

Though susceptibility of the beetles declined with temperature, it was possible to obtain 100% mortality at certain combinations of gas concentration, low temperatures, and time. Thus, in experiment B (Fig. 2), gas concentrations which declined from 10.5 to 3.6 mg CS_2/l in 11 days (level b), caused 100% mortality by the end of day 4, at temperatures of 7.5 to 12.6°C. The gas concentrations had declined to 6 mg CS_2/l by day 4.

At the lower temperatures of experiment C (Fig. 3), gas concentrations which declined from 15.7 to 4.0 mg CS_2/l in 11 days (level c), also caused 100% mortality by the end of day 4, at temperatures of 3.1 to 10.6°C (Fig. 4). The gas concentrations had declined to 7.5 mg CS_2/l on day 4.

Figures 1, 2, and 3 show that the highest gas concentrations were obtained in the lower halves of the masses of grain from day 1 onwards, even though the fumigant was applied to the middle of the top surface of the grain. The fumigant probably trickled down through the grain along a narrow channel before it evaporated. It was not possible, however, to determine how far the liquid flowed into the grain mass.

A comparison between the gas concentrations obtained and the theoretical gas concentrations calculated for day 0.33 showed that it was possible to find the approximate amount of carbon disulphide applied to the grain (Table 1). The best estimates were obtained at the 145 cm depth. The highest gas concentrations which could have been

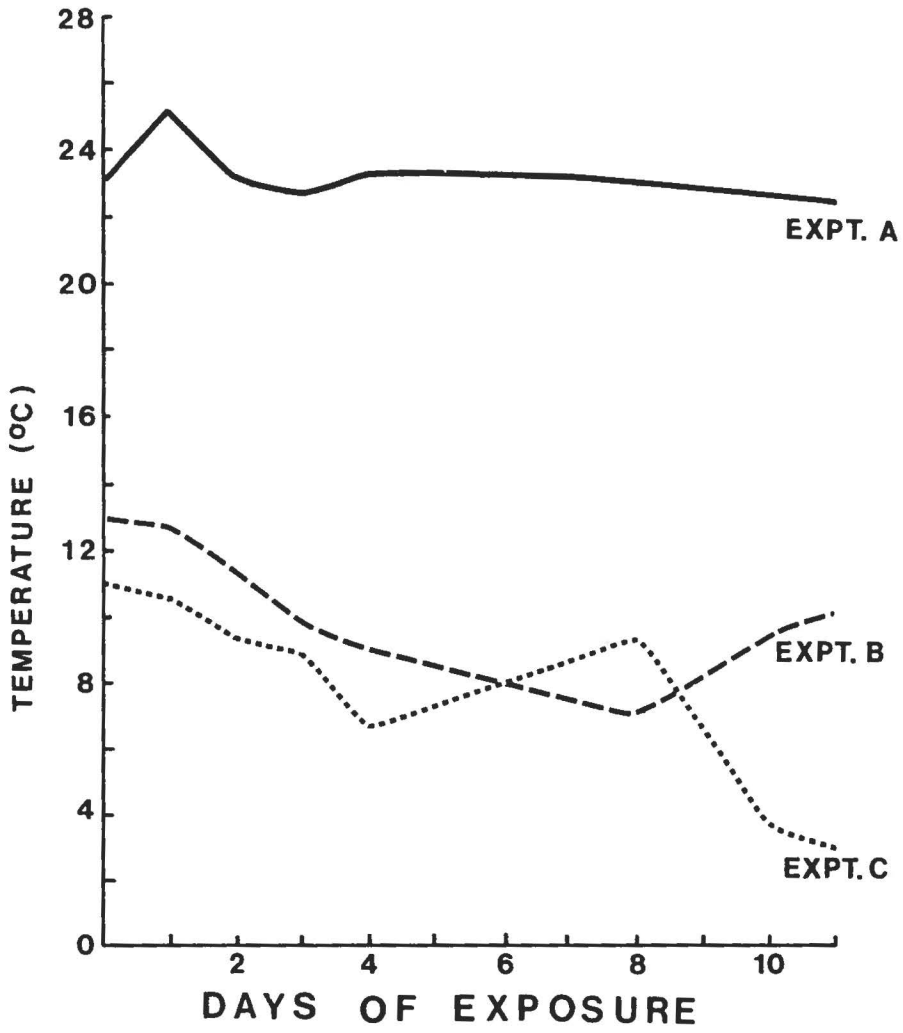

Figure 4. Daily temperatures of grain in experiments A, B, and C.

obtained (g CS_2 applied/vol of drum), was 48.47 mg $CS_2/1$, if it is assumed that the concentration of gas in air spaces is the same as the concentration of gas inside the wheat kernels. The gas concentrations were also calculated by means of regression analyses for day 0.33 because it took 8.0 hours (= 0.33 day) for 19.5 ml of carbon disulphide placed in jars of wheat to evaporate. The intercepts for the regression for day 0.33 were very close to the gas concentration (48.47 mg $CS_2/1$) calculated by the first method mentioned above (Fig. 5 and Table 1).

It is possible to apply this technique to published data (Storey *et al.* 1970) obtained from some 3250-bushel (U.S.) granaries treated with 16.25 gallons (U.S.) of an 80:20 mixture (carbon tetrachloride:carbon disulphide; v:v) which contained 15.3 kg of carbon disulphide. This dose was equal to a uniform concentration of 133.5 mg $CS_2/1$ (15300 g $CS_2/114.5$ M^3 air) throughout the granary. The fumigant was not poured, but sprayed onto the top surface of the grain mass, accelerating the evaporation of the fumigant. For the regression analysis assume that the fumigant evaporated in 4.8 minutes for the aerated granaries and in 11 minutes for the non-aerated granaries. These assumptions are reasonable because carbon disulphide evaporates rapidly, and fine sprays often evaporate before reaching a target at a distance of 0.30 m. The intercepts obtained for pooled aerated bins was 127.5 mg $CS_2/1$ at 4.2 minutes, and 127.8 mg $CS_2/1$ at 11 minutes for the pooled

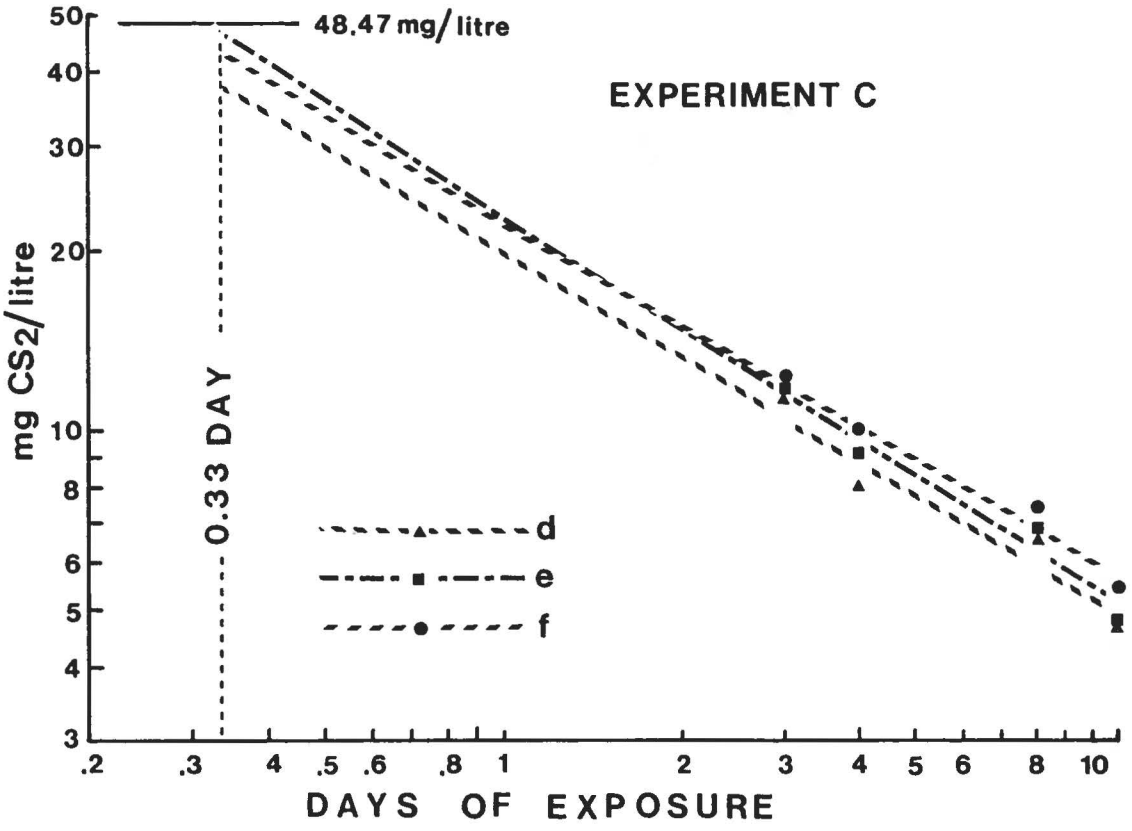

Figure 5. Extrapolations of gas concentrations from depths d, e, and f of experiment C to day 0.33 from gas concentrations measured on days 3, 4, 8, and 11.

Table 1. Calculation of original (theoretical) gas concentrations (mg CS_2/l); intercepts from regressions for 0.33 of a day for experiments A, B, and C, and for depths in grain of 112(d), 145(e), and 175(f) cm.

	Experiment		
Depth in grain (cm)	A mg CS_2/l	B mg CS_2/l	C mg CS_2/l
112 (d)	42.34	40.83	38.08
145 (e)	47.85	45.95	47.41
175 (f)	45.11	43.12	43.30

non-aerated bins. Both of these intercepts were close to the expected 133.5 mg CS_2/l calculated above.

This technique could be of value to agencies in charge of monitoring fumigations for the control of pests in bulks of grain. A similar method for the estimation of the amounts of aluminium phosphide applied to grain has been developed by Barker (1977).

This paper has shown that carbon disulphide can control adult rusty grain beetles in wheat at temperatures below 11°C, and that the original amount of fumigant applied can

be estimated, days after application, from measurement of gas concentrations on successive days in the lower part of the grain bulk.

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STONEFLY *(PLECOPTERA)* HEAD CHOLINESTERASE AS AN INDICATOR OF EXPOSURE TO FENITROTHION

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ABSTRACT: Exposure of nymphs of the stoneflies, *Acroneuria lycorias* and *A. abnormis* to 1, 2 and 40 μg/L fenitrothion, and subsequent measuring of reduction of cholinesterase activity in their heads, showed that cholinesterase activity is a good indicator of exposure to fenitrothion. Cholinesterase activity was shown to be directly related to both fenitrothion concentration and duration of exposure. Reduction in the cholinesterase activity of stoneflies may provide an indicator of freshwater pollution by organophosphate insecticides such as fenitrothion.

INTRODUCTION

Weiss (1959) and Weiss and Gakstatter (1964) suggested that very low concentrations of organophosphorus insecticides in natural waters could be detected by measuring the degree of inhibition of cholinesterase (AChE) in the brains of exposed fish and invertebrates. Holland *et al.* (1967) and Williams and Sova (1966) showed that estuarine fish with reduced brain AChE activity were generally associated with areas of organophosphorus pollution. In freshwater, however, inhibition of fish brain AChE has not been observed in field exposures (Zitko *et al.* 1970, Lockhart *et al.* 1977), although it has been produced in laboratory exposures (NRC 1975).

A relationship has been shown to exist between AChE level and exposure to organophosphates in terrestrial insects (Bodnaryk 1977), but no attempt has been made to correlate exposure to organophosphates with brain AChE activity of aquatic insects although they have been shown to be very susceptible to organophosphate poisoning (Flannagan 1973, Wildish and Phillips 1972).

This is a report on the possibility of using stonefly nymphs as indicators of organophosphate insecticide pollution.

METHODS

Fifty to ninety nymphs of either *Acroneuria lycorias* (Newman) or *A. abnormis* (Newman) were exposed to 1, 2, or 40 μg/L fenitrothion (nominal concentration) in a recirculating laboratory stream system for 96 h (standard bioassay exposure time). Wildish and Phillips (1972) reported the 24 h LC50 of 2 μg/L for *Acroneuria sp.*; our concentrations were chosen in the expectation of analysing animals showing both lethal and sublethal effects. As controls, for each fenitrothion exposure, a like number of the same stonefly species were exposed to clean dechlorinated Winnipeg tap water in a flow-through stream system. After approximately 1, 3, 5, 20, 45 and 70-h, 3-5 nymphs were removed from each fenitrothion exposure and placed in numbered containers in the control system for up to 220 h. Simultaneously and after 96 h, another 3-5 nymphs were removed from the fenitrothion exposure streams, and from the control stream, washed in clean water, decapitated, and the heads frozen. These heads, and heads of nymphs taken after 220 h from the numbered containers in the control stream were analysed for AChE activity. In addition, nymphs showing a tendency to drift were either decapitated and the heads frozen for AChE analysis or put in the control stream for various times then washed in clean water, decapitated and the heads frozen for later AChE analysis. All heads were frozen individually in vacutainer tubes. Studies on stability of AChE activity during periods of frozen tissue storage have been conducted using a number of tissue sources and generally there has been negligible loss in activity (Lockhart, unpublished, Dyer, unpublished).

Table 1. Comparisons of the regressions relating exposure time with AChE activity in moribund and apparently healthy, normal animals with same exposure time.

Acroneuria lycorias (1.0 μg/L exposure)
"normal" slope = −.010
"moribund" slope = −.014
comparison of slopes: $F = 1.33$ (D.F. = 1,33) [$F_{.05}$ (1,30) = 4.17]
Acroneuria abnormis (2.0 μg/L exposure)
"normal" slope = −.009
"moribund" slope = −.011
comparison of slopes: $F = 1.14$ (D.F. = 1,39) [$F_{.05}$ (1,40) = 4.08]

Frozen heads were thawed within two weeks of the completion of the exposure experiments and homogenized in 1.0 ml of 0.25 M sucrose using a Brinkman Polytron homogenizer (30 seconds, speed 7) keeping the sample tubes immersed in an ice water bath to minimize warming. The homogenates were centrifuged at 5000 x g for 10 minutes at 2°C and 10 μl of the supernatant was analysed for AChE activity in 300 μl of phosphate buffer (pH 7.2, 52 mM) with 10 μl of acetylthiocholine iodide as substrate (156 mM) at 25°C on a Zeiss PMQ-II spectrophotometer equipped with microcuvettes, automatic sample changer, and multipoint recorder. This procedure is based upon the method of Ellman *et al.* (1961) and reagents used were in the form of prepackaged kits available from Boehringer Mannheim Corporation. Quality control was maintained using Hyland Q-Pak R, a lyophilized chemistry control serum. Protein in the supernatants was assayed using the technique of Lowry *et al.* (1951) with bovine serum albumin as a standard. Results are expressed as milliunits of activity/mg protein.

The stream systems were monitored daily for mortality in the stonefly nymphs, water temperature, pH and dissolved oxygen. Samples from the exposure and control streams were analysed for fenitrothion content at the end of each experiment.

RESULTS

Temperature (10 ± 1°C), dissolved oxygen (10.5 ± 1.5 μg/L) and pH (7.7 ± 0.5) did not differ significantly in stream systems over the period of the experiment. Nominal and actual fenitrothion concentrations at the end of the experiments were similar: nominal 1, 2, 40 μg/L, actual 1.1, 2.2 and 40.3 μg/L, respectively.

At all three exposure concentrations, when the fenitrothion was added to the stream reservoir, the nymphs became agitated and, perhaps because of the frequent collisions, some entered the drift. These and all moribund animals which would have entered the drift naturally had AChE levels not significantly different from apparently healthy animals with the same exposure time (Table 1).

No mortalities were observed in the three exposure concentrations and their associated controls or in the recovery containers. However, in the 40 μg/L exposure, after 19 h, and at various times in the other two concentrations some nymphs were observed to be on their backs, and except for occasional twitching of legs or mouthparts, totally immobilized. In nature these animals would undoubtedly enter the drift and be lost in the system. Since even after two weeks of observations none of these animals recovered, it seems reasonable to assume that they were, to all intents and purposes, moribund. Figure 1 illustrates the rates at which the stoneflies became moribund in the three concentrations of fenitrothion. Both species of *Acroneuria* reacted similarly to fenitrothion poisoning (Fig. 1).

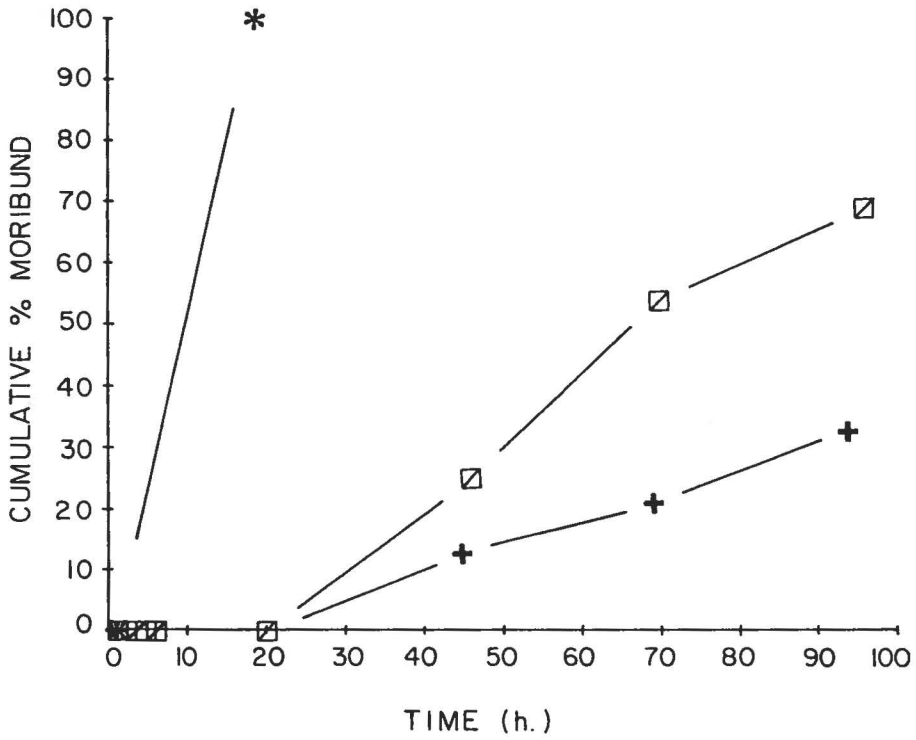

Figure 1. Effect of 40 (*) and 1 (+) µg/L fenitrothion on *Acroneuria lycorias* and 2 (⊠) µg/L on *A. abnormis.*

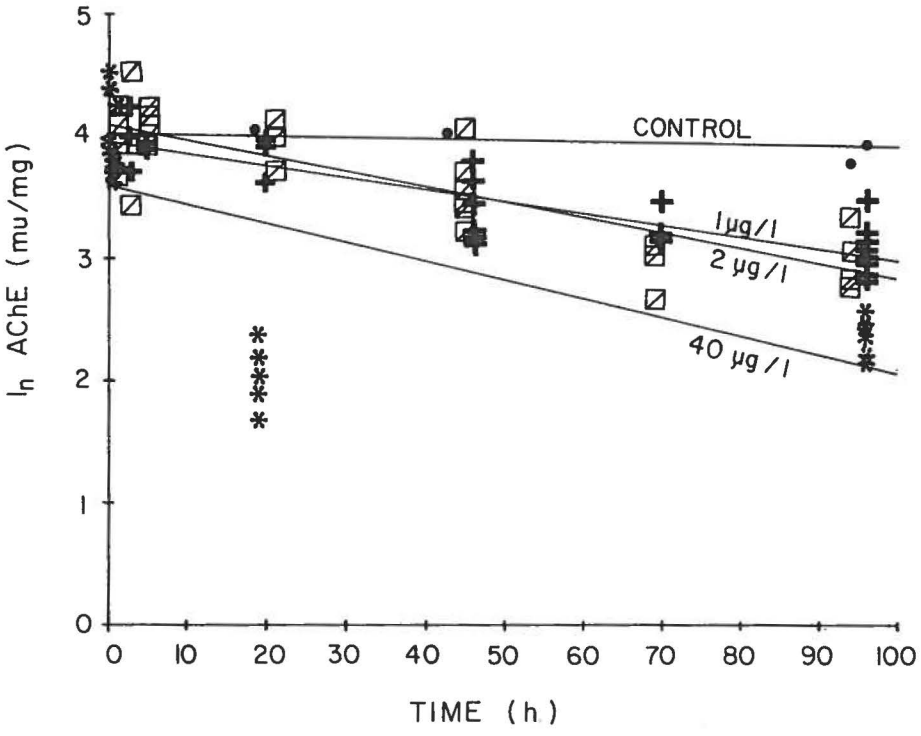

Figure 2. Relations between exposure to 0, 1, 2 and 40 µg/L fenitrothion and natural log of AChE activity in heads of *Acroneuria* spp.

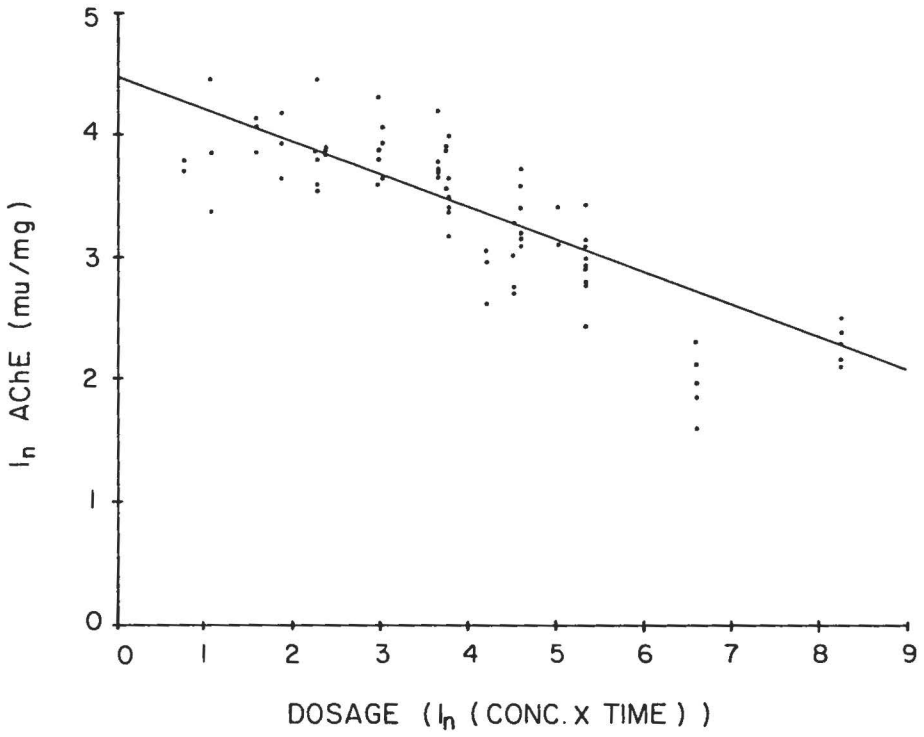

Figure 3. Relationship between natural log of AChE activity in heads of *Acroneuria* spp. and exposure to fenitrothion.

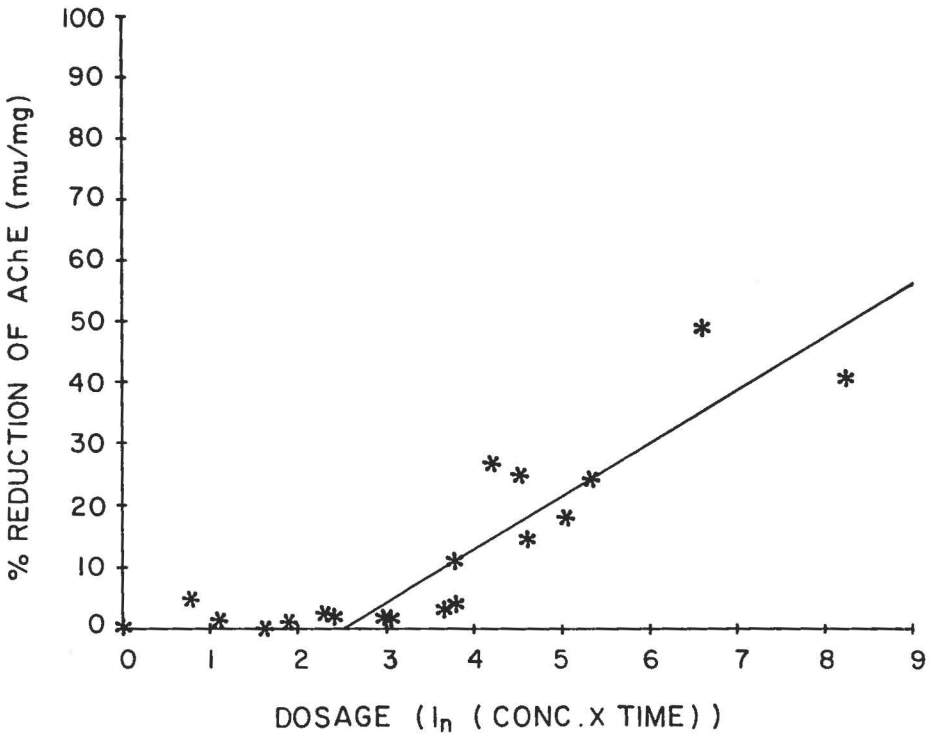

Figure 4. Relationship between percent reduction of AChE activity in heads of *Acroneuria* spp. and exposure to fenitrothion.

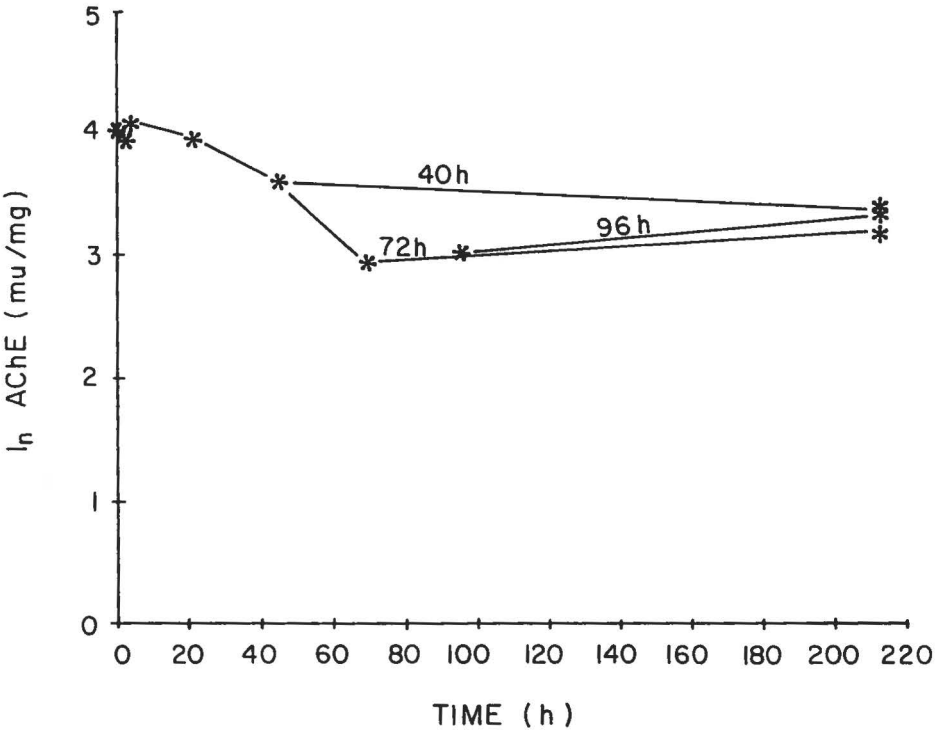

Figure 5. AChE activity in heads of *Acroneuria* spp. after exposure to 1 μg/L fenitrothion for 40, 72 and 96 h, then return to clean water and analysed after 220 h.

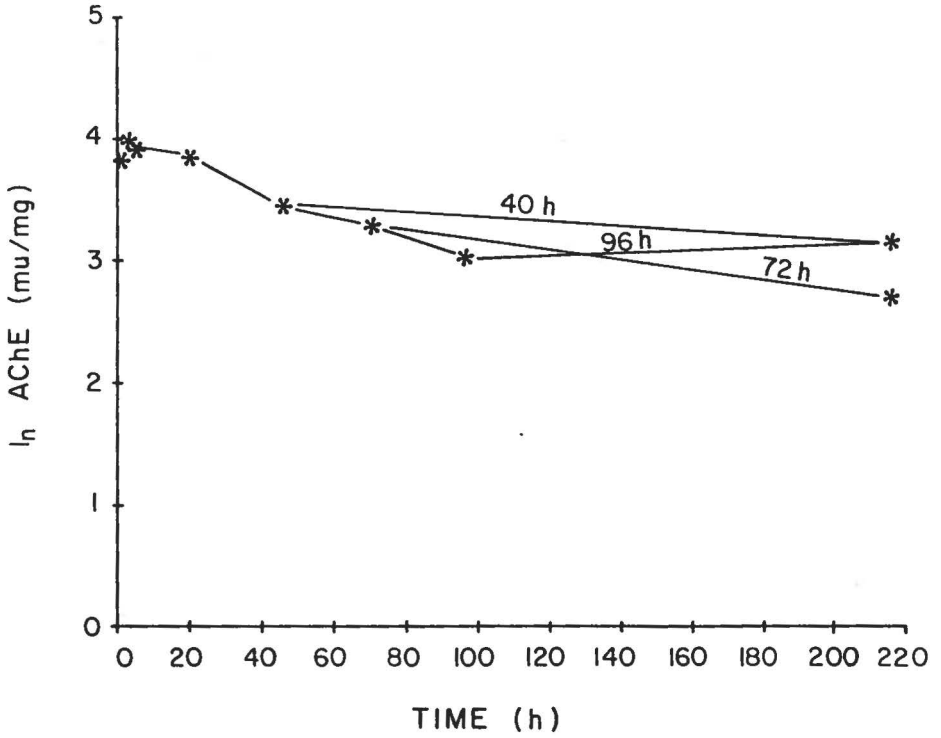

Figure 6. AChE activity in heads of *Acroneuria* spp. after exposure to 2 μg/L fenitrothion for 40, 72 and 96 h, then return to clean water and analysed after 220 h.

Significant reductions in AChE activity occurred with time at all three concentrations (Fig. 2). Largest reductions occurred at 40 μg/L exposure and the two lower concentrations are not clearly separated. The regression line of log AChE on the log of the dosage (μg/L fenitrothion x h exposure) (Fig. 3) is described by the equation:

$$\ln \text{AChE (mU/mg protein)} = 4.47 - 0.265 \text{ dosage } (r = -0.817, n = 81).$$

Since a very good relationship exists between these two factors a knowledge of one factor allows prediction of the level of the other. The AChE activity from all the control samples shows the relationship:

$$\ln \text{AChE} = 4.02 - 0.0009 \text{ time } (n = 32)$$

i.e. almost a straight line, thus 4.02 can be used to represent normal activity in the stonefly heads and percentage reductions related to exposure to fenitrothion can be calculated. Figure 4 shows this relationship, and it is of interest to note that there is an apparent threshold effect at an approximate dosage of 2.5 μg/L h.

Little recovery of AChE activity was observed when nymphs were returned to clean water after exposure to fenitrothion for various times (1 μg/L, Fig. 5; 2 μg/L, Fig. 6). Results from the recovery experiments vary with some exposure groups showing some recovery (e.g. 72 and 96 h exposures at 1 μg/L, Fig. 5) and some showing continued reduction (e.g. 40 h exposure, Fig. 5). These apparent anomalies may be due to the small sample sizes (3) in the recovery experiments.

Addition of fenitrothion to the heads prior to homogenization produced no reduction in activity when compared to control samples.

DISCUSSION

It appears that the appearance of moribund animals and reduction of brain AChE activity are directly related to exposure to fenitrothion. However, the moribundity observed was not related to reduction of AChE activity, since paralysed animals and apparently normal healthy animals both had similarly reduced AChE levels after exposure to the same dosage of fenitrothion. Interference with cholinergic nerve transmission has been generally regarded as the most probable mode of action of organophosphorus insecticides (Heath 1961). There is evidence of there being more than one mode of action in fenitrothion poisoning (Wildish and Phillips 1972; Flannagan 1973; Rorke *et al.* 1974) so it is possible that the functional mortality observed was related to another, possibly non-cholinergic, effect of the insecticide. Alternately, since inhibition of peripheral AChE is important in the development of symptoms of organophosphate poisoning, it is unlikely that reduction of AChE activity in the head is crucial to poisoning (O'Brien 1967). Whatever the case, it seems that stonefly head AChE is inhibited by fenitrothion and that the degree of inhibition is related both to the concentration of the insecticide and the duration of the exposure.

In spite of the small sample size in the recovery experiments, it appears that there may be a slow return of AChE function on returning exposed animals to fresh water. AChE never returned to normal after inhibition had been effected by exposure to fenitrothion. Further experimentation is required to determine how long total regeneration of enzyme function would take. Also, if reduction of stonefly head AChE activity is to be used as an indicator of fenitrothion exposure in the field, some controlled field experimentation is required to delineate possible seasonal or other environmental effects.

CONCLUSIONS

It appears that AChE inhibition is directly related to concentration of and extent of exposure to fenitrothion and that the inhibition continues for an undetermined time.

Although field trials have not yet been carried out it seems probable that AChE activity in stonefly heads could provide a useful quantitative indicator of pollution by organophosphate insecticides such as fenitrothion.

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EFFECTS OF BURYING THE EGGS IN SOIL ON SURVIVAL IN THE RED TURNIP BEETLE, *ENTOMOSCELIS AMERICANA* (COLEOPTERA: CHRYSOMELIDAE)[1]

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ABSTRACT: Effects of burying the eggs in soil on survival in the red turnip beetle, *Entomoscelis americana* Brown, were measured in small containers left out-of-doors in each of 3 successive years at Winnipeg, Manitoba. The numbers of newly-hatched larvae reaching the soil surface from eggs buried at depths of 1, 5 and 10 cm were much smaller than the numbers of newly-hatched larvae from eggs kept at the soil surface. Evidence from growers' fields in Manitoba suggests that fall cultivation is an effective control measure against the red turnip beetle.

INTRODUCTION

The eggs of the red turnip beetle, *Entomoscelis americana* Brown, are laid from early August to late October (Gerber, unpublished) in loose clusters on the soil surface around the bases of food plants; under leaf litter, lumps of soil and other objects which provide cover; in crevices; or in loose soil to depths of 5-6 mm (Hanford 1932; Stewart 1973). In the Prairie Provinces, the eggs commonly are found in rape fields (*Brassica* spp.) (Gerber 1974) and usually hatch in late April and early May (Gerber, unpublished). Soon after hatching, the larvae climb their food plants and feed on the cotyledons and true leaves (Stewart 1973; Obadofin 1979).

The results of a preliminary experiment with *E. americana* by Hanford (1932) showed no survival of newly-hatched larvae from eggs that were buried 2.5-15 cm in soil over winter. In contrast, 85.5% survival was reported for eggs kept at the soil surface. From these results, he suggested that thorough plowing (cultivation) should result in the destruction of practically all of either the eggs or larvae of *E. americana*. Since Hanford used only one replicate in his study, it was decided to confirm the possibility that burying the eggs in soil significantly lowers survival in the red turnip beetle. The results of these investigations are presented in this paper.

MATERIALS AND METHODS

Survival of *E. americana* was studied in experiments conducted out-of-doors at Winnipeg, Manitoba, in each of 3 successive years (Table 1). Each experiment consisted of 4 treatments: eggs placed on the surface of soil (control) and at 1, 5 and 10 cm depths in soil. The treatments each year were replicated 5 times, and each replicate contained approximately 100 eggs.

The eggs were from stock colonies kept in cages out-of-doors at Winnipeg during 1976-1978 (Gerber 1976). The adults in the 1976 colony were collected near Shortdale, Manitoba; those in the 1977 and 1978 colonies were from The Pas, Manitoba.

The eggs were removed from the stock colonies at least 3 weeks before the initiation of the experiments and placed at $21^{\circ} \pm 2^{\circ}$C in the laboratory to ensure the embryos had reached a late stage of embryogensis and entered diapause (Stewart 1973). In late October, these eggs were placed in plastic containers filled with soil. The containers were then buried in the field so that the soil surface was at the same level as the soil surface in the field. They were left in the field until hatching was completed in May of the following year. During hatching in April and May, daily counts were made of the newly-hatched larvae on the soil surface in the containers.

[1] Contribution No. 951, Agriculture Canada, Research Station, Winnipeg, Manitoba.

The plastic containers were 12.0 cm high x 9.0 cm in diameter at the bottom and 12.0 cm at the top. They were fitted with white plastic lids. The bottom of the containers were cut out and covered with screen (mesh diameter 0.2 mm). A circular hole 6 cm in diameter was cut in the lids and covered with screen (mesh diameter of 0.4 - 0.5 mm). These screens prevented the larvae from escaping, but did not interfere with the passage of snow, rain or snow-melt water.

Each container was filled with a loosely-packed clay-loam soil to a depth of 10-11 cm, and eggs were either scattered on the soil surface or placed at depths of 1, 5 or 10 cm below the soil surface. The soil in all of the containers was covered with a single layer of rape leaves to simulate natural overwintering sites. During the time of hatching, water was added to the soil if it showed signs of drying out.

RESULTS AND DISCUSSION

Since the numbers of newly-hatched larvae emerging from the eggs at depths of 1, 5 and 10 cm were much smaller than the numbers from the eggs at the soil surface, it is clear that burying the eggs in soil significantly lowers survival in the red turnip beetle (Table 1). These results are in agreement with those of Hanford (1932), though he found that no larvae emerged from eggs of *E. americana* buried at depths of 2.5-15 cm. The surprising aspect of the present results is the low numbers of newly-hatched larvae from the eggs at 1 cm, because red turnip beetle females lay eggs to depths of 5-6 mm in loose soil (Hanford 1932; Stewart 1973). However, this result may not be totally unexpected, because the legs of first instar larvae have no obvious modifications which would facilitate digging.

Hanford (1932) suggested that burying led to the destruction of either the eggs or the newly-hatched larvae. Since the eggs and small larvae could not be removed successfully from the soil in the present experiments, it was not possible to determine the fate of the eggs. Nevertheless, it is doubtful that the eggs were crushed, as care was taken when placing the eggs in the containers to prevent this from happening. During the winter, the soil became compacted. The average depth of the soil in the containers in the spring was about 18, 20 and 6% less than the average depth when the experiments were initiated in

Table 1. Total numbers of newly-hatched larvae of *Entomoscelis americana* Brown reaching the soil surface from eggs buried at depths of 0-10 cm[a] and the totals for the 1-10 cm treatments expressed as a percentage of the total for the control (0 cm treatment).

	Depth (cm)[b]			
Year[c]	0 (control)	1	5	10
		Totals		
1976	110	1	5	10
1977	232	8	3	1
1978	298	67	24	10
		% of control		
1976	–	0.9	4.5	9.1
1977	–	3.4	1.3	0.4
1978	–	22.5	8.1	3.4

[a] N = 500 eggs/depth/year.

[b] For each year, the means for the 1-10 cm treatments are significantly different from the control ($P < 0.01$).

[c] The experiments were initiated in October of each year and completed in May of the next year.

October in 1976, 1977 and 1978, respectively. The lowest numbers of newly-hatched larvae emerged from eggs buried in the most compacted soil (1976 and 1977) and the highest numbers emerged from the least compacted soil (1978) (Table 1). It is possible that soils can become sufficiently compacted during the winter to trap the newly-hatched larvae in the spring.

From 1973 to 1979, the occurrence of *E. americana* in Manitoba has been extremely sporadic and it usually has been present in only relatively small numbers (Gerber, unpublished). Consequently, it has not been possible to test in the field the effects of cultivation on survival. However, there appears to be adequate evidence to suggest that fall cultivation is an effective control measure for this beetle. During 1973-1979, over 100 fields, which contained rape the previous year, were examined in May and June for the red turnip beetle. Fourteen of these fields contained relatively large numbers (several hundred to 10,000 or more) of larvae and(or) adults. Eleven of the 14 fields had not been cultivated in the fall or spring; one had not been cultivated in the fall, but was tilled in May at the time the red turnip beetle was in the pupal phase; one had been cultivated in the fall but only lightly, because almost all of the trash from the rape crop was still on the surface of the soil; and one had been cultivated in the spring, but it was not determined if it had been cultivated in the fall. In Manitoba, growers normally cultivate rape fields in the fall after harvest if the weather permits. For example, the percentage of rape fields which had been cultivated in the fall in the areas including Grandview and Bield in the north and Riding Mountain National Park in the south was 69, 87 and 83% in 1976, 1977 and 1978, respectively (W. J. Turnock, unpublished). It is possible that the high incidence of fall cultivation is responsible for the sporadic occurrence and relatively low numbers of *E. americana* in Manitoba during 1973-1979.

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A REVIEW OF THE MORPHOLOGICAL FEATURES OF NON-SWARMING, SUBSTRATE-MATING CHIRONOMIDS IN THE GENUS *CHASMATONOTUS* LOEW AND OTHER GENERA OF THE CHIRONOMIDAE (DIPTERA)

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ABSTRACT: A discussion of the morphological features of the species of *Chasmatonotus* Loew associated with their non-swarming, substrate-mating habits is preceded by a review of present knowledge of chironomids that exhibit similar features and are found in habitats such as the intertidal zone of ocean shores and the arctic tundra. The morphological features associated with the above habits include: flagellum of the male antennae with few flagellomeres, five in *Chasmatonotus* species, and reduced plumosity similar to the female antennae; the tentorium not developed anteriorly; the broad vertex of the head produced ventromesad over the scapes; all ommatidia of the male eyes equal in size; thorax slightly flattened, the dorsum extending anteriorly over the antepronotum; the anal angle of the male wing with concave curvature, not acute angled, and wing not narrowed on the distal half; squamae bare; legs much longer than length of the thorax and adapted for walking; and the male hypopygium well sclerotized and swollen. It is thought that the non-swarming, substrate-mating behaviour arose in chironomids as a protection against displacement of individuals from their emergence site by strong winds.

INTRODUCTION

Aerial swarming by adult chironomids, culicids, simuliids, ceratopogonids, representatives of other dipterous families and among other orders of insects has often been recorded (Nielsen and Greve 1950; Downes 1958; Nielsen and Haeger 1960; Lindeberg 1964; Syrjamaki 1964; McAlpine and Munroe 1968; Downes 1969, 1978). Swarming habits throughout the Insecta, the kinds of aerial swarms, the role of swarming and the association between swarming and mating have been reviewed by Downes (1958), Nielsen and Haeger (1960) and McAlpine and Munroe (1968).

A number of morphological adaptations are associated with insects that perform aerial swarms. Among other adaptations, McAlpine and Munroe (1968) mentioned functional dipterism, male wings with a well developed anal angle or lobe and a characteristic triangular shape and males with larger compound eyes than those of females. A long plumose antenna in males of the Chironomidae, Chaoboridae, Culicidae and Ceratopogonidae and the eyes enlarged and meeting in the mid-line in males, the holoptic condition, of the Simuliidae are short range response mechanisms characteristic of insects which mate in flight and are suited for the recognition and capture of the female (Downes 1965, 1969).

According to Oliver (1971), chironomids initiated copulation in a swarm and the main function of the swarm was to bring the sexes together. For some midges, however, mating took place without flight at the emergence site. For these midges there was a correlation between the reduction of the male antennae, a tendency toward brachypterism, enlargement of the male hypopygium and other morphological features associated with a transition to a non-volant life (Downes 1965; Brundin 1966; Oliver 1971).

The following is a review of the morphological features associated with non-swarming, substrate-mating chironomids. In support of the review, information is given about the morphology and behaviour of the species of *Chasmatonotus* Loew, all of which are non-swarming, substrate-mating midges.

MORPHOLOGICAL FEATURES OF CHIRONOMID ADULTS ASSOCIATED WITH NON-SWARMING, SUBSTRATE-MATING HABITS

What factors have brought about the change in chironomid behaviour from swarming to non-swarming? According to Hashimoto (1970, 1976) and Neumann (1976), the "sexual isomorphic walking specializations" [= adaptations to non-swarming, substrate-mating] of intertidal chironomids have occurred where conditions for flight are not advantageous, such as would prevail along rocky, windy shores. Downes (1965) reported that the loss of the swarming habit by some arctic chironomids was an adaptation to prevent the loss of individuals by strong winds. Downes (1978) concluded that there was a tendency among arctic insects to avoid aerial activities in cold and often windy climates. Most non-swarming midges have been reported to live in wind-swept habitats such as an ocean shore, tundra or prairie.

Intertidal Chironomids

Hashimoto (1962) and Neumann (1976) have recognized three ecological types of intertidal chironomids based on their mode of locomotion.

The generalized flying type, in which adults are fully equipped for flying and have three pairs of legs used for body support, is represented by midges in the genera *Tanytarsus, Chironomus* and *Halocladius* (Neumann 1976).

Adults of both sexes that use a walking type of locomotion show a wide range of morphological adaptations. These adaptations include reduction in the number of flagellomeres of the male antennae and the loss of the plumose condition to resemble the female antennae, reduction of the wings to the point of brachypterism, reduction in the size of the scutellum and halteres and the loss of halteres associated with brachypterism, increased development in the length of the legs relative to the length of the thorax, and variation in the torsion of the male abdomen associated with the mating position (Hashimoto 1962; Neumann 1976). Midges that use this type of locomotion are represented by species in the genera *Telmatogeton, Paraclunio, Thalassomya* and *Thalassosmittia* (possess wings); *Psammothiomya, Halirytus* and *Eretmoptera* (brachypterous, halteres present); *Belgica* (brachypterous, halteres absent) and *Tethymyia* (wings vestigial, halteres absent). In the above genera, the differences between the sexes are few such as the larger male legs and the more swollen female abdomen and the degree of adaptation in the morphological features is not very different between the male and the female (Hashimoto 1962).

The species of *Clunio* and *Pontomyia* use a gliding type of locomotion. In these genera there is a greater degree of sexual dimorphism in the species than in species that use a walking type of locomotion. The males have legs not suited for walking and their wings are modified to give an impelent force. Hashimoto (1976) has reviewed movement on a water film for species of the above genera. In both genera, the females are wingless, have reduced limbs and are maggot-like in form. As the females have no locomotory organs, they can only wriggle on the water surface until caught by the male (Hashimoto 1976).

For other references to non-swarming marine and intertidal chironomids see Saunders (1928), Wirth and Gressitt (1967) and Morley and Ring (1972a, b).

Terrestrial and Freshwater Chironomids

Downes (1965) reported that mating in arctic chironomids frequently took place without flight at the site of emergence and that the change of habits may be accommodated by enlargement of the male hypopygium and reduction of the male antennae.

The adults of many species of *Diamesa* fly well and mating takes place on the ground, but for some species the plumosity of the antennae of the male and the number of antennal flagellomeres is reduced (Hashimoto 1970). Hansen (1973) reported *Diamesa cinerella* Meigen, *D. leona* Roback, *D. davisi* Edwards, *D. nivicavernicola* and *D. leoniella* as having reduced male antennae and reduced plumosity. Modifications in other features

reported by Hansen (1973) included: the vertex of the head produced ventromesad toward the frons, its margin indistinct; the dorsomedial margin of the eye round compared to truncate in species with plumose antennae; the tentorium tube-like compared to swollen basally; the notch of the antepronotum obtuse to absent; the anterior margin of the antepronotal lobe concave anterolaterally with setae dispersed mesad compared to anterior margin straight and setae confined to the lateral-most region; the wing broader and the anal lobe less pronounced; the anapleural suture short and the legs longer with respect to the length of the thorax.

Saether (1971) described two new species, *Cricotopus macraei* and *C. flannagani*, the males of each being characterized by female-like antennae, a scutum projected forward to cover completely the median part of the antepronotum, a reduced number of squamal setae and wings with a reduced anal lobe. Sæther (1971) stated that reduced antennae and anal lobes together with enlarged male hypopygium and alterations in the leg proportions were often found in aberrant species of genera where such character states did not normally occur. Included in the above category are species in *Zelandochlus* (Brundin 1966), *Podonomus* (Brundin 1966), *Diamesa* (Saether 1969) and *Rheocricotopus* (Saether 1969). The above modifications are adaptations to a particular habitat and are associated with specific behaviour patterns such as copulation on the ground (Saether 1971).

Oliver (1976) found that males of *Trissocladius tricornis* [= *Oliveria tricornis*, cf. Saether 1976] were dimorphic with respect to the number of antennal flagellomeres. The "long-antennal form" had 13 flagellomeres and the "short-antennal form" had five to seven flagellomeres. In addition to the reduced antennae, the "short-antennal form" possessed a number of female-like characteristics that included a small scape, small pedicel and reduced plume of the antennae, the anterior margin of the broad vertex extending ventromesally between the scapes, a broad more bulbous clypeus, female-like maxillary palps, the anal lobe of the wing right-angled and with no narrowing of the wing distal to the anal lobe. This species mated on the ground and the "short-antennal form" may be regarded as structural evidence for this mode of behaviour. The "long-antennal form" had an enlarged male hypopygium, a low antennal ratio and the plume of the antennae partially reduced. The adults were observed to be in clusters on rocks or bare patches of ground at the margin of lakes, attempting to mate with their own and other species of chironomids but rarely were they observed to fly (Oliver 1976).

It can be shown, therefore, that midges from the intertidal zone that exhibit the isomorphic walking specializations and the freshwater chironomids that do not participate in an aerial swarm have a number of morphological features in common. The most observable ones are those associated with the head, reduced flight ability and substrate-mating. The antennae of the male, with reduced plumosity and fewer flagellomeres and not used primarily for sexual selection or orientation in a swarm and the tentorium more tube-like, not swollen basally, since the antennal muscles of the reduced antennae are not strong are examples of head features. The anal lobe of the male wing more obtuse than acute angled, the squamae with few to no setae and the short anapleural suture of the thorax are indicative of reduced flight ability. The swollen hypopygium of the male and the long legs are indicative of substrate-mating and movement confined primarily on a substrate. Midges that exhibit the above features are not aberrant but are adapted for life in severe habitats such as wind-swept ocean shores, prairie or tundra.

THE GENUS *CHASMATONOTUS*

Morphological Features of the Adults

While attempting a systematic revision of the genus, it was found that the adults of all species of *Chasmatonotus* were non-swarming, substrate-mating midges (Arntfield 1977). The features of the adults appeared to parallel the features of other non-swarming chironomids. The most noticeable features in all species of *Chasmatonotus* were the following: male and female antennae with five flagellomeres and reduced plumosity, the broad vertex of the head of both sexes produced ventromesad over the scapes, the

tentorium tube-like not swollen anteriorly, the slightly flattened scutum associated with weak flight ability as were the large subtriangular preepisternum II and the shortened anapleural suture not half as wide as preepisternum II, the male wing not narrowed on the distal half and the anal lobe obtuse, the bare squamae, the long legs adapted for walking and the strongly sclerotized male hypopygium. The strong, median longitudinal groove on the dorsum of the scutum may have also contributed to the weak flight ability of the adults. The groove would restrict bowing of the thorax for proper flight.

Movement of the Adults

Osten Sacken (1877) found that *Chasmatonotus unimaculatus* Loew and *C. bimaculatus* walked in large numbers on the leaves of low shrubs. Rempel (1937) noted that *C. atripes* ran about on leaves of bushes and seldom flew. Arntfield (1977) reported that these three species were seldom observed to fly and when they did fly it was a weak flight of short duration to a neighbouring leaf or branch. On any particular plant, adults were not found more than two metres from the ground and aerial swarming was replaced by congregation of individuals on several plants in a localized area (Arntfield 1977).

Downes (1974) reported that *Chasmatonotus* species fed on honeydew. Arntfield (1977) always found adults of *C. unimaculatus, C. bimaculatus* and *C. atripes* where there was honeydew. As well as providing a source of energy for the midges, honeydew may also act as an attractant to bring the individuals together to increase the likelihood of mating.

Mating Behaviour of *C. unimaculatus* and *C. bimaculatus*

Arntfield (1977) found that the mating behaviour of these two species was quite similar.

Individual recognition by the midges was accomplished by a behaviour labelled "tumbling". Two midges of the same sex that met on a leaf or branch would tumble over each other for as long as two or three seconds and then continue on their way. If a male and female were involved, the male would initiate mating after tumbling by "prancing" in front of the female for several seconds with one of its wings held perpendicular to the long axis of its body. The male would then crawl back and forth over the female's back two or three times. If she was submissive he would initiate contact of their hypopygia. If she was not submissive she would press her abdomen to the substrate or kick the male from her.

Development of the Non-swarming, Substrate-mating Habits in *Chasmatonotus* species

Based on the morphological features of adult *Chasmatonotus*, it is evident that all species are not able to fly very well. Has the habit of not participating in an aerial swarm originated in the species as a protective measure against movement from the emergence site by strong winds? Clues to the answer can be found in chorological data and the apparent phylogenetic relationships of the species (Arntfield 1977).

In western North America, *C. fascipennis* Coquillett has been found in Yellowstone Park at elevations near 2,740 metres. Although it was difficult to determine the phylogenetic relationships of the species, *C. fascipennis* was considered to be the most plesiomorphic species in the genus. Its sister species *C. maculipennis* Rempel and a new one yet to be described have both been found at low elevation in British Columbia (Arntfield 1977). In eastern North America, *C. bimaculatus* has been taken on the summit of Clingman's Dome, Great Smokey Mountains National Park at 1,830 metres. It has also been taken at high elevation in parts of the Appalachian Mountains. *Chasmatonotus bimaculatus* was thought to be one of the most plesiomorphic of the eastern species and seemed to have its origins in elevated areas. The highest elevation recorded for its sister species, *C. atripes,* was 351 metres at the summit of King Mountain, Gatineau Park, Quebec (Arntfield 1977). Therefore, the oldest members of the genus have originated at high elevation in mountainous regions of North America.

Although speciation has been little within the genus, only 12 species are known (Arntfield 1977), and the species have expanded their niche from high elevation on mountains to the more sheltered confines of valleys and lower elevations, the habits of non-swarming and substrate-mating seem to have remained entrenched in the genotype of the species. As these habits have been shown to be common to chironomids from wind-swept habitats, it is quite possible that they arose in *Chasmatonotus* species originating at high elevation on mountains where winds are likely to be high.

For the species of *Chasmatonotus* and for other chironomids one must recognize that the morphological features involved with non-swarming and substrate-mating are adaptations to a particular mode of existence dictated by environmental conditions. For this reason, these features should be used with qualification in taxonomic diagnoses, in keys to genera and species and in the analysis of phylogenetic relationships of such species and/or genera.

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NOTES ON LOW TEMPERATURE AND WINTER ACTIVITY OF HOMOPTERA IN MANITOBA

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In a study to determine what invertebrates are winter-active, movement of homopterans on the soil surface was determined from October, 1973, to May, 1975, at Fort Whyte, Manitoba, Canada; results of late autumn (October) and winter (November to mid-April) catches only were considered. This interval included two winter periods of snow cover each lasting five months. Snow insulates the soil surface from diurnal and seasonal fluctuations in ambient air temperatures and maintains subnivean temperatures near 0°C, even at ambient air temperatures of −35°C.

Subnivean temperatures were monitored by thermistor probes in the first winter period (October, 1973, to April, 1974), and by a simple radiotelemetric device in the second winter period (October, 1974, to April, 1975) (Aitchison 1974). Eight pitfall traps were placed in each of three habitats: a ridge between two ponds, an aspen-bur oak wood, and a damp meadow. Collection methods and the characteristics of the study area are described elsewhere (Aitchison 1974, 1978).

Adults of four species of aphids were collected: *Aspidaphium utahensis* Smith and Knowlton, *Capitophorus eleagni* (del Guerico), *Rhopalomyzus poae* Gillette and *Rhopalosiphum padi* L. In addition, nymphs of the genera *Amphorophora* and *Aulacorthum* were collected (Table 1). Nymphs of *Amphorophora* and adults and nymphs of *R. poae* were active under snow at temperatures of −2.0 to −5.5°C and thus may be termed as winter-active. Two aphids were trapped in 1973-74, and nine in 1974-75; in the latter case, most

Table 1. Species of Aphidae collected at low temperatures at Fort Whyte, Manitoba.

	Date collected		Temperature
Species	1973-74	1974-75	(°C)
Aulacorthum sp. (nymph)	28/11/73		−3.5
Rhopalosiphum padi	31/10/73		–
Amphorophora spp. (nymphs)		24/10/74	−3.5
		19/12/74	−2.0
		02/01/75	−4.0
		13/02/75	−5.5
Aspidaphium utahensis		14/11/74	−2.0
Capitophorus eleagni		24/10/74	–
Rhopalomyzus poae		17/10/74	–
		28/11/74	−3.5
		13/02/75	−5.5
Total	2	9	

Table 2. Species of Cicadellidae collected at low temperatures at Fort Whyte, Manitoba

Species	Date collected 1973-74	Date collected 1974-75	Temperature (°C)
Acertatagallia sp.		31/10/74	–
		14/11/74	−2.5
		16/01/75	−6.5
		16/01/75	−7.0
Cuerna septentrionalis	28/11/73		−2.0
	07/03/74		−1.5
	21/03/74		−3.0
		28/11/74	−4.5
		05/03/75	−3.5
C. septentrionalis (possibly)	05/12/73		−7.0
	09/01/74		−7.0
Total	5	6	

of the animals were taken in November prior to snowfall (Table 1). One specimen in 1973-74 and four in 1974-75 were immature individuals and could not be identified to species.

Adults of many species of aphids are thought to migrate in autumn to overwintering host plants where they lay eggs which remain dormant throughout the winter; *R. padi* moves to *Prunus* sp. in autumn (Robinson, pers. comm.). One specimen of *R. padi*, which may have been searching for *Prunus* spp., was taken in one of the ridge traps in late October. Males of *C. eleagni, R. padi* and *Rhopalosiphum* spp. have been collected over air intake louvers at Fredericton, New Brunswick, in November, about a month after the first frost, but when most daily temperatures are above freezing (Adams *et al.* 1976). This corroborates evidence presented here of aphid activity at subzero temperatures down to a low of −5 5°C in Manitoba.

Two species of cicadellids were collected. Five specimens of *Cuerna septentrionalis* Walker were taken in 1973-74, at temperatures ranging from −1.5 to −3.0°C, while two individuals, possibly of this species, were collected at the temperatures of −7.0°C (Table 2). In 1974-75 three *Acertatagallia* sp. were taken at temperatures between −2.5 and −7.0°C. (Table 2). Both of these species may be classified as winter-active. Holmquist (1926) noted that leafhoppers were active at temperatures below 0°C in unfrozen leaves under snow in winter months.

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OBSERVATIONS ON SURVIVAL OF EGGS OF *HEMEROBIUS STIGMA* (NEUROPTERA: HEMEROBIIDAE) FOLLOWING EXPOSURE TO FROST

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During the 1930's, eggs of exotic stocks of *Hemerobius stigma* Stephens were released in Canada, without apparent success (Garland 1978). Although low temperature may have affected establishment, the cause for failure was not investigated. In this exploratory study, eggs of endemic *H. stigma* survived exposure to frost.

These observations involved *H. stigma* originating near Macdonald College and cultured continuously in the laboratory. Eggs for study were obtained from one female during confinement in a 150 ml container in an incubator (Controlled Environments Ltd., Winnipeg, Manitoba) at 18°C, 10:14 L/D. Aphids, *Acyrthosiphon pisum* (Harris), for food, and a spruce twig on which to lay eggs were provided daily. Each morning, eggs with identification were placed in 12x35 mm Kimble shell vials. Occasionally, several eggs were together in the same vial. The vials were plugged with #3 Canlab corks with a narrow hole covered with muslin.

To obtain eggs at different stages of development, batches from each consecutive day were incubated at 18°C for 0-6 days. Subsequent treatment consisted of exposure in a screened insectary for two days and nights, November 13-15, 1979. After exposure, the eggs were incubated at 18°C beside batches which, as a control, had not been exposed in the insectary. Hatching indicated survival. Analysis excluded eggs damaged during handling or eaten by larvae in the same vial. Maximum and minimum thermometers were used to record temperatures in the insectary.

During exposure in the insectary, afternoon maxima were 6.1 and 4.8°C. Overnight minima were 1.9 and −3.8°C. At 10 AM on the third day when the treated eggs were transferred to the 18°C incubator, the temperature in the insectary was −2.5°C. Water beside the road was still frozen.

There were 48 eggs in the control group, and 74 eggs in the treated group (Table 1). Despite exposure to frost, 98.65% of the treated eggs survived, compared to 97.92% in the control group. Regardless of the degree of development prior to exposure in the insectary, the treated eggs survived the stress of low fluctuating temperatures, including freezing conditions one night.

Field notes for this region add perspective to these observations. Adults of *H. stigma* have been trapped in sap pails during sugaring operations in the Morgan Arboretum, near Macdonald College (24.IV.1976, L. M. Crozier and D. N. Duffy; LEM[2]). In the same area, females have been beaten from spruce trees during the latter half of April (17-23.IV. 1979, J. A. Garland; LEM), one of which laid viable eggs in the laboratory by April 29. Another spring capture (Montreal, 7.IV.1926, A. C. Sheppard; LEM) and other specimens taken in association with conifers in the Morgan Arboretum late in the fall (8-16.IX.1978, J. A. Garland; LEM) suggest that this species overwinters in this region as an adult. Presence of adults early in spring and late in the fall raises the likelihood of eggs being laid at these times, in which case they might experience occasional frosts.

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[2] Lyman Entomological Museum and Research Laboratory, Macdonald College, McGill University.

Table 1. Egg survival in *H. stigma* following brief exposure to frost in an insectary.

Consecutive egg batches[a]	Number of eggs[b]	Number of survivors
Control (pre-treatment)		
1	14	13
2	16	16
3	11	11
Treated groups		
4 (6)[c]	13	13
5 (5)	11	11
6 (4)	6	6
7 (3)	13	13
8 (2)	8	8
9 (1)	9	8
10 (0)	14	14
Control (post-treatment)		
11	7	7

[a]female A-1933 in rearings
[b]corrected for damaged and eaten eggs
[c]days at 18°C before exposure in the insectary

This study suggests that eggs of *H. stigma* may be able to survive occasional frosts which penetrate their microenvironment. Because the trials were limited to eggs from only one female, the results may not typify the species, even for this region. Also, although this study employed the stress of fluctuating natural conditions in an insectary, it leaves open to question the range of temperature conditions over which survival would persist.

Dr. D. K. McE. Kevan supported this study through a grant to him, NRC A-1378. Also, Dr. J. E. McFarlane was encouraging.

Garland, J. A., 1978. Reinterpretation of information on exotic brown lacewings (Neuroptera: Hemerobiidae) used in a biocontrol programme in Canada. Man. Entomol. 12: 25-28.

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OBSERVATIONS OF A DERMESTID INFESTATION IN THE MANITOBA MUSEUM OF MAN AND NATURE

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Recently there have been many reports of dermestids in museums (Sommer and Anderson 1974, Ward 1976, McKillop 1978, Peden and Carcasson 1979, Wong 1979). These papers described outbreaks of dermestid beetles that damaged museum property or, on the postive side, dermestids that were used for cleaning skeletal material. A dermestid invasion is of importance to a museum as these insects pose a threat to the artifacts and specimens comprisng didactic displays, teaching or research collections. This is a report of an invasion of a museum by two species of dermestids and the manner in which the infestation was brought under control. The importance of periodic surveillance and effective application of control measures must not be overlooked.

Early in 1979 adult dermestid beetles were found on the top floor (6th) of the building complex housing the Manitoba Museum of Man and Nature. These were identified as the larder beetle, *Dermestes lardarius* (L), and the hide beetle, *Dermestes maculatus* (De Geer). Recognizing the seriousness and possible consequences of an infestation of dermestids, each curator was asked to make a careful search of storage areas to determine whether or not breeding colonies existed within the museum. No colonies were found in this search but a widening problem was evident as beetles continued to be found at irregular intervals not only on the top floor, but on lower floors. A large-scale fumigation or general fogging of the museum was considered, but it was felt that every effect should be made to locate the source to facilitate eradication. In addition, a general fumigation would, coupled with loss of revenue, cost many thousands of dollars.

Observations and records of collection sites showed that specimens were most frequently taken near the emergency-exit stairwell and the passenger elevator. Most of the specimens were *D. maculatus* and these were often taken on the top floor near the stairwell. During a five-week surveillance programme in April and early May, 22 specimens, 18 *D. maculatus* and 4 *D. lardarius* were taken (Fig. 1).

On May 6, observations were made on the roof which a few weeks earlier had been deeply snow-covered, but on this date had only snow-melt pools. Near one of these pools, lay skeletal remains of some animals (Fig. 2). On close observation, hundreds of adult dermestids were seen and large numbers of exuviae were found on the downwind side of the pools up against the roof-top structure housing the shaft-head of the elevator (Fig. 3). Larder beetles were observed crawling up the aluminum flashing (Fig. 4) at the base of this structure and were also noted on an air exhaust louvre leading directly into the elevator shaft-head.

Inspection inside this structure revealed a number of bore-holes in the styrofoam insulation (Fig. 5). The clumped distribution of these holes near the louvre indicated that the infestation was localized, recent and in addition, that both larvae and adults were making their way into the building and that once inside the larvae were using the styrofoam as a pupation site. Although Turner (1940) and Shepard (1940) noted that insulation board was often used as a pupation site, the author is not aware of previous mention in the literature of these beetles using styrofoam as a pupation medium.

The animal carcasses were removed from the roof and a spray programme was implemented as rapidly as possible. Initial spraying with Chlordane and Diazinon was repeated when both species were vulnerable. To date evidence indicates that 100% control was effected.

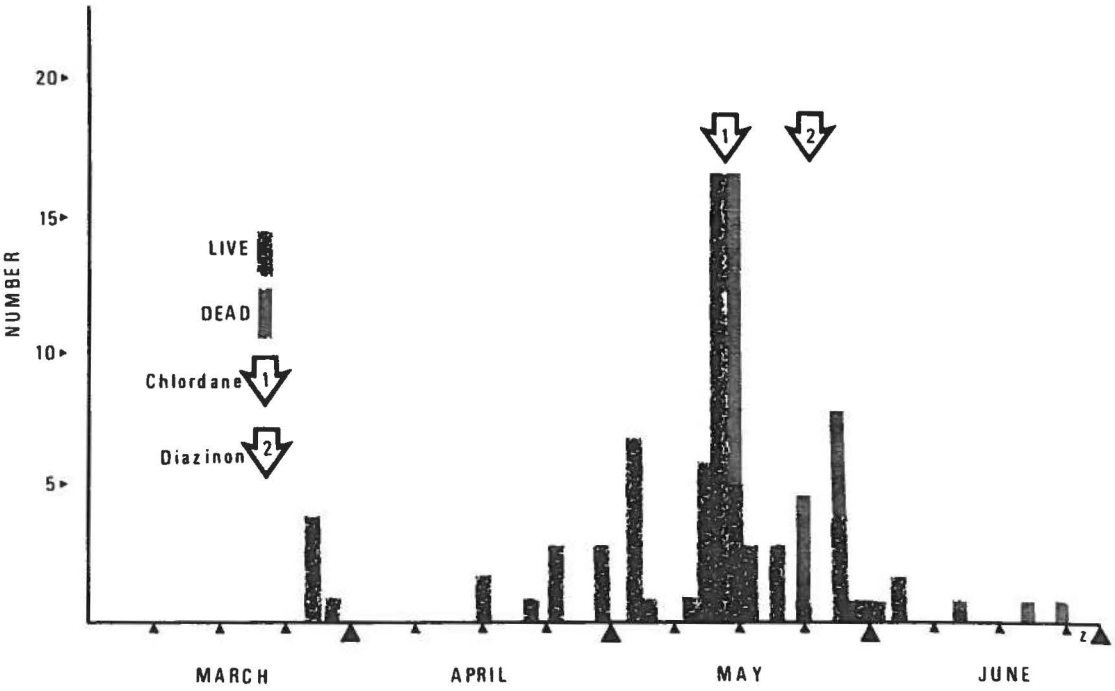

Figure 1. Number of adult dermestid beetles taken in museum.

How did this infestation develop? Obviously the mammal carcasses on the roof served to attract the adult dermestid beetles probably from such nearby sources as tanning factories, furriers and abattoirs. Investigation of why the carcasses were on the roof showed that in late 1977 the central freezer in which large mammals are stored had broken down. Specimens awaiting preparation were removed and taken to the roof where "natural cold storage" was available since temperatures were well below freezing. Once repairs were completed, specimens were returned to the freezer. Unfortunately a heavy snowfall had made location of the specimens difficult and in fact two had been overlooked.

This demonstrates that museum pests can invade through a less than direct "front door" route and that a carefully coordinated corrective action can effectively control such an invasion.

I wish to thank all seventy staff members involved in the surveillance programme, and in particular our Chief of Conservation Mr. Maurice Mann. Renee McKillop and Evelyn Billington typed the manuscript.

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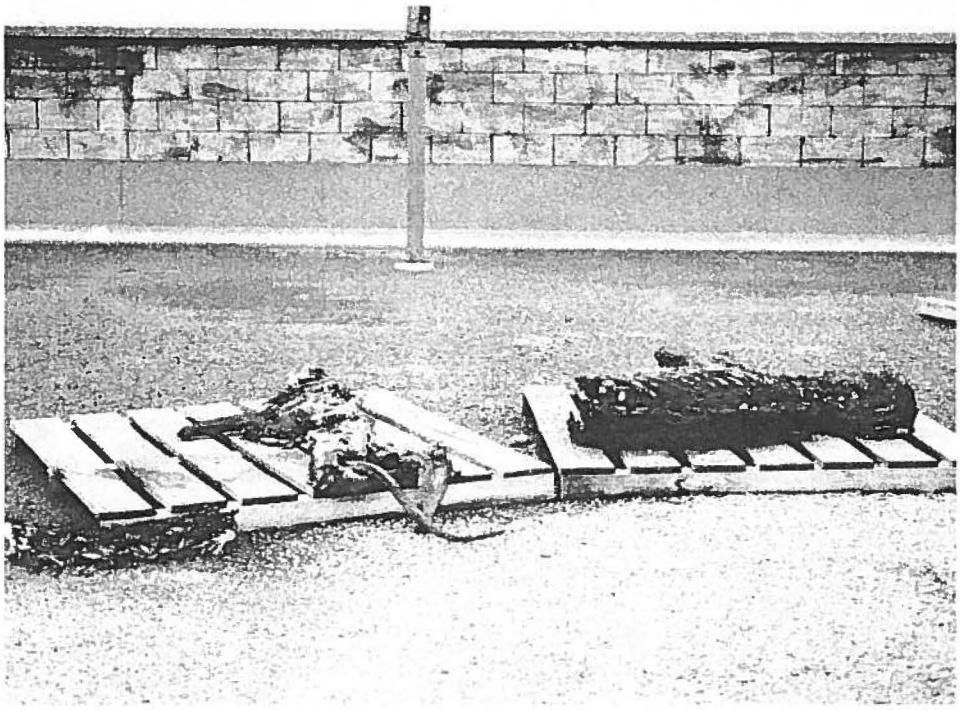

Figure 2. Roof-top skeletal remains.

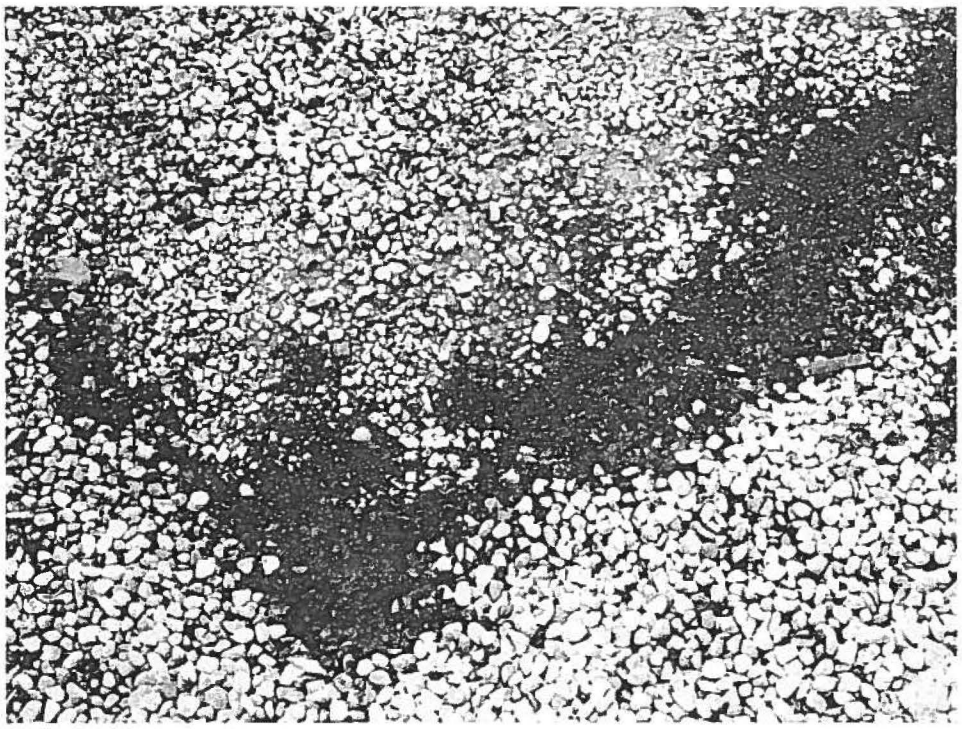

Figure 3. Pupal and larval exuvial drift.

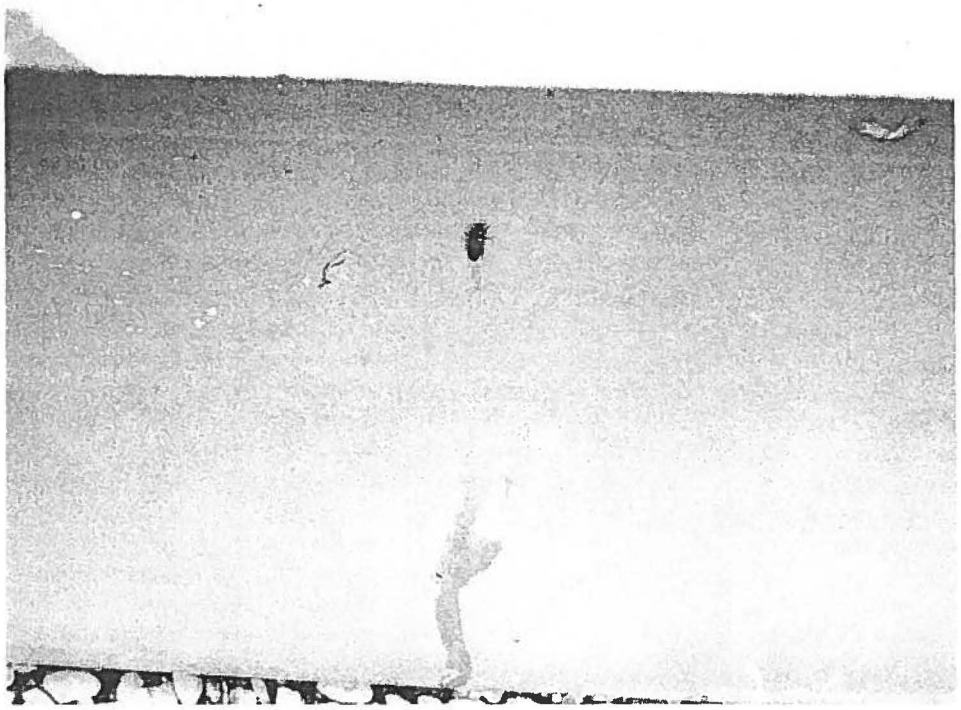

Figure 4. Larder beetle entering museum.

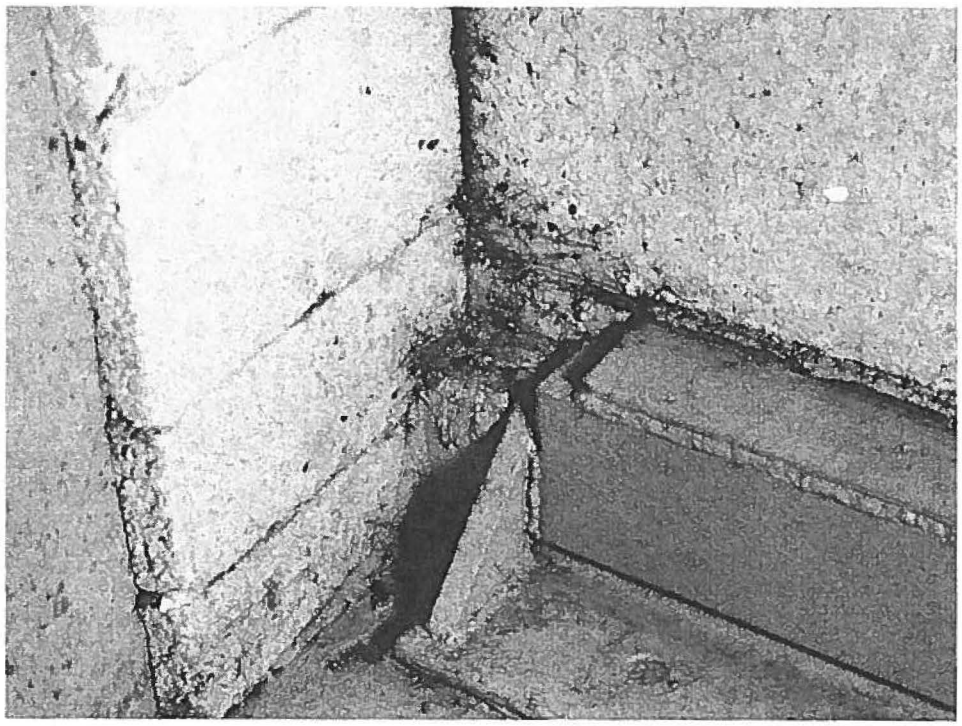

Figure 5. Dermestid pupation bore-holes in styrofoam.

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(Received 28 March, 1980)

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Swedish journal of agricultural research.
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WILLIAM HANEC – 1930-1980

William (Bill) Hanec died suddenly from pneumonia at Winnipeg, Manitoba, on May 8, 1980, at the age of 49.

Bill was born on October 3, 1930 and lived most of his life in Manitoba. His secondary education was completed in Winnipeg, and he obtained the degree B.S.A. in 1955 and M.Sc. in 1956 with the Department of Entomology, University of Manitoba. Bill worked with S. D. Beck at the University of Wisconsin, receiving the degree Ph.D. in 1959. From 1959 to 1977 Bill was a staff member in the Department of Entomology, University of Manitoba, teaching mostly in the field of Anatomy and Physiology. His research interests were mainly in the area of cold-hardiness of insects, using larvae of the European corn borer or the forest tent caterpillar, and he was author or co-author of about 15 scientific publications.

Bill was a member of the Entomological Society of Manitoba. He served as Editor of the Proceedings of the Society from 1959 to 1961, and was President of the society in 1965-66. He was also a member of the Entomological Society of Canada and the Society of Sigma Xi.

Bill was of cheery disposition, a friend of everyone, and available always to help his colleagues, students or friends.

In his non-academic life, Bill was an avid outdoorsman, and loved camping out. He shared these activities with others, and especially in his work with the Boy Scouts of Canada.

He is survived by his wife Olga, and sons William and Greg, all of Winnipeg, his father John and his brother Bohdan.

Grant Robinson.

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