INTEGRATED MANAGEMENT OF GERMAN COCKROACHES IN RENTAL HOUSING

by

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Integrated management of German cockroaches in rental housing

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ABSTRACT

This paper summarizes a study of an infestation of German cockroaches (Blatella germanica L.) in a high rise apartment building in Vancouver and discusses the possibility of developing an integrated pest management (IPM) program for their control.

Eradication is not practicable, nor is it an appropriate objective for IPM programs and consequently tolerance levels need to be established. Most residents were able to tolerate seeing about one cockroach per week, particularly if it was not in their food or cooking utensils, or in their bedrooms. Many of the other residents could also be persuaded to accept this level of infestation.

The suppression of cockroach populations should be approached first by modifying the habitat, and later by applying pesticides selectively. Surveys of the cockroach population must be carried out regularly in order to assess the distribution and severity of the problem and to identify suites that need attention. Because areas that are kept too warm are often heavily infested, considerable benefit can be achieved by maintaining temperatures below 20 C. Clutter should be removed and cracks sealed to reduce harborage for the cockroaches. Proper containment of food will prevent contamination and along with increased sanitation will reduce the availability of food and harborage.

Other procedures that could be incorporated into an IPM program include mass trapping, releasing parasites, the use of repellents and the release of sterile cockroaches.

It is concluded that a management program for cockroaches could be developed and would have the advantages of being a more long term solution and of requiring less use of pesticides than other control approaches, but would have the disadvantage of being much more costly.

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INTRODUCTION

To many residents of British Columbia, cockroaches are assumed to be foreign pests encountered only during vacations in Mexico or Hawaii. Few people will ever encounter a cockroach in a western Canadian residence and thus most will always be unaware of the difficulties of finding satisfactory solutions for cockroach infestations.

Although less common than many other household pests in this province, cockroaches, mostly Blatella germanica L., do occur in some dwellings and occasionally develop high populations. Application of insecticides will often suppress the population, but their effect is short lived and thus the problem frequently recurs three to twelve months after the treatment. Many infestations are stubbornly persistent and may not be eradicated even after extensive and regular applications of chemicals. This is often contrary to the expectations of the public which mistakenly believes that effective control is easily achieved for all pest problems.

The widespread concern that exposure to chemicals may be harmful often results in opposition to the application of pesticides by the residents. Questions about the harmful effects of pesticides raised during these confrontations cannot be given conclusive answers and thus few opinions are ever changed.

Many non-chemical techniques have been demonstrated to give partial control, but no one approach has been able to give adequate results by itself. This paper explores the possibility that a selection of these partially successful techniques brought together in an integrated pest management (IPM) program would provide a satisfactory solution to the problem of cockroach infestations.

An IPM approach would differ from standard control practices in that it would use a number of tactics in order to maintain the problem below an established threshold, rather than using only insecticides in an attempt to eradicate the infestation. It would include public education and would allow for extensive contact with residents. To reduce the number of cockroaches, environmental-modification tactics would be emphasized and regular building-wide surveys using traps would be used to provide information on progress. Use of insecticides would be much more limited than in a regular control program, and would be chosen as the last, rather than the first resort.

The major reason for controlling cockroaches is to alleviate the anxiety experienced by residents of infested dwellings. The often cited disease vector potential of cockroaches is not a serious threat in southwestern British Columbia and is therefore not a pressing reason for instituting control. Cockroaches are not a common pest in western Canada thus people are less likely to tolerate them than are inhabitants of cities where infestations are widespread. Tolerance therefore plays a prominent role in the problem of infestations in this area.

Most cockroach problems are confined to high density housing, such as apartment buildings, or to commercial establishments, particularly where food is prepared. Cockroach problems in single-unit housing account for only a small percentage of all infestations in British Columbia. When houses do become infested, the populations are generally small and will sometimes collapse on their own after one or two years. Apparently some environmental factor, or factors, necessary for cockroach proliferation are lacking in the buildings in this region and thus the usual high rate of population growth is hindered.

Southwestern British Columbia is considered throughout this paper as a unit area because of its uniformity of climate, culture and legislation. It includes the areas known locally as the lower mainland and southern Vancouver Island and includes the cities of Vancouver and Victoria. The combined population of southwestern British Columbia is about 1.5 million.

Despite the region's mild winters and moderate summers, the temperatures are too low for cockroaches to survive outdoors during a large part of the year. The relative humidity is moderate despite the area's proximity to the ocean and high rainfall.

Although there are some old and dilapidated buildings in southwestern British Columbia they are uncommon and are not usually infested with cockroaches.

Part of the information in this paper is based on studies conducted on a cockroach infestation in a Vancouver apartment building, known as the Acadia High Rise, from April 1980 to May 1982 (appendix 1). Supplementary information was obtained from observations of four other

buildings and from a review of published literature.

Laboratory colonies of cockroaches were maintained for use in behaviour and toxicological observations. The insects were obtained from an apartment in November 1981 and were housed in five gallon aquariums in which cardboard egg cartons were placed for shelter. The insects were prevented from escaping by the application of petroleum jelly to the upper walls of the cage. In some cases "Fluon" was used (Ebeling and Wagner 1963) and was found to be a more effective barrier and much less messy than the jelly.

An IPM program was never fully established at Acadia thus the fate of the infestation at that site cannot be used as a measurement of IPM effectiveness. After September 1982 the programs that had been instituted during this study were abandoned and the problem was turned over to a local pest control firm. It is also important to note that all the techniques mentioned in this paper were not field tested, thus this report should be considered as a guide to the different approaches rather than as verification of their usefulness.

The scope of this thesis is limited to the problem of German cockroach infestations in high density rental housing. Although this is in specific reference to the situations encountered in southwestern British Columbia, parts of this report will have relevance to cockroach infestations elsewhere in the world, particularly outside the tropics.

The other cockroach species, particularly Periplaneta americana and Blatta orientalis, differ significantly in their ecology and thus would probably require a different approach from that described here for the German cockroach.

BIOLOGY OF THE GERMAN COCKROACH

The reviews by Cornwell (1968) and Guthrie and Tindall (1968) cover cockroach biology in great detail and are a valuable asset to studies in this area.

ORIGIN AND SYSTEMATICS

Cockroaches are often cited for their primitive appearance and close resemblance to ancient fossil forms (Cornwell 1968, Ebeling 1975). Their similarity to termites is apparent from their body shape and wing venation as well as from the presence of intestinal protozoa in some species (McKittrick 1964).

In the classification scheme of McKittrick (1964) cockroaches are grouped together in the superfamily Blattoidea under the order Orthoptera. At least five families are recognized within North America.

The family Blatellidae is a large group, most of which are 12 mm, or less, in length. It contains two important pest species Supella longipalpa (F.) and Blatella germanica L. Also of note is the cockroach Blatella vaga L., an outdoor species that is common in some parts of the world, but has never been established in Canada. Although morphologically similar to the German cockroach, it only occasionally invades homes and it not considered a problem pest species (Cornwell 1968). German cockroaches (plate 1) are

Plate 1: ADULT FEMALE COCKROACHES

readily distinguished from other common cockroaches by two longitudinal black markings visible on the pronotal shield. In younger nymphs these lines apear as a single dot.

Although now cosmopolitan, German cockroaches probably originated in northeastern Africa and were introduced to Asia Minor several centuries ago, and later to Europe and the Americas (Rehn 1945). They are known under various common names including croton bug, shiner and steamfly. Although they are not a very common pest in western Canada, infestations are very abundant in some eastern cities such as Toronto. Mampe (1972), in his report on a survey of American pest control operations, claimed that the German cockroach was the most important household insect pest in United States.

LIFE CYCLE

Since many of the characteristics of cockroach biology vary according to the nature of the environment, caution is necessary in making generalizations about all infestations (Kunkel 1966, Tsuji and Mizuno 1972, 1973, Gould 1941, Haydak 1953 Melampy and Maynard 1937). It is important to note that field populations will have more prolonged development and lifespans (Ogata 1976) and lower fecundity than those described in published reports, most of which are based on studies conducted on well-fed colonies maintained at high temperatures.

Although the lifespan of a German cockroach is generally about 190 days some may survive up to 360 days (Willis et al. 1958) or longer (Guthrie and Tindall 1968).

OOTHECAE

The success of the cockroach in colonizing new environments is due in part, to its ability to produce a large number of eggs and thus assure survival for a substantial number of its descendants.

The embryos are contained in an oblong case (ootheca) about 3 mm wide and 8 mm long which is carried by the female until the time of nymphal emergence; about 17 days after the ootheca is first visible. An ootheca generally contains 30 to 40 eggs, however the number may be as low as 3 or as high as 50 (Willis et al. 1958).

Although certain stimuli, particularly exposure to insecticides, will cause a female to drop the ootheca prematurely, only those within 7 days of hatching will survive (Parker and Campbell 1940).

NYMPHAL PERIOD

German cockroaches undergo simple metamorphosis, with five to seven instars prior to molting to the adult form. The total nymphal period lasts for 40 to 50 days (Ross et al. 1981, Willis et al. 1958).

First and second stage nymphs are 3 to 5 mm long and appear almost completely black. To the layperson, they more resemble ants or small spiders than cockroaches (Ebeling 1975). Mortality in the early stages is high, perhaps due to their sensitivity to desiccation. After each moult their appearance changes slightly. The most conspicuous differences are the increase in size, the broadening of the light-tan coloured markings on the body and a lengthening of the antennae. Determination of instar stages can be done by counting the number of segments in the cerci and by measuring the pronotal width (Tanaka and Hasegawa 1979).

ADULTS

Adults survive for about 128 days (males) to 153 days (females) (Willis et al. 1958). They are distinguished from nymphs by the presence of wings and by their light colour and large size. The wings are thin and membranous and, although capable of sustaining flight, are almost never used for this purpose. Adults are also swifter runners and are more reclusive than nymphs.

The sexes are readily distinguished among the adults by the females' larger size and more rounded abdomen. Males have a slender appearance and a distinctly pointed body. Cockroaches mate a few days after molting to the adult form. Although the female requires only one mating in her lifetime, she generally will copulate several times. The first sperm packet fertilizes most or all of the eggs produced by the female and thus the genetic donation of all subsequent matings is very small (Cochran 1979). Production of viable progeny by parthenogenesis does take place in some cockroach species but is not known to occur among German cockroach females (Roth and Willis 1956, Willis et al. 1958).

Cockroach courtship is highly stereotyped and is triggered by the reception of a non-volatile pheromone by the male through physical contact with the cuticle of the female (Nishida et al. 1975). Male cockroaches begin their courtship ritual with a wing raising action thus exposing the dorsal glands which produce a substance on which the female will feed. The male then pushes his abdomen under the female and clasps

her genitalia firmly to prevent her escape and begins copulation (Cornwell 1968, Roth and Willis 1952).

Most females will bear four to eight oothecae during their lifetime of which the earlier ones will produce the greater number of young. Although of only 34 days elapses between the hatching of successive oothecae in laboratory colonies (Willis et al. 1958) data from field populations suggest that a substantially larger part of the adult female population is reproductively inactive than would be expected from this figure (Keil 1981).

ENVIRONMENTAL REQUIREMENTS

If German cockroaches could thrive anywhere in a building, the prospects for their control would be much reduced. Fortunately however, they are usually confined to the kitchens and bathrooms, presumably because of their requirements for harborage, heat and water, which are all available in these locations.

Further details of these environmental requirements are discussed later in the section on environmental modification.

MOVEMENT AND DISPERSAL

An understanding of cockroach movement is essential for the prediction of infestations. It is also needed to evaluate the potential for physically sealing the apartment to reduce cockroach problems and for understanding the potential efficacy of traps.

That cockroaches are nocturnal is well known to most people. Harker (1956, 1960), working with P. americana, showed that the cockroach's activity is mostly concentrated in the four to eight hours following the onset of darkness and that the insects accustom themselves to a specific diurnal cycle which will not immediately change even if the photoperiod is altered.

Consequently, if a resident normally turns out the light and goes to bed at 10:00 P.M., when this pattern is broken, perhaps because of a party or late night studying, the cockroaches will begin their foraging at 10:00 even though the lights are still on.

After a few days in a new light regime the cockroaches will readjust their activity cycles to minimize their exposure to the light. Harker showed that diurnal rhythms are controlled by secretions from the cockroaches suboesophageal ganglia which is influenced by stimuli received through the eyes. Maintenance of the activity cycle is dependent on an alternating light - dark regime and is lost under the conditions of continuous light or dark. The operation of the diurnal rhythm is similar in all major cockroach species. Hocking (1958) in a study on the activity of the German cockroach concluded that it did not have any essential features that differed from Harker's findings with the American cockroach.

Cockroach movement occurs as a result of one or more of a number of behavioural components; to find a more favorable environment, to move away from adverse stimuli, to search for food or water or for mating purposes. It is influenced by enviromental factors which include temperature, humidity and light intensity. To initiate movement, both motivational and environmental factors must be appropriate (Ebeling 1975).

Cockroaches do not move continuously. Even under similar environmental conditions all cockroaches do not exhibit the same amount of activity. Hocking (1958) found the number of excursions made by twelve adults to food at night varied from 8 to 55. His results also showed that females were more active than males, and that insects that became excessively active usually died in three to four weeks time. Activity is probably influenced by many biotic factors including age, develomental stage, health and nutritional status, although no studies are available to confirm this.

DISPERSAL WITHIN BUILDINGS

A mark-and-recapture study conducted in a two-storey apartment by Owens (1980) indicated that up to 30% of the adult German cockroach population will move between adjacent dwellings over a seven day period. Akers and Robinson (1981) have also shown that movement occurs between adjacent rental units. Studies of P. americana (Jackson and Mair 1961) and P. fuliginosa (Fleet et al. 1978) have demonstrated the ability of other species to move long distances as well.

The rate of cockroach dispersal is increased by the presence of unobstructed dispersal corridors, particularly sewers and pipe chutes. Although they are able to squeeze through incredibly narrow cracks, a driving force must be present to coax the insects through an orifice. Ebeling (1975) found that after 24 hours only 8% of a group of 100 adults

moved through a 2 mm aperture to a darkened refuge in the adjoining area. When the aperture was located in the ceiling of a test compartment, no insects moved through the opening.

DISPERSAL INTO BUILDINGS

Although it is not possible to say with certainty how cockroaches colonize buildings in southwestern British Columbia, it is probable that they are introduced along with the personal belongings of new residents who arrive from another infested dwelling, or are introduced with food obtained at an infested establishment.

Of six tenants contacted after they had moved from infested suites in Acadia to apartments in other parts of the city, only one had sighted any cockroaches after moving into their new premises.

The occurrence of and failure to control cockroach infestations is often blamed on the colonization of the building by outdoor reservoir populations (Mallis 1969, Piper and Frankie 1978a, Jackson and Maeir 1955, 1961). Certainly in any situation where outdoor survival is favored, influx from external populations is likely to be a serious problem. The migrations of German cockroaches between buildings that have been noted (Mallis 1969) indicate that the insects need only survive for short periods outside in order to pioneer new infestations.

A report by Beatson and Dripps (1972) of cockroaches in a garbage dump in England would lead one to conclude that outdoor proliferation of cockroaches in north temperate areas is possible. However it is likely that such incidents are isolated and are due to unusual circumstances, probably in this case from the heat generated by the decomposing refuse. In normal circumstances, German cockroaches would not survive. Tsuji and Mizuno (1973) showed that no stage of the German cockroach could survive a forty-day chilling at 5 C, indicating that any individuals that were outside during the winter months would certainly die.

No reports have been made of outdoor cockroach populations in southwestern British Columbia. Four field trips made around the study site failed to detect any cockroaches around the building, or on any outdoor structure, nor were any of the nearby buildings infested. On these grounds, reinfestation of the High Rise from outdoor reservoirs seems improbable.

POPULATION DYNAMICS

Populations of German cockroaches in apartments undergo frequent changes in age structure and population size (Ross and Wright 1977, Keil 1981, Grothaus et al. 1981). An understanding of these dynamics is important for both the prediction of damage and for the evaluation of control techniques.

The rapid growth of populations is an important factor in the persistence of German cockroach problems. Theoretically, if optimal growth conditions existed and no mortality occurred, a single gravid adult female could produce twenty million descendants in one year (Grothaus et al. 1981). Even the most effective pesticides are likely to leave a few survivors and which will be able to reproduce and replace the eliminated individuals within a relatively short period, therefore key to managing cockroach problems is to concentrate on reducing the growth rate rather than causing mortality.

Natural causes of mortality among cockroaches are not well documented. Diseases are prevalent in most populations (Tsai and Cahill 1970) but are not normally lethal to the host. Diet also seems to play a part in longevity (Haydak 1953). It seemed to me from casual observations of the colonies maintained during the study that about 90% of the nymphs survived to adulthood, which is consistent with the suggestions of Grothaus et al. (1981). Of more significance to the growth of cockroach populations are those factors which modify the insect's developmental and reproductive rate (Grothaus et al. 1981).

Among these are temperature (Tsuji and Mizuno 1972), cockroach density (Komiyama and Ogata 1977), diet (Melampy and Maynard 1937) and the availability of food (Kunkel 1966, Mueller 1978).

Factors governing the maximum population size or carrying capacity of apartment environments have not been established. Obviously populations cannot expand indefinitely, and thus some upper limit must exist. The observations of Keil (1981) and Owens (1980) that populations are limited by availability of harborage is consistent with observations made during the study at Acadia. This point will be discussed further under the heading of Sanitation.

Assessing the isolation of populations within buildings is similarily difficult. The degree of movement and interbreeding between apartments has not been studied and probably varies greatly with different building constructions. Consequently it is not possible to say whether controlling the cockroaches in one apartment will affect the population level in other dwellings.

Lack of information on the population processes of urban cockroaches causes significant problems in the evaluation of cockroach control. For example, in a paper by Barak et al. (1977) the efficiancy of cockroach traps was evaluated by comparing captures during the first week with captures during each of the following weeks. This practice is often used because it is not possible to find two infestations that are sufficiently similar that one could be used as an independent control for the other. Unfortunately it ignores the possibility that populations will naturally fluctuate over time, thus

the observed changes in the population may not be due to the control tactic employed. The authors, who suggest that failure of the population to increase during deployment of traps is an indication of some control being exerted, are assuming that the population size is not limited by a fixed carrying capacity.

DAMAGE CAUSED BY COCKROACHES

Although cockroaches are known as potential vectors of human disease, the more realistic reason for controlling them is to mitigate the revulsion experienced by residents.

THE ROLE OF COCKROACHES IN THE SPREAD OF DISEASE

The health hazard of German cockroach infestations is often overstated. Claims commonly made by some pest control operators of high risk of infections from diseases carried by the German cockroach are usually greatly exaggerated and misleading.

It is erroneous to assume that because some species of cockroaches have been demonstrated to carry disease organisms in some situations, that all cockroach species will carry these diseases in all situations. It has also not been proved that these cockroaches could and would pass on infectious agents to residents of infested dwellings. The supposition that all cockroach infestations are a threat to the public health ignores the possiblity that different species have different vector potentials and that infestations in southwestern British Columbia do not have access to sources of some of these diseases.

Despite the widespread occurrence of German cockroaches, they have not been shown to be commonly involved in the outbreaks of any human diseases. Many people have lived for long periods in heavily infested dwellings and have not contracted the illnesses which these insects are suspected of causing.

Table 1 lists the human pathogens for which the German cockroach is implicated as a vector. Some of these organisms are known to occur naturally in wild populations of cockroaches, whereas others have been shown to be vectored by cockroaches only in the laboratory. The work of Roth and Willis (1957) is noteworthy for its thorough discussion of this topic and for its review of the literature up to the date of its publication.

Although there is considerable evidence for the association of German cockroaches with these agents, some of the pathogens, such as leprosy and typhoid, are either unknown or exceptionally rare in western Canada and thus are not a great concern. Others are of enteric origin and could only be picked up by cockroaches feeding on sewage, an unlikely situation at buildings such as the Acadia High Rise. Some of the pathogens associated with cockroaches, such as Staphylococcus, are widespread and the possibility that they are associated with household insects (as has been demonstrated by Alcamo and Frishman 1980) may not be significant in their epidemiology.

All of the pathogens mentioned here have other modes of transmission and in no case is the cockroach thought to be major means of spread. Polio, for example, has long been known to be spread

Table 1: THE MICROORGANISMS FOR WHICH THE GERMAN COCKROACH IS IMPLICATED AS A VECTOR

DISEASE	CAUSAL AGENT
Urinary tract infections	*Pseudomonas* and *Eruginosa* spp.
Abscesses, Food poisoning	*Staphylococcus aureus*
Associations with pus	*Staphylococcus* spp.
Intestinal infections	*Escherischa coli*
Gastroenteritis	*Paractobactrum serogenoides* *Paractobactrum coliforme* *Salmonella murbitacus*
Food poisoning	*Salmonella typhimurium* *Streptococcus* spp. *Clostridium* spp.
Leprosy	*Mycobacterium leprae*
Polio	*Polomyelitis* Virus
Asiatic cholera	*Vibrio comma*
Amoebic dysentry	*Entamoeba histolytica*

(Adapted from Roth and Willis 1957 and Alcamo and Frishman 1980)

primarily through contact with other human carriers. Even though insects (mostly flies) have been known to be contaminated by the virus their role in the transmission of the disease would at the very worst be only accessory (Howe 1952).

The most convincing evidence for bacterial transmission by B. germanica concerns the spread of Salmonella typhimurium, a causative agent of food poisoning (Ash and Greenburg 1980). However, this bacterium is widespread and infections are not restricted to establishments with insect problems. Food infections from cockroach vectored S. typhimurium could be prevented by following normal sanitary practices, including refrigeration of contaminated foods and preventing lengthy exposure of the food in places where cockroaches may come into contact with them. No cases of food poisoning were uncovered during the study at Acadia.

It should also be pointed out that although the cockroach may have the potential to act as a vector, the infection rate is clearly quite low. Rueger and Olson (1969) were unable to detect Salmonella in any German cockroaches collected around the U.S.A.. In fact, of 6,298 cockroach specimens from 19 cities representing five cockroach species, only the specimens from two cities (both P. americana) were found to be infected. None of the 62 cockroaches collected by Frishman and Alcamo (1977) from 25 different locations in New York state carried Salmonella. Cardone and Gauthier (1979) also could not isolate this pathogen from 60 specimens collected at 20 establishments in Alabama.

In a later section the importance of establishing the threshold levels of human tolerance for cockroaches will be discussed. In situations relating to human health, the perceived objective is usually to reduce vector populations to zero and thus to eliminate all potential for harm. Although this is a desirable goal it is often not possible and if populations are low may not be necessary.

Cornwell and Mendes (1981) discuss some aspects of density thresholds for cockroach borne pathogens but do not present much evidence to support their proposed standards. Certainly, if cockroach populations could be reduced to a level where the contamination of foodstuffs is insignificant, there is no pressing need to eradicate them. Unfortunately no studies have been conducted to establish such a threshold for German cockroaches in rental housing, thus further work is needed in this area if IPM is to be made acceptable to health authorities.

ALLERGIES TO COCKROACHES

An additional health consideration is the role of cockroaches as allergens (Bernton and Brown 1964, 1970a, 1970b). Clearly many people are sensitive exposure to particles derived from cockroaches, such as might occur in house dust. However, the deleterious effects on their well-being is not clear.

FACTORS IN PEOPLE'S TOLERANCE TO COCKROACHES

Reactions of residents to the presence of cockroaches vary widely. Feelings of anxiety and revulsion are common and so is complete acceptance of the situation. Most tenants fall somewhere between these extremes. The adverse reactions of some individuals to insects is not restricted to just cockroaches, and is a problem that is encountered in any situation where people come into contact with insects (Olkowski and Olkowski 1976b).

My contact with residents left me with the impression that concerns about the presence of cockroaches are only rarely associated with a fear of being physically harmed by the insects. Usually low tolerance is expressed as revulsion at the thought that the insects are nearby. This was often described by the residents with phrases such as "cockroaches give me the creeps".

Persons with low tolerance typically expressed reluctance to view even securely contained or dead cockroaches; thus there could be no rational fear of harm involved. On occasion people would display emotion at the mere mention of cockroaches even though the discussion might be taking place outside the building well away from the nearest infestation.

Classification schemes for human behaviour patterns are a subject of considerable disagreement among psychologists. Nevertheless, delimiting the type of behaviour involved in insect tolerance is useful for discussion purposes (Bourne and Erkstrand 1979). A commonly encountered scheme labels behaviour that is associated with anxiety as neurotic. Phobias are a type of neuroses that are characterized by an overreaction of fear to an apparently harmless object or situation.

Assuming that cockroaches are not perceived as being of acute harm, low tolerance to their presence can be considered a phobic response, even though the reasons for overreaction differ greatly. Many phobias are thought to represent a displacement of emotion onto a stimulus which is unrelated to the real cause of the stress. Fear of insects can be a safe way for the mind to vent anxiety built up over family or personal problems. The phobia is then reinforced by the attention the person receives as a consequence of the behaviour he or she is displaying (Gray 1978). Factors associated with tolerance levels at Acadia included gender and prior exposure. In general women were much less tolerant than men, although considerable variation occurred within both groups. Residents who had never lived in an infested dwelling were less tolerant

than those who had, and new residents in the building were consistently less able to cope with the situation.

The size and distribution of the cockroaches also affected tolerance. Small cockroaches, particularly those in the first and second instars, were regarded as less of a threat than older insects. Also of interest was the comment by residents that cockroaches on the floor or under the sink seemed more acceptable than those on the counters. Cockroaches in the utensil drawers were considered even more annoying. In low tolerance individuals hysterical reactions resulted when cockroaches were found in the bedroom, an area where the residents were least tolerant of their presence.

Establishment and manipulation of resident's tolerance levels is discussed in a later section, however, it should be mentioned here that the occasional cases of hallucination, delirium or hysteria encountered among residents are not typical of phobic responses in neuroses and are more probably associated with some other psychotic syndrome (Davison and Neale 1974). These people would not be expected to respond to attempts to increase their tolerance of cockroaches.

OTHER PROBLEMS

A variety of lesser problems are sometimes caused by cockroach infestations, however most of these are only of concern in apartments with large insect populations.

Cockroaches deposit fluid droplets of excrement which, in areas of aggregation, may cause damage by their staining effect. Generally the only objects that are seriously affected are paper products, particularly photographs, documents and books. Occasionally artworks are damaged. Staining, however, is not generally of serious concern since cockroaches do not usually occur in areas where the susceptible products are stored. The commonly encountered stains on walls and counters can usually be removed with soap and water.

Mallis (1969) mentions a report of German cockroaches chewing the cloth covers of reports in a government office, however, this is very unusual since damage caused by the feeding habits of this species does not usually occur.

A characteristic "roachy" odour is common in some infestations, and is variously described as fetid, mildewy or nutty. Indeed the smell may originate from a combination of sources, including mildew and mold, which are often present in the humid cockroach habitats.

INTEGRATED MANAGEMENT OF COCKROACHES

Many comprehensive reviews of the theory and benefits of IPM have been published (Flint and Van den Bosch 1981, Bottrell 1979, Goldstein and Goldstein 1979, Apple and Smith 1976) and thus there is no shortage of documentation of this approach. The development of the strategy for the IPM of cockroaches described here was, in part, based on a review of these works.

~~The term~~ "integrated pest management" implies that all possible control practices are assessed from a wide perspective and that a holistic strategy is adopted to solve the problem. Development of an IPM program requires that the ecological, social, political and economic components of the environment be understood and that the program be compatible with as many of these as possible. All IPM programs establish a threshold level of pest caused damage, below which the insect is tolerated and no control action is taken. Consequently all IPM programs rely heavily on monitoring and prediction of pest population densities, distributions and damage. Eradication is generally not an objective of IPM.

Although any pest control technique or product may be used in an IPM program, emphasis is ~~usually~~ placed on "natural" ~~controls~~ that

exploit weaknesses in the organism's biology. Ideally, numerous control techniques are employed so that if a failure occurs with one method the damage will still be under partial control by the others. Often techniques employed are, by themselves, only partially effective in controlling the pest problem, but when employed with other partially effective techniques they provide a satisfactory level of control.

A good IPM program is dynamic and will be continously modified in order to remain in balance with the environment to which it is being applied.

Although IPM was originally developed for specific applications in agriculture, it has since been expanded to include all areas of pest control. Notable are the IPM projects for pests of cotton, alfalfa and fruit trees. IPM has also been applied to forest pest problems, notably for bark beetles.

IPM IN URBAN ENVIRONMENTS

IPM programs in urban settings differ from those in other environments in that they make greater use of public education and have higher potential for increasing tolerance levels.

Ideally the pest manager carefully considers the needs and well being of the residents, and thus an urban IPM program should be "people oriented" rather than "pest oriented".

IPM has received less attention in urban pest control than it has in other areas. This is probably because most people believe urban pests must be eradicated and are therefore only interested in techniques that increase mortality. Furthermore, there has been no profit incentive to encourage industry to adopt IPM approaches.

Although it is true that many of the control programs run by professional pest control operators have some aspects of IPM incorporated into them (Katz 1979) there have been few attempts to establish threshold levels of tolerance to the insects, or to utilize adequate monitoring systems, both of which are vital parts of IPM.

The best documented urban IPM program was developed for insect pests in street trees in Berkeley California (Olkowski 1973, Olkowski and Olkowski 1976a, Olkowski et al. 1976, 1978). In this case, monitoring, public education, mechanical and biological control tactics were used along with the establishment of acceptable damage levels to successfuly reduce the need for application of pesticides.

Few attempts have been made to approach cockroach control with a holistic view. The cases described below were not necessarily intended to be IPM programs but they all have elements in common with integrated control.

Gupta et al. (1973, 1975) conducted a cockroach control program in single family dwellings in New Jersey which included surveys using pyrethrin flushing agents, assessment of sanitation, community education and deployment of various combinations of boric acid and Drione® powder and chlorpyriphos, diazinon, pyrethrins and dichlorvos

sprays as well as propoxur in an insecticidal bait. Follow-up surveys after the treatments were never carried out long enough to give adequate assessment of population suppression and an ongoing management program was not established (Anonymous 1980).

In Maryland a cockroach control program was developed for a low income public housing unit which included a high level of tenant contact along with applications of Drione® and chlorpyriphos made on the basis of need. Regular surveys were made using Drione® as a flushing agent, and suites were evaluated for the need of increased sanitation. At the end of a six month period 91% of the residents felt that cockroach control had improved and that a pest management scheme was acceptable (Anonymous 1980, Wood 1980).

In the early 1970's a pest management program for German cockroaches was established in 420 married-student apartments at the University of California, Berkeley campus (Slater et al. 1979). The program included assessment of infestations by inspections and tenant complaints, community education, use of pyrethrins, dichlorvos, diazinon and boric acid. The authors noted a decrease in complaints received by the housing department and indicated that the program was ongoing.

The most sophisticated attempt to use IPM for cockroach infestations is that documented by Piper and Frankie (1978a, 1978b). The authors developed control programs for numerous types of housing in Texas, most of which were infested with the smokey brown cockroach. Included in this study is a description of an attempt to control German

cockroaches in a student residence at Texas A&M University using mass trapping techniques, the details of which will be discussed later. Additional components of the control programs at other sites included public education, biological control using a hymenopterous egg parasite, application of boric acid, evaluation of residence sanitation and cockroach surveys using traps. Great emphasis was placed on strategy, particularly in the development of tailor-made control programs for each dwelling based on the residents level of tolerance to cockroaches and pesticides.

COMPONENTS OF AN INTEGRATED COCKROACH MANAGEMENT PROGRAM

All biological systems are composed of a large number of parts. In most cases, this diversity is responsible for the stability that we observe in nature. Although many of the components are not essential to the operation of the system, they allow it to function in an optimal fashion.

IPM systems derive similar benefits of stability and optimization by having many components. I believe that an urban IPM program could function with as few as three control techniques, although it would be better if ten to twenty approaches were taken. More than this might be difficult to manage, and might not add significantly to the control program.

It is often claimed that non-chemical control procedures do not give a satisfactory solution. However, it is not necessary that any single component in an IPM program give complete control, since it is always backed up by the other procedures. Although one control technique may only solve part of the problem, a number of additional procedures might give a more complete solution.

STRATEGY AND OBJECTIVES

All IPM programs are heavily dependent on strategy. Before strategies can be developed, the objectives of the program must be clearly laid out. A common mistake in pest control is to choose inappropriate objectives. For example, the pest control operator may believe that the objective is to kill all the insects, or worse, he may believe that the objective is to apply the pesticide. These objectives fail to acknowledge that the real problem to be solved in this case is the anxiety of the residents thus the objective need not require killing insects or using pesticides.

IPM programs are generally highly tuned to the particular environment in which they are being applied thus the strategies employed should be sensitive to the needs of that particular situation and may not be applicable to other environments or infestations. It is therefore important that different IPM strategies be developed for each building or area.

ESTABLISHMENT AND MODIFICATION OF HUMAN TOLERANCE LEVELS

Since tenant revulsion is the major factor justifying the control of cockroaches, tolerance levels need to be established at the outset of an IPM program. Programs can then be directed at increasing the tolerance of highly phobic individuals in order to reduce the need for cockroach population suppression. Since cockroaches cause no physical damage, the term "damage threshold", which is used in other pest management areas, is not appropriate. Olkowlski et al. (1976) used the term "aesthetic injury level" (AIL) to describe the degree of tolerance that residents had toward infestations of aphids in street trees. This concept was subsequently used by Piper and Frankie (1978a) in reference to residents' tolerance to cockroach infestations.

Injury levels, rather than the usual standard of zero population survival, serve as a more realistic point to which control results can be compared, and better reflect the programs' objective of relieving tenant anxiety.

If cockroach populations exceed the AIL, control measures are then increased or initiated to supress population growth. Unlike IPM in crops, the injury is not permanent thus it is permissible for pest populations to exceed the AIL occasionally.

It is expected that a few of the residents will have very low tolerance to insects, and that some of them may require that the cockroach population be reduced to zero in their apartments. In most cases these people would represent a small minority for whom more

extensive use of pesticides would be in order. At Acadia, in suites where cockroach captures in disposable sticky traps were below three cockroaches per trap per week[1], the occupants would only occasionally see an insect and it was observed that most residents would find this situation tolerable.

The number of insects sighted by the tenants was affected by several variables. The number seen was sometimes less than the number caught in the trap, but was more often greater. Residents who were awake late at night, the time of greatest cockroach activity, saw far more insects than other residents. The young student-family makeup of the Acadia community meant that people were often up late either to feed an infant, for parties or to study.

Resident's tolerance to cockroaches was also subject to change. During periods of intensified stress from school, family and finances, people's AIL usually dropped considerably. The end of the spring school term was often a time of realized poverty, birth of children and writing exams. Where both spouses were students, marital relations would often be under considerable stress as well. Since these factors coincided with increased cockroach encounters during late night activity, the months of April, May and June were typified by increased hostility toward the cockroach problem, even though the insect population level was no different.

1. The method of trapping and evaluating cockroach populations is in Appendix 3 on page 118.

During an opinion survey conducted at Acadia in May 1982, residents were asked if having cockroaches would bother them if they saw one per year, per month, per week, per day or per hour. The results shown in table 2, indicate that 79% of the residents believed they could tolerate seeing one cockroach per week in their apartment. Reducing insect population densities to a level where residents see about one per week would be a realistic objective for many apartments, but this could not be easily achieved in a short period. Residents at Acadia were usually encouraged to tolerate seeing about five cockroaches per week, or about one per day, a level which 53% of those surveyed indicated would not bother them.

In a survey of 648 public housing residents in the eastern United States, Wood et al. (1981) found that 53% did not consider seeing two cockroaches per day to be a problem. As the authors point out, this type of information is at least an indication that many residents might be willing to accept less than complete control.

Piper and Frankie (1978a) state that tolerance levels to cockroaches are usually in the range of 0 to 5 insects observed per week, which is consistant with the findings at Acadia.

Contrary to the belief of many professionals in pest control, the manipulation of people's AIL is not impossible. There are many things that can be done to encourage intolerant individuals to accept encounters with cockroaches, most of which could easily be incorporated into a public education program. Approaches that would be suitable for residents such as those at Acadia would include the following:

Table 2: THRESHOLD TOLERANCES OF RESIDENTS TO COCKROACH ENCOUNTERS.

(PERCENT OF 147 RESPONDENTS FROM 83 SUITES)

MAXIMUM TOLERANCE	PERCENT	
One per year (or fewer)	3	21
One per month	18	
One per week	26	79
One per day	29	
One per hour (or more)	24	

Familiarization With Cockroach Biology

Familiarizing people with the biology and ecology of the insect will often remove unfounded fears and will give them an appreciation of the place of cockroaches in nature. It was observed that even highly entomophobic persons would sometimes become fascinated by cockroaches.

Developing Perspectives in Pest Control

Sometimes low tolerance was associated with an individual's belief that effective control was readily available and foolproof. Providing information that allowed residents to make a more informed judgement often resulted in increased tolerance to cockroach infestations.

Contact With The Residents

Some low tolerance originated from the residents' belief that their problem was being ignored. Regular contact with residents is therefore important to assure them otherwise. Often these people were satisfied if they saw that someone was working on the problem and did not necessarily demand that the measures be completely effective. A single cockroach trap in an apartment often made residents feel more at ease even though they knew it was not reducing the overall cockroach population in their dwelling.

Relief of Social Concerns

Some residents expressed concern that other people would think that they were unhygenic and poor housekeepers because their apartments were infested with cockroaches. For this reason it seemed of value to emphasize to all residents that it was normal for even the cleanest apartments to have a few cockroaches.

WORKING WITH RESIDENTS

Developing a program to optimize communication and to deal with the concerns and problems of residents is one of the most important parts of integrated management. It not only allows for rapid identification of the problems in that particular building, but also serves to increase the tolerance of the residents to cockroaches.

Obtaining cooperation from residents is an essential aspect of urban IPM, but it is seldom achieved without considerable effort. Although residents have a legal obligation to cooperate with the control efforts (Anonymous 1979b), threats of eviction or legal action usually make matters worse. The type of cooperation needed cannot be obtained by force.

On the few occasions where an individual felt threatened or annoyed by the cockroach control program he or she sometimes witheld information

on the distribution and extent of the problem in the suite and disrupted trapping efforts. Their attitudes sometimes rubbed off on their friends and neighbours in the building which undermined the general high level of respect that residents had for people working on the cockroach problem.

Although no legal actions were attempted during the study period, it is probable that very little could have been achieved by this means. The Residential Tenancy Act (Anonymous 1979b) grants agents of the landlord the right to enter dwellings for the purpose of maintenance (inlcuding pest control), but does not specify what the agent can do within the suite[1]. A tenant could not under normal circumstances have prevented a pest control operator from entering their suite, but could probably have found a lawful way to harass him on the premises. Even if grounds could be found to evict uncooperative residents, it might take up to six months to expel them and would seriously reduce the goodwill of other residents towards the pest control program.

In setting up an IPM program, regular contact with the residents is necessary to assure them that someone is working on the problem and to encourage them to keep working on the control of cockroaches in their own apartment.

Although very time consuming, door-to-door calls are the most effective means of contacting the tenant population. Waiting for people to complain was found to be much less productive. During the two year study at Acadia, four opinion surveys were taken to give the tenant-run cockroach committee an opportunity to contact all residents

1. Although tenants in Acadia were also obliged to obey the conditions of a lease, the working of this document with respect to pest control was too vague to be legally binding.

and to solicit opinions on cockroach control.

Information handouts were also found to be a useful tool and were a good means of disseminating large amounts of information with a minimum amount of work. Whether or not the handouts were read depended on how well they were presented and on the level of interest of the resident in the problem. The use of handouts was particularly well suited to situations such as Acadia where most residents had a university education and were accustomed to written communication.

Posters were also found to be a useful way to contact residents and were used extensively. In the May 1982 survey of residents, 125 of 154 respondents indicated that they had read the most recent handout and 73 percent of those who had read it said they thought that the pamphlet was useful.

Community meetings were a more personal way to contact tenants than handouts, but they require extensive planning and coordination to be effective. Only about 20 percent of the residents attended meetings but those present generally represented the most concerned individuals in the building. Meetings also had the advantage of providing an opportunity for the residents to find out how their neighbours felt about the cockroach problem.

Volunteer committees of building residents can be a useful component in an IPM program. Their assistance can significantly reduce the amount of labour required for information dispersal and for surveys. Since residents in the committee generally have a good understanding of the needs of the community they can be particularly helpful in tailoring the IPM program to that particular situation.

Appendix 2 contains some of the written comments submitted by the residents of Acadia regarding the tenant committee who assisted in cockroach management in the building. It is interesting to note that most of the statements were positive indicating that the tenants were pleased with the performance of the committee.

WORKING WITH THE MANAGEMENT

Management personnel are usually the ones who will choose what form of control will be employed and are therefore the people who must first be convinced that IPM is a desirable alternative. They are also the ones who must supply keys and maintenance for the building, and thus their cooperation is vital.

In British Columbia, landlords are required by law to see that pest control is provided to their rental units (Anonymous 1979a). Mention is often made by management of their liability in this respect. Although in the wording of the legislation the landlord is required to keep the establishment free of all pests, considerable discretion is used by most government authorities in interpreting this mandate, thus building owners are generally required only to take measures to minimize whatever infestations occur.

Cockroach phobias, embarrassment and poor understanding of biology and control tactics often occur in management as well as in tenants. Although the number of management people dealt with is small, there are more extensive barriers to communication and relatively few means to

encourage cooperation and consequently the problem is made more difficult to deal with.

When first exposed to the problem of cockroach control most managers make the incorrect assumption that there is a simple solution to the problem. Usually they begin to understand the complexities involved only after years of failure.

The management is usually in the position of having to deal with a problem that they do not have to live with. Although some will say that they are dealing with it for the good of the tenants, it seems more likely that they are doing it to reduce the number of complaints that they receive. One objective of an IPM program must therefore be to reduce resident complaints to the management.

One way to accomplish this would be to redirect complaints so that they go to the pest manager rather than to the building management staff. Pressure is then taken off the landlord who would normally need to react to each inquiry. Unfortunately this approach would often not be favoured by the management since they usually feel a responsibility to be aware of tenant complaints. In some cases, however, the management might be convinced, particularly if it were provided with a synopsis of the complaints received.

Regular contact with the management is also important. This would be done most appropriately through regular submission of letters, reporting the state of the pests in the building, and by periodic telephone conversations and meetings.

COCKROACH SURVEYS

If regular assessments of cockroach distribution and numbers are not made, then the effectiveness of the control measures taken cannot be adequately assessed and the need for additional or improved techniques will not be realized. Surveying is a critical part of any control program thus it is surprising that most pest control operaters spend so little effort on it, particularly since it could potentially reduce the time and labor spent on callbacks (Kardatzke et al. 1981).

There are five different survey procedures that have been commonly employed for assessment of cockroach infestations. In order of increasing effectiveness these are: counts of complaints received from residents, survey of residents' cockroach sightings, counts of visible insects using a flashlight, counts of insects flushed out after application of pyrethrins and counts of insects captured in traps.

Presently, most pest control operators in southwestern British Columbia depend mostly on telephone complaints received from tenants to plan "call back" treatments. This method typically identifies only suites where the residents have a low tolerance to insects but are not necessarily the most infested in the building. Some people will not complain even if their infestation is bad and consequently many problem areas go unnoticed.

Cockroach populations can also be assessed by asking residents either how bad their problem is or how many insects they have seen during the previous week. The problem of variable rates of interception

of cockroaches by tenants has already been discussed. Residents seldom have a good understanding of the current state of the cockroach infestation and consequently this type of survey usually does not yield accurate information on population changes.

Some pest control companies will also carry out "flashlight counts" of the dwellings in the building to supplement the information received from complaints. A pest control operator will enter each apartment and search the kitchen and bathroom areas for cockroaches using a flashlight to inspect dark cupboards and crevices. The presence of living insects or their remains are noted and the residents may be asked if they have seen any cockroaches. Unfortunately this type of survey is limited to daytime hours, when cockroach activity is minimal. Although most high density infestations are located using this technique, moderate and low density populations may not be detected.

Suite-by-suite surveys can be vastly improved by the use of a chemical "flushing" agent to chase cockroaches out of their harborages where they can be counted. Synergized pyrethins are the most commonly employed flushing compound, although Drione® and dichlorvos are also effective for this purpose. During the study at Acadia I used carbon dioxide from a portable cylinder for flushing and obtained good results. It had the advantage of being readily accepted by residents who were worried about the use of pesticides. Carbon dioxide is also odourless and is consequently less irritating to the occupants. Since it was necessary to use a large volume of gas to flush one apartment, the cost of using this product was much higher than it was for other agents.

Insects chased by the flushing agent should ideally be collected so that they do not annoy the resident. Portable vacuum cleaners can be modified with in line traps to simplify the job (Keil 1981). This also allows large catches to be counted at a later time, probably with greater accuracy than could be achieved in the field.

Most formulations of pyrethrins are effective as flushing agents. Although Reirson and Rust (1977a) found a 3.34% formulation to give better results than a 0.25% formulation, but this difference can be overcome by using more of the lower concentration. Thoroughness of application seems to be more important than formulation.

Use of Traps

In most circumstances, traps are the best means available to determine the extent of a cockroach problem. They consistently yield more insects than visual counting techniques (Reirson and Rust 1977a) and are easier to employ than flushing counts. They have the disadvantages of taking longer, and of being more expensive than other survey methods. They are also sometimes tampered with by the tenants.

Trap capture rates are affected by many factors and the results may vary even when the trap is exposed to a fixed number of cockroaches for a fixed time. A trial was conducted early in the study to determine

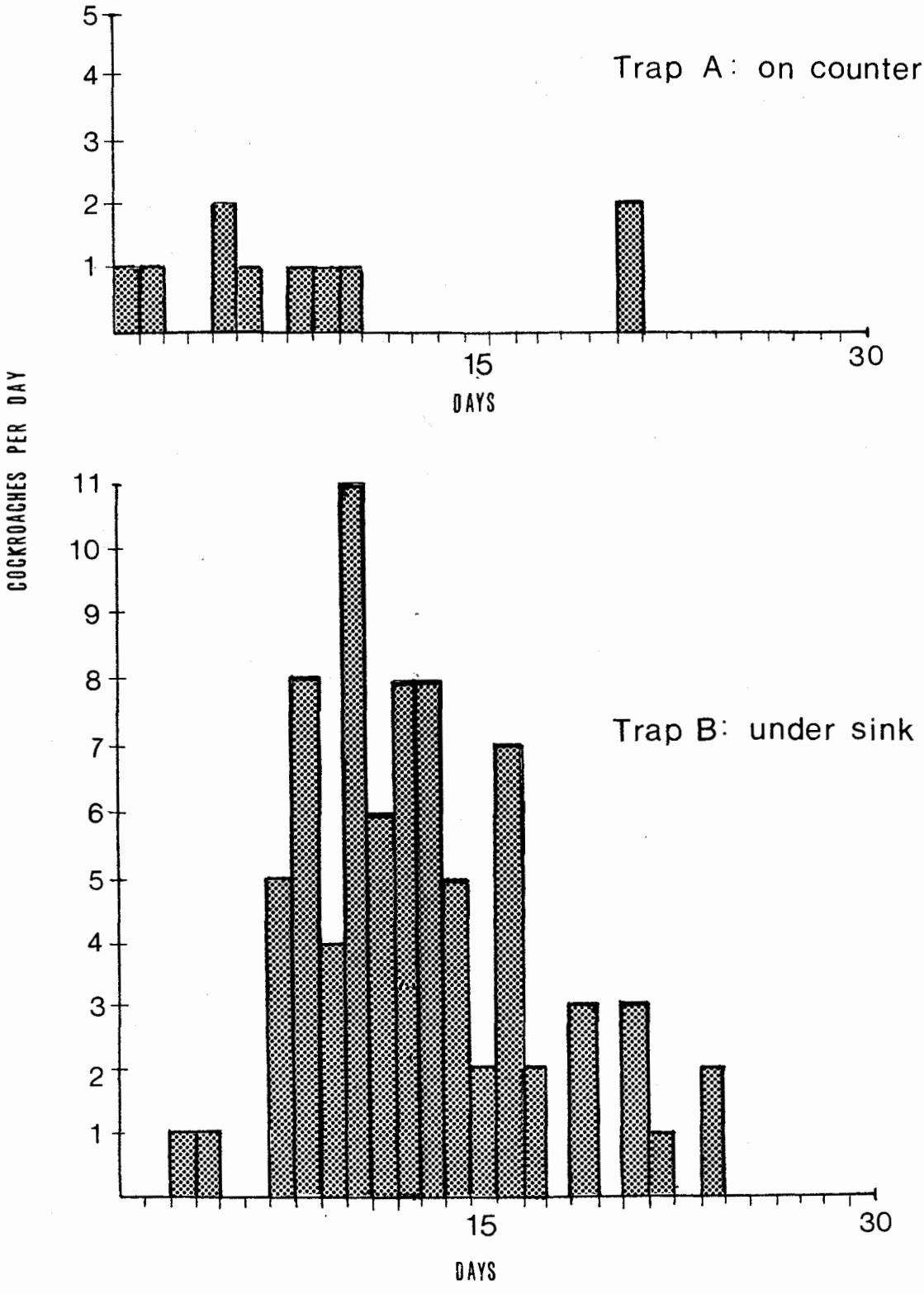
the variation in captures that would occur during a thirty day survey. Two disposable sticky traps were placed in the kitchen, one under the sink and one on the counter. The cockroaches in the traps were counted daily and were not removed. The results of this experiment, shown in figure 1, demonstrate the large fluctuations in the daily catch.

These results also show that traps placed in different locations capture different numbers of insects. This was also seen during the mass trapping trial, which will be discussed later. The strong influence of location on trap captures has also been demonstrated by Bennett 1978. In general traps placed in areas frequented by cockroaches capture the most insects. For example, traps placed in the middle of the kitchen floor consistently capture fewer cockroaches than those placed at the wall-floor intersections (Ebeling et al. 1966).

All of the previously described factors that influence cockroach movement will probably also affect catches. Rust and Reirson (1981) suggest that population density, availability of food and the acclimatization of the insects to the bait are important factors. In addition to these, the type of bait in relation to the type of environment will also influence trap efficiency (Ross 1981). Cardboard sticky traps generally lose efficacy over time as the glue dries up and consequently the age of the trap can also be a significant factor when comparing rates of capture.

Although it is assumed by most people that higher population densities result in larger numbers of cockroaches being caught in the traps this has never been substantiated by correlating capture rates with

Figure 1: BAR GRAPHS SHOWING DAILY CAPTURES OF COCKROACHES IN STICKY TRAPS IN SAME KITCHEN.



the size of field populations. No doubt capture rates are at least to some degree independent of population size, thus comparisons between apartments must be made cautiously until further studies clarify this point. Traps were used extensively at Acadia to survey the cockroach problem. The results of this monitoring are summarized in appendix 3.

Assessment of Survey Traps

Many brands of cockroach traps are available. During the study six traps, five commercial and one home-made, were examined for their value as survey devices. A report of the evaluation of two additional traps is given later in the section on mass trapping.

For the purpose of cockroach surveys, the features of a trap that are most important are: ability to capture cockroaches, length of time the glue remains sticky, and cost. The trap should also be appealing to residents and easily opened to count the insects inside.

Some of the features of the five disposable cockroach traps that were examined are summarized in table 3. All of them except the Magic Trap seemed to have sufficient stickiness to adequately capture cockroaches. The Raid and Roach Motel traps had visible attractants whereas the others either had none or had incorporated the attractant into the glue. Because the Roach Motel and Raid trap were difficult to open, and the Mr. Sticky and Magic traps were quite flimsy, the Roach Tent was considered the best overall survey device, although it did

Table 3: COMPARISON OF DISPOSABLE SURVEY TRAPS

Brand	Distributor	Unit Cost $	Sticky Surface cm^2	Opening Ease	Sturdy-ness	Appear-ance
Roach Tent	Cherry Blossom Co.	1.00	127	G	G	P
Roach Motel	Boyle-Midway Inc.	1.50	102	P	G	G
Raid	S.C. Johnson & Sons Ltd.	1.50	201	P	G	G
Mr. Sticky	DGR Stationery Ltd.	1.00	153	G	P	M
Magic Trap	Sanex Chemicals Ltd.	0.47	138	G	P	P

Key: G = Good M = Moderate P = Poor

have the disadvantage of being conspicuously decorated with drawings of cockroaches which lowered its appeal to residents.

Re-useable jar traps are an alternative to purchasing disposable sticky traps. Jar traps are easy and economical to make and have been widely used to capture cockroaches (Dold 1964). A thin 3 cm band of petroleum jelly is smeared below the inner rim of a one quart jar to prevent the escape of any cockroaches that enter the jar in search of harborage, food or water. The jars are baited with a slice of apple or other suitable attractant and placed upright in an infested area. The exterior of the jar is sometimes wrapped in paper to assist the insects in climbing up the side. Crumpled paper placed inside the trap provides shelter for the captured insects thus reducing the number that escape. These last two features make the jar darker inside which may encourage the insects to enter the trap. Although more trouble to maintain and deploy, the jar can be obtained at a lower cost than any of the dispsoable sticky traps (about 30 ¢) and is renewable.

Jar traps were used throughout the study at Acadia, primarily for the purpose of obtaining live insects for study. They have the disadvantage of requiring maintenance at least once a week to replace the bait and remove the cockroaches. They also usually capture fewer insects than the adhesive traps (Piper and Frankie 1978a), probably because the cockroaches have difficulty in finding the entrance.

Since the cockroaches inside the trap remain alive, a carbon dioxide cylinder, a pair of forceps and an empty ice cream container must be carried to handle the insects during trap counts.

It was noted at Acadia that residents found the sight of the cockroaches scurrying around inside the jar upsetting and worried about the possibility of the insects escaping. Indeed, the jars do occasionally get knocked over allowing the insects to get away. The occurance of cannibalism and the hatching of oothecae also add to the unreliability of jar trap counts.

Cockroach Attractants

Although German cockroaches can be attracted to many different substances, there is still no product available that is highly attractive in the field. Intense attraction to chemical stimuli is a reaction that is known to occur among the winged holometabolus insects such as Lepidoptera, Coleoptra and Diptera, but is not usually seen among the more primitive and less mobile groups such as the cockroaches (Ebeling and Rierson 1974).

In experiments on cockroach attractants there is often a variable response from insects within the same population and problems with individuals acting inconsistently over a period of time. Consequently, attractants that seem promising in the laboratory are often ineffective in the field. It is important to note that all of the previously discussed factors influencing cockroach movement will also alter their response to an attractive compound.

The two most significant problems in attracting German cockroaches are that search behaviour cannot be initiated in inactive individuals that make up most of the population, and that even when the searching has begun, the insects are inefficient in locating the source of the attractive odor. If the bait is not found within a short time, cockroaches will typically stop searching. For this reason, most baits are effective over short distances only.

Most known cockroach attractants are food based and are intended to lure hungry individuals in a population. However, several alternative food sources are usually available in an apartment and relatively little feeding is needed to sustain a cockroach for a long time (Willis and Lewis 1957). These factors result in even the best lures attracting only a small part of the population.

Table 4 lists some food products that have been used as baits for the German cockroach. Of these, fresh apple and fresh bread were found to be most useful during the study. Moist or liquid baits are generally more attractive, but they deteriorate quicker than dry components (Miesch 1964, Miesch and Howell 1967). Even plain water is fairly attractive in situations where alternate sources are unavailable (Ross 1981).

Some attempts at using pheromones for attracting cockroaches have been made, but none has been particularly successful. Although two sex pheromones have been identified for the German cockroach, both are non-volatile substances that are confined to the cuticular wax of the female. These are picked up by the male through physical contact and

Table 4: FOOD ATTRACTANTS

Product	References
Fresh bread	Reierson and Rust 1977a, Ebeling et al. 1966
Boiled raisins	Rust and Reierson 1981 Akers and Robinson 1981
Fresh banana	Reierson and Rust 1977a,
Fresh apple	Piper and Frankie 1978a
Potato and sugar paste	Miesch 1964
Beer	Mallis 1969

function only in recognition and initiation of courtship (Nishida et al. 1975, 1976a, 1976b, 1979, 1980, Bell et al. 1978, Burgstahler et al. 1975, 1977). Although better results have been obtained from using sex pheromones on the American cockroach (Bell et al. 1977), the level of attraction is still not very high. Even if an effective sex attractant were to be discovered, it would lure only the adult males which represent a small part of the total population.

A pheromone causing aggregation of all stages of the German cockroach is also known to exist (Bell et al. 1972, Ishii 1970, Roth and Cohen 1973), although its chemical makeup has not yet been identified. Its action is most striking among the first and second instar nymphs. The pheromone is thought to be produced by the rectal pad cells and is known to be present in the cockroach faeces and on certain body parts (Ishii and Kuwahara 1967, 1968).

Aggregation of cockroaches in specific locations is often seen in apartment and laboratory populations. Cockroaches have been shown to benefit by aggregation in that stimuli received during this behaviour accelerates the rate of development (Petit 1940, Willis et al. 1958) and probably assists in the location of mates. Nevertheless, the aggregation pheromone has not been shown to lure cockroaches over great distances. This compound may act by inhibiting the movement of cockroaches that come in contact with it rather than by initiating a search behaviour (Burk and Bell 1973, Glaser 1980). Extracts of the pheromone have been shown to increase trap captures only slightly (Reierson and Rust 1977a).

The faeces have also been shown to contain a substance which modifies the directional orientation of individuals who contact trails that have been contaminated by cockroach activity (Kitamura et al. 1974, Bell et al. 1973). It is suggested that German cockroachces return to previously occupied resting sites through directional clues derived from the reception of chemical stimuli on previously occupied pathways. No applications have yet been developed to use this behaviour to improve trap captures.

Several organic esters have also been shown to be attractive to cockroaches (Sugawara et al. 1975) but in comparison to other lures they do not seem very promising (Reierson and Rust 1977a).

Population Estimation and Modelling

Mathematical models, especially those with the capability to predict population trends and damage levels, can be valuable tools in IPM programs, unfortunately few attempts have been made to model urban pests, and none are yet available for application to German cockroach problems in residential environments.

The deterministic model described by Grothaus et al. (1981) was developed to predict population trends of the German cockroach in laboratory colonies, but is not sufficiently realistic to be applied to field populations. It is based on the exponential growth of populations unlimited by food, water, or harborage and which are reared at a constant temperature. They did, however, show that pesticide applications would need to be made very regularly if they are to successfully control the population.

Keil (1981) attempted to estimate the population of a German cockroach infestation on a naval vessel by flushing out the insects with synergized pyrethrins and propoxur. After several subsequent applications and collections, he estimated the residual population and established the relative tendency of various subclasses of the population to be captured. A later study, however, showed that Keil's removal technique underestimated the population size (Ross et al. 1981).

PESTICIDES

In the last fifty years a great deal of research has gone into the development of insecticides to control cockroach infestations. Consequently much more is known about chemical control than about other tactics, and the level of technology involved in their use is more sophisticated and refined. Insecticides are therefore a very powerful tool in cockroach control and cannot be lightly disregarded.

However, pest management programs in residential settings need to be people oriented, thus public concern about the safety of using insecticides indoors cannot be ignored. As most professionals are aware, many of the objections put forward by residents are not founded on facts and are often emotional rather than rational. This, however, does not mean that valid reasons for limiting the use of pesticides do not exist. Seemingly the most sensible solution to the pesticide dilemma lies somewhere between the choices of complete elimination and complete reliance on insecticides, although where to draw the line is not generally clear.

In IPM, the philosophy is to use chemicals as a last resort and to limit use wherever possible. They are applied on a basis of need which is determined by population surveys (such as that described by Kardatzke et al. 1981) and are never employed as a preventative measure. Where a choice of appropriate products is available, preference is given to the least toxic substance or that which could be used in the safest manner.

Widespread use of pesticides for the control of cockroaches has led to a problem with the insects developing resistance to many of the commonly used chemicals (Batth 1977, Collins 1973, Johnston et al. 1964, Mulrennan and Burden 1974). However, since IPM programs do not rely on insecticides alone, resistance should not be a serious concern. Nevertheless, checks of the susceptibility of the cockroaches to insecticides should be made periodically as described by Barson and McCheyne (1979), Burden (1974), Dold (1964) or Chadwick (1972).

Table 5 lists the major chemicals that have been developed for use against cockroaches. Some of these are not widely used in Canada, however, a familiarity with all these products can be an asset to the pest manager, particularly for reviewing other research work and fielding questions from the public. Also, some insecticides are not used because their action is too slow or because they are not sufficiently effective for regular control programs. Since IPM deals in long term control and does not seek eradication, some of them could be useful.

Table 5: SOME INSECTICIDES THAT HAVE BEEN TESTED AGAINST COCKROACHES

Common Name	Generic Name	Usual Formulation	References
Acephate	Orthene	1.0% spray	Reierson 1975
Bendiocarb	Ficam	1.0% spray	Rust and Reierson 1978
Borax	Borax	99% powder	Ebeling et al. 1966
Boric acid	Boraton	99% powder	Ebeling 1975
Carbaryl	Sevin	2.0% spray	Rust and Reierson 1978
Carbon dioxide	CO_2	Gas	Tompkins and Cantwell 1973 Cantwell et al. 1973
Chlorpyriphos	Dursban	1.0% spray 0.5% bait	Gupta et al. 1973 Wright and Hillman 1973
DDVP	Vapona	2.0% ULV spray	McNeal and Bennett 1976
Diatomaceous Earth and pyrethrins	Diacide	powder	Tarshis 1961 Ebeling 1971
Diazinon	Basudin	1.0% spray 2.0% powder	Flynn and Shoof 1971 Gupta et al. 1973
Encapsulated diazinon	Knox Out	1.0% spray	Rust and Reierson 1979
Encapsulated pyrethrins	Sectrol	0.2% spray	Bennett and Lund 1977 Bennett 1978
Fenchlorphos	Ronnel	2% spray	Cornwell 1976
Fenthion	Baytex	0.5% spray	Anonymous 1981
Lindane & BHC	Lindane	0.5 to 1.0% spray	Mallis 1969
Malathion	Carbophos	spray	Flynn and Shoof 1971
Propoxur	Baygon	1.0% spray 1.0% bait	Flynn and Shoof 1971
Pyrethrins	Pyrethrin	3.0% ULV spray 1.5% aerosol	McNeal and Bennett 1976
Rotenone	Rotenone	1.0% powder	Anonymous 1981
Silica aerogel and pyrethrins	Drione	powder	Ebeling and Wagner 1964

A thorough discussion of all insecticides used against cockroaches would be beyond the scope of this paper. Several reviews are available elsewhere (Cornwell 1976, Mallis 1969, Bajomi and Elek 1979). The comments below are restricted to a few products, propoxur, boric acid and pyrethrum, which are of particular interest to cockroach IPM in southwestern British Columbia. Some brief comments on baits, insecticide tapes and growth regulators will be made as well.

PROPOXUR

Propoxur (Baygon®) is by far the most popular insecticide used by homeowners and pest control operators for cockroach control in southwestern British Columbia. It is described here because the problems with its use are typical of a residual insecticide used in "crack-and-crevice" treatment.

Propoxur is considered by the government regulatory agencies to be safe for household use and has been widely marketed throughout the world without serious problems. However, like other carbamate insecticides, propoxur has been suggested as precursor to n-nitroso carbamate compounds (Eisenbrand et al. 1975) most of which are known to be highly carcinogenic (Jaszczuk et al. 1979, Lijinsky 1980). It has been argued by some that the pesticide may react with nitrites in the human body to form carcinogens and that even with the small doses received by residents, a health hazard may exist. Feeding studies with laboratory animals, however, have not substantiated this claim (Kuhr and Dorough 1975, Jurek 1978) nor has the carcinogen been shown to occur in

living organisms. An additional concern is that chronic exposure to propoxur may cause learning disabilities (Rosenstein and Chernoff 1978, Rosenstein and Elfring 1976, Kuhr and Dorough 1975) however, the significance of this claim has never been fully evaluated. Although the evidence with propoxur as a health hazard is not very strong, particularly in view of the low exposure that residents would receive, it is sufficient to frighten many people and makes justifying its use to residents very difficult.

Propoxur is most effective when injected as a 1.0% solution into crevices throughout the kitchen and bathroom areas. Relatively few insects are killed during application and thus the number of insects killed is mostly dependent on the residual action of the insecticide.

In practice great reductions in the cockroach population are not achieved unless the application is extremely thorough. Cockroaches tend to be repelled by propoxur residues (Ebeling et al. 1966, 1968, Bennett and Wright 1971, Burden 1975) and consequently will avoid treated areas resulting in higher survival than expected. The more harborages that are treated, the less chance there is of large numbers of insects escaping death.

It was noted at Acadia that residents often cleaned the treated areas soon after the application resulting in removal of most of the insecticide. Propoxur is highly unstable in alkaline environments and is easily inactivated by cleaning agents.

Two to six weeks following the treatment, the number of cockroaches killed by the residue declines, leading many people to believe that most of the chemical deposits have disappeared. However, undisturbed crystals of the spray are visible in the apartment for up to 12 months. I treated some glass and arborite plaques with a 1.0% premixed aerosol solution of propoxur (Green Cross®) and found that it would kill cockroaches confined to the surfaces even after six months. Slow breakdown of propoxur has also been noted by others (Gupta and Rawlins 1966, Grayson 1974, 1975) indicating that the observed decrease in effectiveness of insecticide residues is not because of elimination of all the active chemical. Two explanations for this reduction in mortality are that the repellency of the insecticide residue increases over time or that the surviving cockroaches learn to avoid the treated areas.

DRIONE®

Drione® dust is not as widely used as other urban insecticides, even though it is readily available. It is composed of an oil laden silica aerogel powder to which synergized pyrethrins are added. A small amount of ammonium fluorosilicate is present to act as a flowing agent. Although the silica aerogel will kill cockroaches by increasing the water lost across the cuticle (Ebeling et al. 1976), mortality is caused by the pyrethrins which are aided by the toxic effects of the fluorosilicate. In practice, Drione® is so repellent that few insects

will come in contact with it after it is applied (Ebeling and Wagner 1964) and consequently it is not effective as a residual insecticide.

The main value of silica aerogels is as a treatment for structural void areas. The dust is light and will coat surfaces evenly, particularly if applied with a high-power dust-blaster. The dust is sometimes also applied as a crack and crevice treatment although it is much less suited for this purpose. Exposed insects are killed immediately and the harborage is rendered unsuitable for continued colonization. If the cockroaches are unable to find other suitable habitat, the effects of reduced harborage will cause a decline in the population size. The Drione® will remain active for 6 to 12 months.

Difficulties in obtaining toxicological information on Drione® prevented a thorough review of its safety for urban use. It is widely believed to be non-toxic to humans and is categorized as a schedule five pesticide (unregulated) under the B. C. Pesticide Control Act (Anonymous 1978).

BORIC ACID

Boric acid has been shown to be effective for the control of cockroaches (Gupta et al. 1975, Moore 1972, Ebeling et al. 1966, 1968, 1976, Slater et al. 1979, Wright and Hillman 1973). In some cases it has been used by itself, and on others it has been deployed effectively with other insecticides and control tactics. Although boric acid has been used effectively in the past, it is not popular today

because of its slow action and because it is poorly marketed. It is also not easily obtainable in a registered pesticide formulation which also discourages its use.

Boric acid is often recommended because of its its low mammalian toxicity (Ebeling 1975, Piper and Frankie 1978a, Slater et al. 1979) from which the reader is sometimes led to believe that it is safer to use in residential dwellings than other insecticides. This opinion is frequently based on simple comparisons of acute toxicity and ignores the concentrations and quantities used. Although the acute oral toxicity of of boric acid (LD_{50} = 3,000 mg/Kg) is much higher than pure propoxur (LD_{50} = 100 mg/Kg) (Martin and Worthing 1974), only about 100 to 500 g of 1.0% propoxur solution is used whereas 400 to 800 g of 99% boric acid would be used in a similar situation. Therefore, choosing to use boric acid in an apartment means that twice the amount of a pesticide mixture that has an acute toxicity three times greater than propoxur will be deployed.

A number of residents at Acadia used boric acid to control cockroaches in their apartments. Usually they obtained the powder from the local pharmacy who dispensed 60 g containers for use as an antiseptic and eye wash. Typically the resident would sprinkle part or all of the package into crevices throughout the kitchen, often leaving small piles of it in cupboards or on the counter. Most of these people seemed to believe that since boric acid was a common household product it would be completely safe to use. Curiously, most people still preferred boric acid over propoxur even after the toxicology of the two products had been explained to them.

In view of the large number of serious boric acid poisonings that have been reported (Anonymous 1966, 1969, Ducey and Williams 1953, Pfeiffer 1951, Goldbloom and Goldbloom 1953) it would not be truthful to imply to residents that this pesticide is harmless or less harmful than other insecticides. Any registered insecticide can be used safely, even though it will have some potential for causing harm under certain circumstances. There is no evidence to suggest that boric acid is any safer than other insecticides in this respect.

A study of chronic toxicity by Weir and Fisher (1972) indicated that long term exposure to low levels of boric acid would not be harmful. It is not absorbed through unbroken skin and small amounts taken orally are rapidly excreted (Pfeiffer 1951).

Like other dust insecticides, boric acid powder is most suited for application to void areas surrounding cabinetry and in the walls using a pressurized dust blaster (Ebeling 1975). It can also be applied as a crack and crevice treatment using bulb or bellows dusters, however, these methods tend to be very messy and often leave a great deal of pesticide residue in exposed areas.

The advantage of boric acid is that, unlike other insecticides, it is not repellent to cockroaches and so more insects are likely to come in contact with the lethal residue (Ebeling et al. 1966, 1968). It also has a very long residual life which would reduce the need for retreatment.

PYRETHRINS

The group of insecticides known as pyrethrins are also of particular interest for IPM programs in that they are widely marketed and have the reputation of being safe to use. The natural pyrethrins are extracts of the flower heads of certain plants in the Chrysanthemum genus, a fact that is often mentioned in order to give the insecticide an "organic" image. All of the available formulations are synergized by piperonyl butoxide.

Several synthetic pyrethroids are also available, some of which cause higher mortality, have less odor, are more stable, are less toxic and are less expensive than the natural products (Chadwick 1979, Cornwell 1976).

Typically pyrethrins are applied as a 1.0% solution either from an aerosol can or with ULV misting equipment. They are generally used as a combination space spray and crevice flushing agent. Since the residual action is minimal, only those insects that are doused with insecticide will succumb. A common problem is that some of the population is exposed to sublethal amounts of the pyrethins and recovers quickly. This may be one of the reasons why pyrethrins give quite variable results. Reierson (1973) obtained very poor control using 1 to 3% pyrethrins applied as a ULV spray, however, Moore (1977), Bennett and McNeil (1974) and McNeil and Bennett (1976) reported a very good result from using pyrethrins in ULV equipment and total release aerosols. It appears that thorough application is a key factor for their successful use.

Most companies in the pest control industry use pyrethrins in combination with a residual insecticide to achieve the high levels of mortality required for their objective of extermination. In an IPM program, however, they could be used alone since the requirements for cockroach mortality are not as strict. Pyrethrins would be particularly useful for quickly decreasing large populations to manageable levels after environmental modifications have been made in a dwelling.

Pyrethrins have a very long history of safe use (Mallis 1969, Cornwell 1976) and it would be difficult to conceive of a situation where they might pose a hazard. They are of low mammalian toxicity and are rapidly metabolized. Many studies have been made, all of which support the claims that pyrethrum is a safe product (Malone and Brown 1968, Barthel 1973, Ashwood-Smith et al. 1972, Griffin 1972, Bond et al. 1972, Williams 1973). The toxicology of the synergist piperonyl butoxide has also been well studied and has not been shown to be an acute or chronic hazard (Brown 1971, Conney et al. 1971). Although it is widely known that some people are allergic to certain pyrethrin mixtures (Ebeling 1975, Martin and Worthing 1974) the problem is not widespread and allegedly the allergenic agent is not present in the recently refined pyrethrins (Mallis 1969).

OTHER PRODUCTS

A number of toxic cockroach baits have been developed for use in control programs (Miesch and Howell 1967, Cornwell 1976, Bare 1945,

Gupta et al. 1973) however, none is particularly effective. If cockroaches could be easily attracted to baits then they could be trapped without the use of pesticides, which would be preferable. Another pesticide formulation worth mentioning are the plastic tapes impregnated with insecticide that are available in the United States for the control of cockroaches (Bennett and Lund 1978, Reierson and Rust 1977b). They are convenient for use by householders and probably cause less exposure to the applicator than pressurized spray cans. They kill cockroaches well but are expensive and are not available in Canada.

Interest in the use of insect growth regulating compounds for the control of pests has expanded considerably in recent years. Initial results from using growth regulators on German cockroaches has looked very promising (Riddiford et al. 1975) however none are yet available for this purpose. It is difficult to see how these compounds would have any advantage over other insecticides, however the fact that they are widely claimed to be of very low toxicity suggests that at least they are more likely to be accepted by residents than other insecticides.

ENVIRONMENTAL MODIFICATIONS

Population reductions achieved by pesticides, have only a short term effect unless the environmental factors influencing cockroach growth, survival and fecundity, are in some way reduced. In most cockroach control programs the need for environmental change is ignored, usually because of the high cost and extensive labor required.

In integrated management programs, however, environmental modifications are an important part of the ecology based strategy and serve as the major technique for reducing cockroach populations. Reduction of four environmental requirements will be explored here; food, water, harborage and warmth.

Reduction of Food Sources

Cockroaches, like most insects, have specific habits and preferences associated with feeding. Their dietary range is often overestimated, leading to the erroneous belief that they will eat "practically anything". Such exaggerations probably have their origin in the unusual feeding behaviour of the American cockroach which is reported to gnaw on hair, fingernails, wood (Mallis 1969) and greenhouse plants (Ebeling 1975). The foods of the German cockroach are more restricted.

The foods eaten by German cockroaches are mainly composed of carbohydrates. In general, the more favored foods are starchy substances. Fats, oils and proteins appear to be less often consumed (Cornwall 1968).

To eliminate all food sources in an attempt to exterminate the cockroaches by starvation would not be a very realistic task, particularly since we know little about where and when they feed. A more reasonable objective would be to limit food which might reduce both the number of cockroaches the apartment could support and the fecundity of the population.

Mueller (1978) has shown that restricting food to laboratory colonies will delay maturity and reduce longevity of the German cockroach. Kunkel (1966) has shown similar deleterious effects on starved insects. As part of the public education program we always encouraged residents to wipe down their counters and cupboard shelves regularly with a damp cloth and to wash dirty dishes as soon as possible and not leave them on the counter overnight. We also recommended that food not be left exposed on the counter or in the cupboards and that all edible products be kept either in the refrigerator or else in insect proof containers.

The consequences of these actions are discussed later in the section on sanitation.

Reduction of Harborage

Abundance of harborages is an important factor in determining the size of cockroach infestations and is probably even more advantageous to the population than the availability of food and water (Keil 1981). The association of cockroaches with poor sanitation is probably a result of the increased habitat (Owens 1980) rather than the presence of edible filth.

Cockroaches show a strong preference for resting in locations where their bodies are in close contact with the surrounding structure. Within these harborages the insects are protected from air movement (Cornwell 1968) and are insulated from temperature changes. Perhaps tactile stimuli received from the harborage play a role in stimulating nymphal development. A large number of harborages also gives the cockroaches more protection from pesticides and consequently apartments with lots of clutter are difficult to treat (Gupta et al. 1973).

Choice of resting places is influenced by the physical environment, including light intensity, and by the presence of aggregation pheromones which are present in sites contaminated by other cockroaches (Busvine 1980). Adult cockroaches prefer crevices between 1.6 and 4.5 mm wide for harborage and nymphs may inhabit spaces as small as 0.5 mm wide (Cornwell 1968). From observations of resting behaviour in my own colonies, the cockroaches appear to be more often resting on vertical than horizontal surfaces. Berthold and Wilson (1967) found that a vertical space of 4.8 mm was more attractive than different orientations of spaces varying from 1.6 to 12.7 mm.

Favored refuges noted during the study included beneath loose arborite and the underlying wood substructure of the countertops, behind the moulding joining the wall with the floor, in stacks of newspaper, under or inside cardboard boxes and in the cracks where shelving meets the wall. Other harborages noted were: under dish racks and behind the bathroom mirror. Some cockroaches were also seen beneath the stove and aggregations were occasionally seen in the corners of cupboards.

In practice, cockroaches are reported from a great variety of locations in the apartment, more varied in badly infested apartments where insects penetrated dressers or living room sofas. In my experience, however, most cockroach harborages are within a radius of 3 m from the focus of the suite's infestation, ie: near the sink in the kitchen.

Other harborages not observed during the study but mentioned by other workers include: refrigerator motors, electrical appliances, door hinges and behind picture frames and wall ornaments (Ebeling 1975, Mallis 1969).

Other harborages, such as those under cabinets and in wall voids, were not sampled.

Harborage is reduced primarily by the removal of clutter. Storage space in most apartments is limited and consequently kitchen and bathroom cupboards and counters tend to be overcrowded. Many items, such as old newspapers, are of little value and residents can be convinced to throw them out. Other objects, such as canning jars, can be stored in other locations in the apartment, where it is too cold or dry for cockroaches

to survive. Residents at Acadia were also encouraged to not store excessive amounts of extra food.

Benefit would be likely to result from reduced harborage in the building structure. This could be done by sealing cracks and crevices with silicone glue or plaster and duct tape. Voids which cannot easily be sealed off could be filled with a repellent, such as Drione®, or with a residual insecticide such as Boric acid.

Sanitation

Sanitation usually refers to the removal of both clutter and filth that is present to varying degrees in all dwellings. Probably the two should be considered separately since the former is a determinant of habitat availability and the second a factor in food availability. Sanitation has been mentioned in numerous papers as being an important part of the cockroach problem (Wright 1979, Bennett 1978, Gupta et al. 1973 and Robinson et al. 1980). Evidence collected at Acadia on the value of increasing sanitation to reduce cockroach population growth was contradictory. There were many filthy apartments which maintained low or moderate cockroach populations and a few very clean apartments which developed high populations. In general, however, it did seem that the cleaner and less cluttered apartments had fewer cockroaches.

Certainly the removal of food and shelter from laboratory cockroach colonies causes the population to decline. Whether an apartment can be sufficiently sanitized to cause a significant population decline has not been conclusively demonstrated. Possibly sanitation has more effect on preventing establishment of infestations than in reducing existing populations. When the cleanlines is improved there it may not be a drastic effect on the existing cockroaches because they will continue to live for a considerable period of time. It may therefore be more appropriate to say that the role of sanitation is to limit rather than control infestations.

An obstacle in the utilization of sanitation is the difficulty in establishing acceptable sanitary standards. Residents cannot be asked to keep their premises "clean" since this word is interpreted differently by each person. Which areas to clean and how often must be clearly laid out. Bennett (1978) reported criteria for rating sanitation of residences, however the value of his categories are greatly diminished by their subjectivity.

The results of sanitation seen in Acadia (appendix 5)are similar to those of Owens (1980) who used commercial services to increase the sanitary level of apartments, but was unable to reduce the population levels significantly.

Since it is the resident who must maintain the sanitary level of the apartment, improved sanitation can only be accomplished through public education programs. Rigorous or forced cleanup programs would not yield sufficient results to justify the extensive effort necessary and would generate a great deal of bad feelings among the community.

Reduction of Water Sources

The availability of water is a limiting factor in all infestations and is probably the main reason for the insects being limited to the kitchen and bathroom areas. Even at a high humidity the cockroaches need to drink additional fluids to avoid lethal desiccation (Cornwell 1968).

The drying power of air varies according to both the temperature and to the amount of gaseous and particulate matter held in suspension in the air relative to the total amount that could be suspended at that temperature, and is described by the term "relative humidity" (RH). As the temperature of an isolated volume of air increases the RH will drop and the drying power of the air will increase along with its capacity to hold a greater mass of water vapour.

Although the cockroach does not obtain any fluids directly from the air, its need for drinking water varies with the RH of the habitat. In humid environments the insects are much less restricted by availability of water than in dryer sites where they desiccate more rapidly (Cornwell 1968). Furthermore, habitats with low humidity encourage the cockroach to remain in areas of lower temperatures where its development and fecundity will be reduced, but where desiccation will be slower (Gunn and Cosway 1938).

The RH of most apartment kitchens varies and is difficult to control. In many suites, water from the kitchen sink leaks into the

cupboards either from faulty plumbing or from water being splashed onto the counter while washing the dishes. In these cases sealing the countertop and repairing the faulty pipes reduced the availability of water. Leaky pipes in wall voids are difficult to detect and will probably always be a source of water for some populations. Water also condensed on cold water pipes in most suites which further added to the problem. Although it does not seem likely that all sources of water could be eliminated, efforts should at least be made to minimize its availability wherever possible.

Reduction of Temperature

Temperature management can be an effective means of reducing cockroach numbers in residential premises in temperate areas. Several observations made during the study indicated that temperature may be the most critical factor in the regulation of German cockroach populations in southwestern British Columbia. Most of the infestations observed in single-unit dwellings in Vancouver never grew very large. In one case the insects died out completely during the winter months without any apparent cause. The houses were noted to be drafty and were cooler at nights than the average apartment dwelling. It was also noted that none of the other ten apartment buildings near Acadia had ever had cockroach problems. One of these structures, also a student high rise residence, had a reputation of being "too cold". In contrast, the residents of the

infested building had complained for several years that the heat in their building was too high. Many areas of the building, particularly hallways, were notorious for being hot and stuffy. Comments on the temperature profile at Acadia are contained in appendix 6.

The reasons for temperature effects are not clear, but they seem to be caused by reduced fecundity, slower development, reduction in activity or migrations to warmer environments. For example Ogata (1976) showed that cockroach infestations in wooden houses in Japan had significantly slower development than infestations in concrete apartments and suggested that the major reason was the lower temperature in the wooden structure.

If given a choice of resting spots at various temperatures, a German cockroach will usually remain at temperatures between 21 and 33 C. A notable preference is shown for environments above 25 C even though the insect desiccates much more rapidly at these temperatures (Gunn 1935). Although higher temperatures will reduce the life span, this is compensated by an increase in developmental rate (Gould 1941). Individuals begin reproducing much earlier and consequently the higher temperatures result in more rapid growth of the population.

SEALING OF APARTMENTS

It is a widely held belief among residents that sealing cracks and crevices will alleviate cockroach problems. Unfortunately reports of using this technique are scant and no scientific evaluation its effectiveness has ever been published. Some observations on using sealing to control cockroach problems at Acadia are reported in Appendix 7.

It was concluded that although sealing would probably be of some benefit in an IPM program, further evaluation is necessary. Sealing compounds would certainly need to be applied thoroughly, which could probably only be done by a trained individual.

REPELLENTS

German cockroaches are known to be repelled by a wide variety of stimuli. Since the objective of an IPM program is to reduce people's contact with cockroaches, the repellents would be useful for excluding insects in areas where they are least desired, such as in utensil drawers and for reducing harborage in wall voids and under kitchen cabinetry.

Synthetic Chemicals

Several effective chemical repellents have been developed by Phillips Petroleum Company and have been used to reduce the infestation of shipped goods. One of these, MGK R-874 (2-hydroxyethyl n- octyl sulphide) has an oral LD_{50} (rat) of 8,330 mg/kg and thus is considered to pose no health risk, even when used near food (Cornwell 1976). Other effective repellent chemicals have also been described (McGovern et al. 1975). Many insecticides, including Drione®, are known to be highly repellent as well (Ebeling et al. 1966).

Light

Most occupants of infested dwellings are aware that cockroaches generally avoid bright light and can be seen scurrying for shelter when the kitchen light is switched on at night. A few of the residents at Acadia said that they regularly left the lights on all night in order to deter the cockroaches. However, it is known that under conditions of continuous lighting, the insects soon become habituated to the illumination and consequently the amount of activity does not seem to be decreased (Cornwell 1968). Even in normal lighting it is not uncommon to see the odd individual moving about during daylight, particularly when the infestation is very large and individuals are under stress.

Ultrasound

Recently, numerous devices have been marketed which are alleged to control a variety of insect pests, including cockroaches, by producing ultra-high frequency sound. Although ultrasound has been shown to have potential use in the integrated control of rodents (Culver 1980, MacLean 1974), it has not been demonstrated to be of value in urban insect control.

Observations made on several different ultrasound generating devices (20,000 to 60,000 Hz mostly at 120 db at the source) led me to the conclusion that they are not effective for the control of cockroaches. When laboratory colonies were exposed to the ultrasonic devices, no

changes in behaviour could be observed, indicating that they may not be able to perceive high frequency sounds. Some of the units emitted pulsed or variable frequencies, but this did not seem to make any differnce.

This is consistent with the findings of Ballard and Gold (1982) who did not detect significant repellancy of German cockroaches using sound frequencies between 1000 and 60,000 Hz.

Ultraviolet Light

Since short wavelengths of light are known to affect the development behaviour, and survival of cockroaches it is possible that ultraviolet light could be used for the control of infestations (Gingrich et al. 1977). It has been shown that irradiation of early instar nymphs, the most sensitive stage, results in a 90% to 100% mortality within six days (Cohen et al. 1973, 1975). Sublethal doses resulted in delays in molting and inhibited normal weight gain. These were caused, at least in part, by a decrease in food consumption resulting from a metabolic alteration produced by exposure to ultraviolet light. Increases in the occurrence of structural malformations among exposed cockroaches were also noted.

During these studies it was found that light from the 254 nm band, such as that emitted from a Hanovia low-pressure mercury germicidal lamp caused the highest mortality. Treatments at 280 and 297 nanometers were also effective.

I observed that even low intensity ultraviolet light would elicit a

negative response among cockroaches that was far stronger than that to other light sources. It has been shown that the repellency soon wears off, however and the insects resume normal activity. (Cohen et al. 1975).

Although it might be highly desirable to use ultraviolet light in apartment kitchens to reduce cockroach populations, any exposure to these wavelengths is a hazard to the resident's vision. Unless it could be shown that this would not be a significant danger, the applications of ultraviolet light will be limited.

One possible use at Acadia would be for control of cockroaches in the basement boiler room. Maintenance staff only rarely enter this area and a switch could be installed on the door to switch the lamps off when the door to the room is opened. Another use would be to install them inside kitchen cupboards.

MASS TRAPPING

Since traps are capable of capturing large numbers of cockroaches, it is possible that they could be used to reduce infestations. There are no reports of complete control of German cockroaches using traps alone, but their use in IPM programs still seems warranted. The results of mass trappping trial conducted at Acadia are reported in Appendix 8.

Barak et al. (1977) describes mass trapping of German, Oriental and American cockroaches in Wisconsin using Zoecon® traps. Although they observed a decline in the number of cockroaches seen and trapped over time, the authors did not consider the reduction to be adequate. Twenty-four traps were deployed in a bakery for a five week period during

which 2435 German cockroaches were captured. Although the numbers had declined during the trial, no statistically significant difference was found between captures in the first and last weeks, 524 and 279 respectively. Similar results were recorded for mass trapping German cockroaches in a tavern and a restaurant.

In a 35 week trial at a student residence at Texas A & M University, Piper and Frankie (1978a) record capturing 5912 German cockroaches using 33 Zoecon® traps in a 72 m^2 apartment. A previous 37 week trial using petroleum jelly jar traps, removed 915 insects from the same dwelling. Their objective of reducing populations to a level where only three cockroaches were seen per week was not achieved by trapping, even though the numbers captured in the traps declined by the end of the 72 week trial. They noted that the number of trap stations with cockroaches had diminished, indicating a restriction in the distribution of cockroaches in the apartment. From this and other mass trapping experiments, they conclude that the suppressive action of trapping is useful as part of an IPM program.

The traps did not provide a simple cure for cockroach infested dwellings, but did seem to be useful for providing some population supression. More traps might have given better results, although at a cost of $1.00 per unit this could be quite expensive, particularly since the traps need to be replaced every 6 weeks. Results from mass trapping should not be expected for the first three months.

The two traps described below are marketed for the purpose of mass trapping cockroaches. Unlike the disposable traps previously discussed as monitoring tools, the Roatel and Electro trap are high in cost and capable of holding large numbers of insects.

Roatel® Trap

The plastic "Roatel"® cockroach trap (Fumakilla, Japan) has been reported by others as being effective in capturing German cockroaches (Piper and Frankie 1978a, Ross 1981). Unlike most other traps, it contains no sticky inserts and is re-usable. The insects are trapped by pushing through delicate one way doors while drawn by a food based attractant contained in an inner chamber.

Since the cockroaches are not harmed, the trap is ideal for use in situations where live insects are needed for study. This feature is a nuisance during mass trapping when quick disposal of the insects is desired. Residents would probably find this system less desirable because the insects can be seen moving around inside the trap.

Roatel® traps are not readily available in southwestern British Columbia, but cost about $10.00 in other countries. Since many traps would be needed for a mass trapping trial, the cost would be quite high.

Electro® Roach Trap

A relatively new product is an electronic device retailed under the name of "EX1-Electro Trap"® by Ground Control Electronics of Delta, B. C.. About the size of a small typewriter, the EX1 uses an attractant bait to lure cockroaches into an inner chamber where an intermittent electric current causes them to jump into a replaceable sticky insert.

The use of a high voltage strip is thought to prevent the cockroaches from being repelled by contact with the non-drying glue thus forestalling a learned avoidance of the trap. The shock is not designed to harm the insects, thus the living cockroaches inside the trap are supposed to emit sex and aggregation pheromones that attract more cockroaches.

My limited testing of the EX1 indicated that it had promise for use as a mass trapping device in IPM programs. Although the high cost of the unit at $600 precludes its use as a monitoring tool, it may be useful for reducing high denisty populations. Further evaluation is necessary to establish the cost effectiveness of the unit.

Residents' reaction to the trap was extremely positive. The few negative comments that were received mostly centered around the large size and high cost of the unit. Other concerns mentioned were the unpleasant odour of the trap and the effect that operating the unit had on T.V. and radio reception.

BIOLOGICAL CONTROL

Many people have emphasized the importance of natural controls in IPM programs (Flint and Van den Bosch 1981, Piper and Frankie 1978a). Although the use of biological control agents for control of urban cockroaches is highly desirable, the natural enemies of the German cockroach have not been well studied thus more work is required to evaluate their possible applications in IPM. Regrettably no biological control agents were tested at Acadia during this study.

Some good reviews of biological control tactics are available (Coppel and Mertins 1977, DeBach 1974), however, most of the theory and practice of this technique has been applied only in forestry and agriculture.

Some of the known enemies of the German cockroach are listed in table 6. Although some of the natural enemies of other cockroach species will probably also prey on B. germanica this would need to be tested. Other bacteria and many nematodes have also been shown to infect the German cockroach (Tsai and Cahill 1970, Cameron 1955), however, their pathogenicity has not been well established and most appear to be only symbiotic.

No cockroach parasites were confirmed from the infestations at Acadia, nor did any of the local entomology museums contain any known parasite specimens. This would indicate that the enemy complex of the urban cockroach is quite impoverished and would mean that there is potential for reducing the pest population by introducing a parasite species.

Most of the past work on cockroach control has centered on the use of the Eulophid miniwasp, Tetrastichus hagenowii, a parasite of the ootheca (Cameron 1955, Edmunds 1955, Fleet et al. 1975, Piper et al. 1978, Burks 1943). The ability of this species to parasitise the German cockroach is not well documented, but is probably low due to the egg carrying behaviour of the host. Piper and Frankie (1978a, b) used T. hagenowii releases to reduce populations of the smokey-brown cockroach in residential areas in Texas but did not report any use

Table 6: SOME NATURAL ENEMIES OF THE GERMAN COCKROACH

	Stage attacked
ARTHROPODA (insects and mites)	
Hymenoptera:Evanidae	Egg
Evania appendigaster L.	
Evania punctata Brulle	Egg
Brachygaster minutus O.	Egg
Hymenoptera:Eulophidae	
Tetrastichus hagenowii (Ratz)	Egg
Hymenoptera:Ampulicidae	
Dolichurus corniculus (Spinula)	Adult, nymphs
Coleoptera:Rhipiphoridae	
Rhipidus pectinicornis Thbg	Adult, nymphs
Corina:Pterygosomidae	
Pimeliaphilus podapoliphagus Tragardh	Adult, nymphs
SCHIZOPHYTA (bacteria)	
Eubacteriales:Enterobacteriaceae	
Serratia marcescens Bizio	Adult, nymphs
Spirochaetales:Spirochaetacae	
Bacillus (Unidentified)	Adults, nymphs
THALLOPHYTA (fungi)	
Moniliales:Moniliaceae	
Beauvaria bassiana (Balsamo) Vuillemin	Nymphs

(Adapted from Roth and Willis 1960, and Cameron 1955)

against the infestations of German cockroaches dealt with in the same study.

Although residents with strong phobias for insects might object to having hymenopterous parasites released in their homes, most people would not find them fearsome. The wasps are very small and resemble aphids or gnats rather than bees or hornets. They are harmless to people and would not be present in large enough numbers to be considered annoying.

CONTROL BY RELEASE OF STERILE MALES

A technique for controlling cockroaches by the introduction of a deleterious genetic load into the population has been developed by researchers at the Virgina Polytechnic Institute (Ross 1973, 1980, Ross et al. 1981, Ross and Cochran 1981, Keil and Ross 1977). A cockroach gene has been isolated that causes the death of the embryos in the ootheca and can be introduced into the population by heterozygous male adults. Since the egg case cannot be split open by the few remaining nymphs, the ootheca will not hatch. In this process, called embryonic trapping the female is rendered infertile. Although this technique is similar to the sterile male release program used in other insects, it has the advantage of not causing debilitation of the insects from radiation damage.

Ross's limited field testing gave supression varying from 14% to 100%. The major difficulties encountered were estimating the size of the field population and judging the correct time for releases.

No doubt there would be problems in convincing residents to allow the release of cockroaches in their dwelling, however if the technique were proven effective, I believe that most of the tenants could be swayed without difficulty.

THE COMMERCIAL POSSIBILITIES OF IPM IN URBAN HOUSING

If integrated pest management is to become viable it must be made attractive to private business interests.

It is doubtful that there is sufficient business in British Columbia for a company dealing solely in cockroach control to survive. Competition in the urban pest control industry is intense and the number of possible contracts is limited. The greatest potential for immediate implementation of IPM lies with the existing pest control firms, any one of which could offer it as an alternative or supplementary service to customers. Unfortunately the appeal of IPM to many consumers would be low due to its relatively high cost.

During the study several companies indicated to me that they did not believe that IPM could be offered at a viable price. They pointed out that most of their expensive contract bids were unsuccessful since consumers generally hired the least expensive rather than the most effective company. This problem is compounded by those pest control operators who underbid and rely on the over-use of pesticides in order to minimize their labor costs. Although they often give poor results, they can usually survive on the abundance of short term jobs.

In contrast, there are some consumers who, after many experiences with chemical oriented programs, become interested in alternative approaches. In some of these cases, the landlord is in a political or moral position where he is obliged to provide the safest solution to the

pest problem, and may therefore be willing to pay a higher cost.

Table 7 summarizes the costs of operating an IPM program. A company might charge about $30 per hour for labor, out of which salaries, business expenses and support services would be paid. In addition to this, cockroach traps and other materials would need to be purchased and copying charges for the information distributed to tenants would need to be paid for. About ten pesticide applications would need to be made each year. Irrespective of whether Drione®, boric acid, pyrethrins or propoxur is used, the cost of applying it would be about $30 per treatment including labor, materials and equipment. The amount of labor needed to operate the IPM program would be considerably more than that required for a chemical control approach, and consequently the total cost would be higher. Table 8 details the amount of labor that would be needed to operate an IPM program in a 100 unit building such as the Acadia high rise.

The cost per rental unit would be $35 per annum or $2.91 per month. Unfortunately this is still more than double the amount most companies would charge for a regular pest control program.

Table 7: MINIMUM COST OF AN IPM PROGRAM FOR THE ACADIA HIGH RISE

Item	Cost per Unit
Labor (at $30 per hour)	$24.60
Cockroach Traps	4.00
Pesticide Applications	3.00
Other Materials and Equipment	3.00
Copying Costs	0.40
TOTAL	$35.00

Table 8: MINIMUM AVERAGE ANNUAL TIME REQUIREMENTS FOR A 100 UNIT BUILDING

Activity	Hours
Surveys (2)	30
Meetings	4
Research	12
Report Preparation	12
Other	24
TOTAL	82

CONCLUSION

The cockroach problem at the study site at Acadia (appendix 1) was largely due to the building construction which allowed abundant harborage and corridors for movement between apartments. The building was designed in such a way that temperatures in the apartments were unusually warm which allowed for maximum growth of the cockroach population. The situation was aggravated by the installation of carpets, which provided food, harborage and insulation for the insects and also by the clutter and poor sanitation of some apartments and by the low tolerance of residents to cockroach infestations.

An ideal integrated management program for the control of cockroaches at sites such as Acadia would first develop a rapport with residents, and secondly devise a method of monitoring the distribution and abundance of cockroaches. Once the nature of the residents concerns and the cockroach population are known, then measures should be taken to reduce the conflict between the residents and the insects.

The most appropriate initial measures would be to modify the environment of the building to reduce the potential for the cockroaches to increase their population. Foremost of these measures should be to reduce the apartment temperature wherever possible. The second most valuable tactic would be to reduce the amount of harborage by reducing clutter and sealing crevices. Any other efforts directed toward improving the sanitation of the infested area will probably also be of value.

Once environmental modification is under way, areas with high infestations that were identified by the survey should be treated with insecticides to hasten the demise of the problem. One possible program would be to inject Drione® into the wall voids followed by a crack-and-crevice application of propoxur in the kitchen and bathroom followed by a thorough treatment with pyrethrins. However, any one of a number of insecticides could be substituted.

Integrated cockroach management must be looked at as an on-going program if it is to be of any value. After the initial measures are taken to reduce the problem, monitoring and communication with tenants must be continued.

Other control tactics such as parasite releases, mass trapping, sealing, use of repellents and release of sterile male cockroaches require further research before their place can be fully evaluated. No doubt some of this work could be conducted as a part of an IPM program.

Clearly a sufficient number of techniques are available for the control of cockroaches that an IPM program could be developed to deal with the problem. The major obstacles to instituting IPM in an urban housing setting are that the cost would be discouragingly high and that there is a shortage of individuals who would be qualified to run such a program.

The difficulty of establishing acceptable threshold population levels for the cockroach infestation will also deter any attempt at IPM, however if further research in the area were to be carried out in cooperation with microbiologists and health scienctists a satisfactory solution to this problem might be found.

Even if an IPM program such as the one described here could not be implemented, some of the components of the program, such as monitoring and temperature reduction could be incorporated into present pest control programs.

APPENDIX 1: COCKROACH STUDY

The central study site was a fourteen story student residence known as the Acadia High Rise (Plate 2). It is managed by the University of British Columbia Department of Conferences and Student Housing on the university campus in West Point Grey. The building contains 100 rental units and provided accomodation for 190 adults and 80 children. It forms a part of the Acadia student family housing area which collectively provides 375 rental units. In addition to Acadia, U.B.C. operates three other residence areas comprising a total of 1500 units.

The rental units in Acadia are provided for both married students and single parents. I was a resident of the high rise for four years (November 1977 to June 1982) while my wife was pursuing studies at U.B.C.

HISTORY OF THE INFESTATION

The early history of the infestation is not known in detail because of the extensive turnover of management and residents. The following outline was pieced together from the few records that were kept by the tenant society.

Plate 2: THE ACADIA HIGH RISE

The earliest mention of cockroaches in Acadia was in January 1975 when the problem was discussed at a landlord-tenant meeting. A survey conducted by a concerned tenant in September 1975 reported that:

"... of the 86 units surveyed, 25% had cockroaches, 43% had weevils, and 33% had silverfish. Spot spraying has been proceeding at the request of tenants who feel they need it."

I observed that residents generally understate the problem in their own suite. Typically if the resident has not seen any cockroaches for two weeks they will say that their suite is not infested. It is therefore probable that the 25% figure represents only the more densely infested suites.

If the infestation arose from a single gravid female, it would likely require a number of generations to populate the building which, would probably take at least two years. This means that the first introduction probably occurred before September 1973, and possibly as early as 1968, the year when the building was opened.

The first attempt at control was carried out in September 1975 when a pest control firm employed a crack and crevice treatment with propoxur at a cost to the university of $2700 including a one year follow up program.

A second attempt by the same company in the summer of 1977, again used propoxur treatments, in this case backed up with a limited use of 5% diazinon dust in wall void areas. Some silica aerogel and pyrethrins were also employed. The garbage chute, a long suspected source of the infestation, was permanently closed after the treatment.

By April 1977, many suites had large infestations. Follow up treatments continued for several years.

In June 1980 the tenant society (known as the Acadia High Rise Tenant Association) organized a committee of volunteers to assess the extent of the problem and to explore alternatives to building-wide sprays. This group, known to the residents of Acadia as the Cockroach Committee, managed the cockroach problem for several years and provided a great deal of assistance in conducting this study.

BUILDING PROFILE

The Acadia High Rise is fourteen stories high, not including the utility rooms on the roof and below the main floor.

The basement boiler room, which maintained infestations throughout the study, was warm (33 C), humid (90% RH) and dark, except during periodic servicing.

The main floor consisted of four apartments, an electrical room, stairs, elevator shafts, a laundry room, several storage areas, public washrooms, entrance foyer, garbage storage room (no longer in use), office space and a public nursery. Infestations were known from all four suites and the garbage room. Curiously, no insects were ever found in the garbage chutes leading to the other floors.

The next twelve floors were identical in layout (figure 2), each containing eight apartments built around a central core (figure 3),

Figure 2: BASIC FLOOR PLAN OF THE ACADIA HIGH RISE

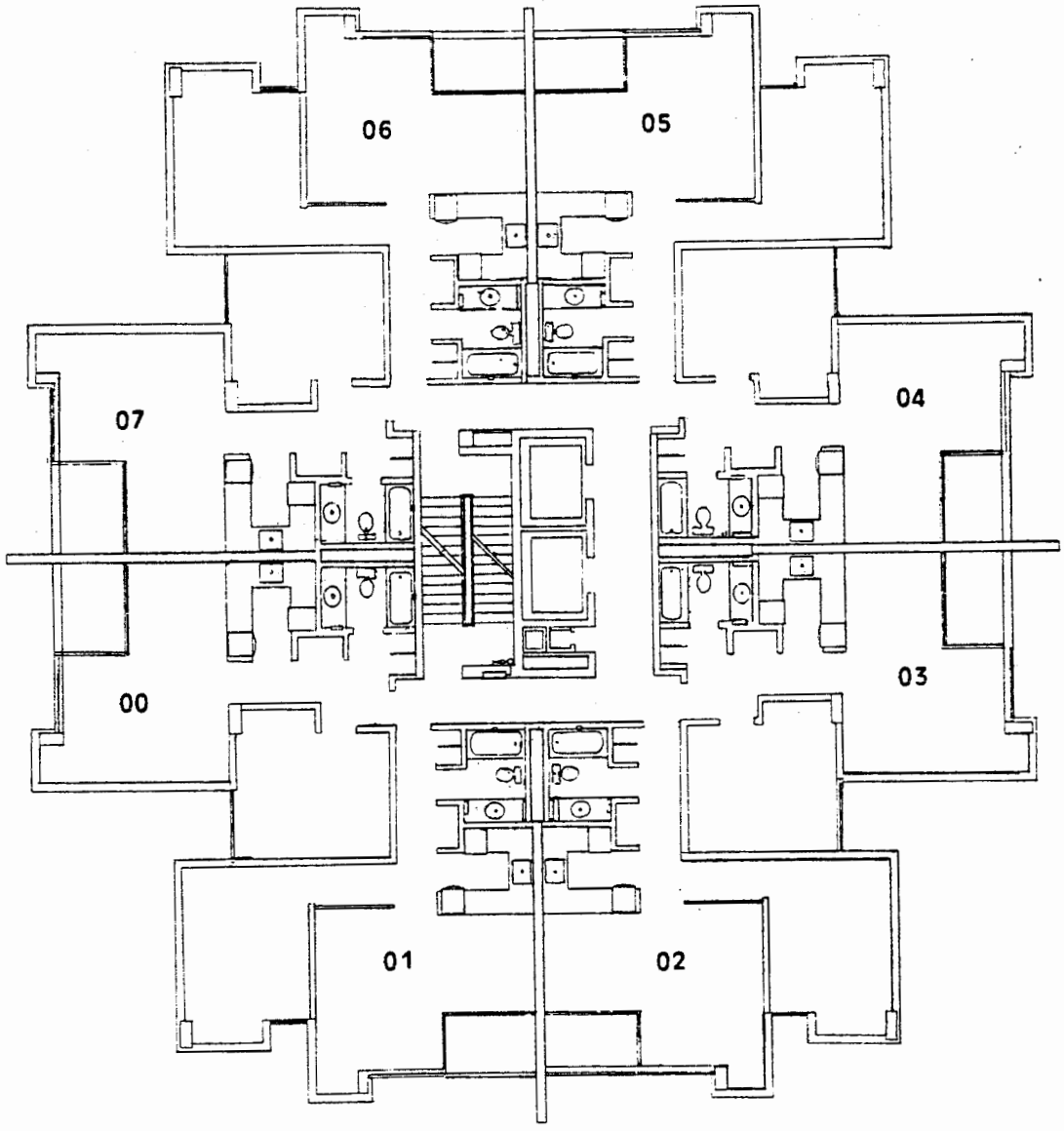
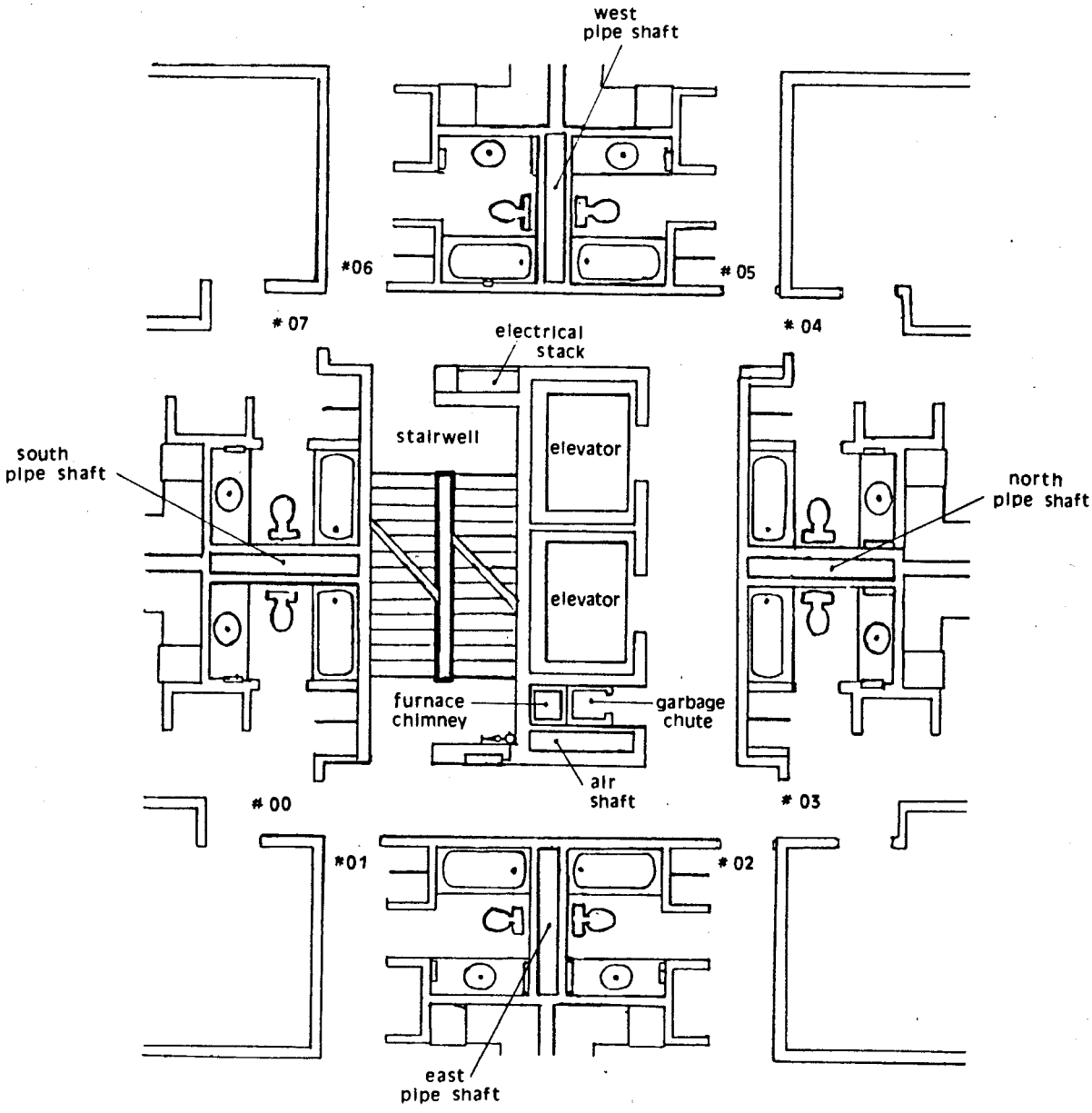


Figure 3: DETAILS OF THE CENTRAL BUILDING CORE OF THE ACADIA HIGH RISE



consisting of stairs, elevator shafts, a garbage chute, a smokestack, a hallway and an electrical shaft. Cockroach infestations on these floors were confined to the apartment areas. Four pipe shafts ran vertically through the building and contained the plumbing pipes that serviced the apartments. It was thought that cockroaches used these as corridors for movement between floors.

The penthouse was primarily used as a study area. In addition to three large open rooms the penthouse has public washrooms, a janitorial room, four public balcony areas and a common lounge area used for study and community meetings. A small infestation was known to exist in both washrooms in the penthouse.

Above the penthouse is the roof area where outlets for plumbing vents as well as a mechanical room containing the elevator machinery and the fan system for the hallway air vents. No cockroaches were detected on the roof.

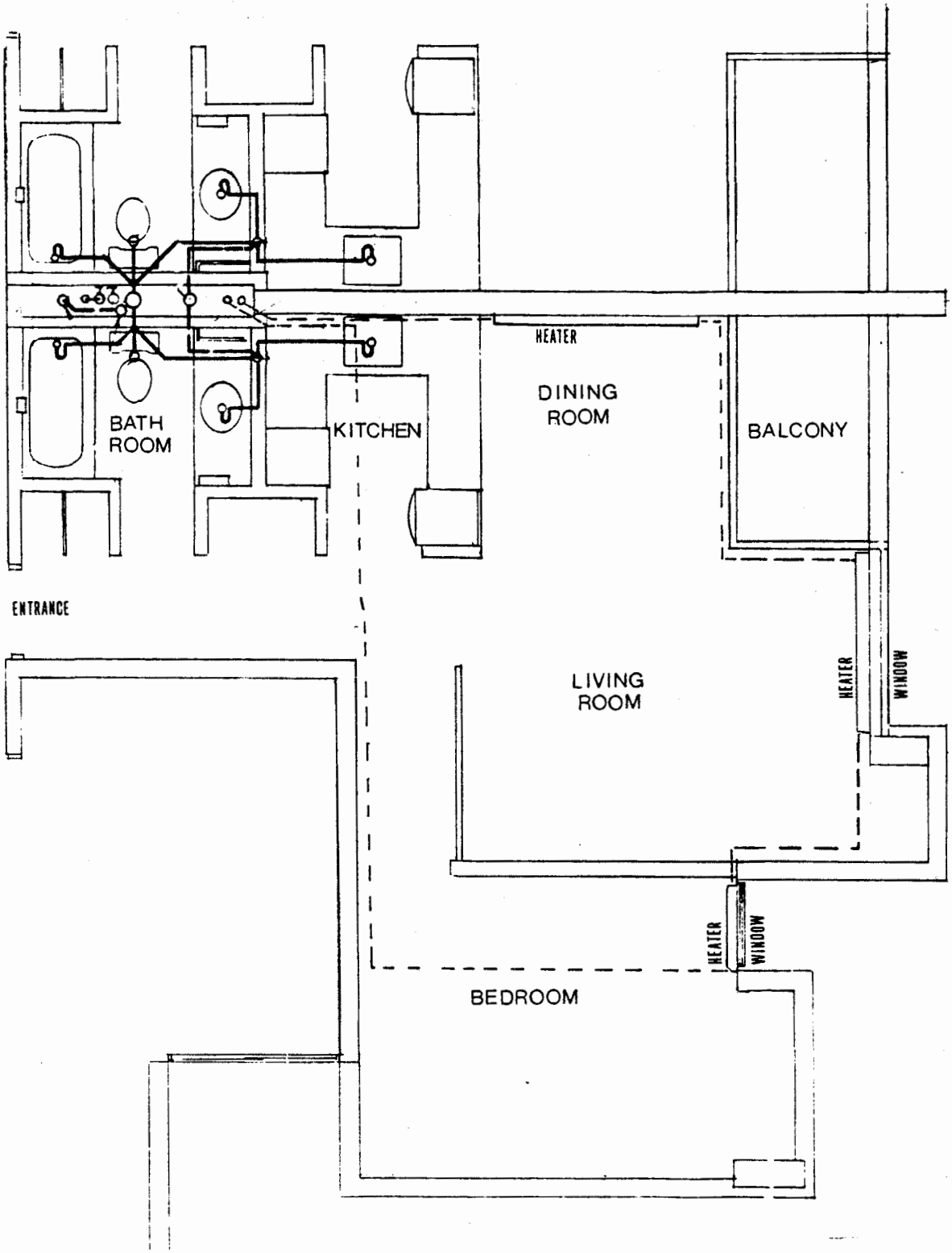
APARTMENT PROFILE

All units at Acadia were similar in design and had a living area of about 63 square meters. A plan of a typical suite is shown in figure 4. Heat was provided by hot water radiaters located in the dining room, living room and bedroom and was controlled manually rather than with a thermostat.

Virtually all cockroach infestations in the building were confined to the kitchen and bathroom areas of the apartments. Cockroaches seen in other locations were thought to usually represent individuals that were displaced from their normal habitat. Insects which showed up on house plants located near the window were possibly attracted there by the moisture. Occasionally cockroaches were accidently carried into other areas of the apartment along with goods from the kitchen or bathroom. Strays were most often reported from the dining room, however occasional mention was made of cockroaches in the living room, hallway and bedroom areas. On the one occasion when a cockroach was sighted in the outdoor patio, the tenant suggested that it had probably been carried out with the garbage.

Most of the cockroach sightings in the building occurred in or near the kitchen area. Infestations under the sink and in the cupboard located between the sink and the stove were most common. Less common were sightings of cockroaches in the upper cupboard, although in a few cases quite large populations were established there. In those apartments where cockroaches were abundant on the kitchen floor, the

Figure 4: PLAN OF A TYPICAL SUITE IN THE ACADIA HIGH RISE



suite was usually carpeted and the insects appeared to be emerging from the junction of the hallway carpet and the kitchen linoleum. In some cases insects would also appear on the floor from under the stove. In general however, cockroaches were most often seen on the counters.

The cockroaches in the bathroom harbored mostly in the loose plastic moulding that surrounded the room. Populations were also noted under the counter and behind the mirror.

Since 1975 the original hardwood floors in the hallway, living room and dining room areas of the apartment have been gradually covered with carpeting. A few tenants mentioned that their cockroach problem increased after the carpet was installed. Although this claim was never verified, it seems reasonable based on the following observations:

- The carpets were harder to keep clean than the wood floors and tended to trap food particles between the fibers.
- The carpets trapped moisture, which the cockroaches need for survival.
- The carpets acted as insulation thus keeping the cockroaches warm during cool periods.
- Additional habitat was created in the space between the floor and the carpet.

The presence of cockroaches under carpeting was confirmed in two suites with high populations, indicating that colonization and survival in this area was possible. In all cases, however, these seemed to be supplementary to the main infestation which was located in the kitchen.

PROFILE OF THE TENANTS

The tenant population in the building was transient and thus their makeup varied somewhat throughout the study. The average residency was two years but the range was from one month to five years.

The lease required that at least one member of each family had to be a student pursuing full time studies at the university. Although some spouses were also students, many were either homemakers or employed in full time jobs. Most tenants were between 20 and 35 years of age. Well over half had completed one post-secondary degree.

The family composition observed in the survey of May 1982 is summarized in table 9. The predominance of families with infants and expectant mothers was a striking feature of the High Rise community.

Tenant societies have been active in Acadia since the first year of its operation. Through these groups, laundry and other facilities were managed and community events were organized. They also played a significant role in coordinating communication both within the tenant community and between tenants and the management.

Relations between tenants and management were generally poor. This often led to confrontation, generally sparked by a tenant who felt threatened by an action taken or statement made by management personnel.

Attitudes toward pesticides and cockroaches were quite varied within the community. Residents' opinions on these subjects are best illustrated by the written comments that they submitted during the study period. A synopsis of these is presented in appendix 2.

Table 9: COMPOSITION OF FAMILIES IN THE ACADIA HIGH RISE

Families	92
Adults	184
Children	89
% Pregnant Women	11
Families with Children	80
% over 35 years of age	8
Average age of children	32 months (range 1 - 168 months)

From a survey taken in May 1982.
Based on 92 returns of 100 suites.

PROFILE OF THE MANAGEMENT

Matters relating to pest control in Acadia were charged to one person in the University of British Columbia administration, who in association with approximately eight other staff members, handled various aspects of the cockroach problem. Unfortunately, the staff members involved changed several times during the two year study and consequently the development of a pest management program was often in jeopardy. Fortunately, interest in alternative approaches to cockroach control originated from tenant groups and thus some continuity was maintained.

The contact of the management of Acadia with the cockroach problem was mostly through complaints. The residents with whom they spoke were most often those with very low tolerance or those with unusually high cockroach densities, thus the staff were encouraged to believe that most apartments had similar problems and that most people reacted in similar ways. Relatively little contact occurred with residents whose problem was either stable or decreasing, consequently the management never understood the problem at Acadia completely.

APPENDIX 2: COMMENTS FROM RESIDENTS

Below are a selection of comments submitted to me in writing by the residents of the Acadia High Rise. They are divided into categories according to the nature of the response, and have been edited for brevity and clarity.

THE COCKROACH PROBLEM

1. Our cockroach traps are continously full which I find disgusting. I have just moved here and I find the cockroaches very unsettling. I find it hard to relax because I think that every little itch I have is a cockroach crawling on me. I have developed the habit of turning on the kitchen and bathroom light, then waiting a minute before entering so that I do not have to see the cockroaches. Although I'm sure I will become "dessentized" after living here for a few weeks, I am sure I will never be happy when there are so many cockroaches around.

2. It is terrible that we should have to live with these dirty bugs.

3. The cockroach infestation is degrading, embarrassing and psychologically dangerous.

4. I do not want to take cockroaches with me when I move from this building.

5. For a cockroach to be a disease vector of Salmonella it would have to transmit the bacteria to exposed food on which the organism could multiply. A person would have to ingest one hundred million organisms to suffer sypmtoms. Education on food sanitation would prevent this unlikely occurrence. I feel that continued efforts at sealing and reducing food sources would lead to the most favorable results.

6. Having just returned from Hawaii where the cockroaches grow very big, I can probably stand a few of these little ones.

THE USE OF INSECTICIDES

I. Respondents Favoring the use of Insecticides

1. Insecticide use is alright as long as it is effective.

2. I could not care less about the use of insecticides.

3. I feel the building should be sprayed to get rid of this problem once and for all. I think that living with these disgusting bugs is a much greater risk to our health than would be the use of an insecticide.

4. If the insecticides will get rid of the cockroaches then I am in favor of their use.

5. I used to think that chemicals should not be used, but when our apartment became a cockroach factory I couldn't stand it any more and had it professionally sprayed. I now feel that the entire building should be properly treated.

6. I am in favor of the use of insecticides as long as the apartments are throughly treated and an on-going maintenance program is implemented.

7. Spray the building before the cockroach problem gets any worse.

8. I would like to see the building sprayed so we can eliminate the cockroach problem once and for all.

9. Insecticides should be used providing they cause little or no harm to human beings.

10. Although I don't like insecticides I think the problem in this building is bad enough that something needs to be done. So if they work, why not use them?

11. As long as the insecticides are government approved and are used properly they are O.K.. I would, however, like all the residents to be given full information on the spray and its hazards.

12. Living in an apartment with cockroaches is very disagreeable. If application of insecticides can eliminate the problem, then lets go with it.

13. I think tenants are over-reacting to the possible harm from pesticides, although I guess if my apartment were not so infested I might not be so eager to have the building sprayed.

II. Respondents Opposed to the Use of Insecticides

1. I don't like pesticide use, especially around children or pregnant women. Since this building houses mostly families I think it is rather risky spraying insecticides. For my own family, I fear the spray quite a bit.

2. I am not in favor of insecticide use as it is usually only a short term solution. Eventually the cockroaches will develop resistance.

3. I would prefer to apply the insecticide myself to selected inaccessible areas. I am very concerned about their possible effects on my unborn child and would not want it to be used now while I am pregnant. I am primarily concerned about the use of Baygon®, and have no objection to use of the Drione® dust or pyrethrin spray.

4. I have tried spraying Baygon® in the kitchen area, but it only works temporarily. Since I have an infant who crawls and who picks up things the instant I am not looking, there is no safe place to use the insecticide. If the cockroaches come back in only a month, is it worth the expense, hassle or health risk?

5. I am strongly opposed to the use of insecticides.

6. Insecticides are dangerous to humans, particularly children. If they must be used, it should be when no one is around.

7. I do not like the use of insecticides and would attempt any other method first. If the situation became intolerable I would use insecticides as the last resort - just short of vacating the suite. I feel that insecticides are often used only as a bandaid treatment and are the lazy way to solve the problem.

   I am primarily concerned about the effect of the chemical residue on myself and my family. Even if the company and the researchers indicate that the insecticide is safe, I am still skeptical. I also find the inconvenience of moving everything out of my cupboards and of finding somewhere to go for ten hours to be annoying.

8. Insecticide use for cockroaches is not justifiable. The spray has undetermined and untestable effects on the human metabolism. It is also impossible for us to prevent our child from contacting the spray residue. The proposed spraying of the building will certainly not solve the cockroach problem. We will go to any legal means at our disposal to prevent our apartment from being sprayed and will refuse to cooperate with the building treatment.

9. I am concerned that small children might be poisoned, and that the insecticide will not be effective.

10. I am opposed to the use of Baygon®. I have heard that the spray leaves visible blotches of residue and that a lingering odour will be present for months. I am also concerned that there may be unknown long term effects on our children. We are just now learning of cases where small quantities of harmful substances can cause damage at the cellular and genetic level, so it might be with some products that there is no safe level of exposure.

11. Cockroaches bother me less than my fear about the risks of using insecticides. I have doubts that a spraying program would be effective in the long run. It exposes children to an unnecessary hazard.

12. I am absolutely opposed to the use of insecticides. They do not and will not work.

13. I have only seen two cockroaches during the last nine months. Naturally, under these circumstances I am not keen on having pesticides used in my apartment.

14. I don't think that anyone should be forced to have their apartment sprayed if they are opposed to it. It is an invasion of their privacy and an encroachment of their rights.

15. If insecticides did any good, we might be in favor of them, but so far, no one has convinced us.

16. I am against the indiscriminate use of insecticides. Since my son is allergic to sprays, I would have to move out if the building were treated.

17. I doubt that insecticide use will eliminate the cockroach problem since two previous building wide-sprays were unsuccessful. I think another attempt would be not only inconvenient, but also risky.

18. I would rather not have my child used as a guinea pig.

19. Pesticides have often been used in the past and have only later been shown to have lethal consequences to humans.

20. I think the poisons are dangerous and can understand why people with children are concerned.

III. Respondents Who Were Neutral About the Use of Insecticides

1. I have very little information about the effects of insecticides and therefore stand uncertain.

2. If insecticides could provide a long term solution I would consider their use favorable. My feelings about use of pesticides would depend on the nature of the chemical being used.

3. I am uncertain as to whether I am in favor or opposed to using insecticides. My position would depend on the type of insecticide, the concentration and where it is used. I feel that people get too emotional about insecticides before they find out the facts.

4. I am uncertain as to which would be more injurious to my health, cockroaches or insecticides.

5. I don't like the idea of using insecticides, but if somebody can guarantee that it is safe for my body, then its O.K.

THE CONTROL OF COCKROACHES

1. The pathways of the cockroaches need to be blocked off by taping, caulking, or whatever, then the existing cockroaches should be killed. If the the pathways are left open, they'll always come back. Maybe we should put our money into caulking instead of insecticides.

2. We have made a special effort to keep our apartment clean; taking out the garbage, keeping our food in containers, etc. We've also taken advantage of the sealing material provided. As a result, we have not seen a cockroach in a year. I believe that if everyone did the same it would definitely help.

3. The key problem is with the tenants who make no effort to contain the cockroaches by sealing before the spray.

4. Perhaps the management should consider caulking all of the apartments especially around the pipes and baseboards. I notice that a lot of tenants have complained of increasing cockroach problems since new carpets were installed.

   How about hiring a pest control manager? Some people are using cucumber peels and bay leaves with success.

5. Keeping the cockroach population low and developing tolerance for it is a good idea. For the first three and a half years that I lived here I rarely saw a cockroach so it was O.K.

6. We have had good success with using fiberglass resin to seal cracks in the apartment.

7. Turn the heat down in the hallways. Not only is it uncomfortable to us but it no doubt aggravates the cockroach problem.

8. Let the tenants continue using alternative methods of control, centering their efforts on suites with the most serious problem.

9. The heat in the building should be lowered to make the environment less favorable to cockroaches. Let some of the fuel costs saved go toward preventing cockroach problems.

10. People should try to make the environment unfavorable for cockroaches rather than use insecticides. The temperature in the apartments should be kept lower. People should wear sweaters rather than turn on their heat. Also residents should wash the dishes at night before going to bed.

11. You should emphasize long term cockroach control through habitat manipulation rather than short term control by using insecticides

12. I suggest that other residents keep their garbage on the balcony as we do.

13. Cockroach control is best carried out by temperature control, proper food storage and adequate cleaning; not by chemicals.

    People should be made aware of the cockroach problem before they move in so that they would find the low infestation levels tolerable.

14. I don't think you should waste your efforts trying to eliminate the cockroaches. I think a more realistic view is to try and reduce the cockroach population to a minimal level.

THE COCKROACH COMMITTEE

1. The committee is excellent for public relations and for reassuring us that the someone cares about our cockroach problem.

2. Although the committee has been thorough, I feel that most tenants have been lazy in their efforts. If apartments were tidier and if people kept their apartment temperature turned down, there would be much less of a problem.

3. The cockroach committee has worked hard even though the funding has not been very high.

4. The cockroach problem is being managed well by the cockroach committee, so let us leave well enough alone and not spray the whole building.

5. The efforts of the pest control committee are admirable, and their effectiveness is as good as can be expected without the use of insecticides.

6. I appreciate the availability of cockroach traps and of information on cockroach control.

7. The committee has taken a fairly scientific approach to determine the extent of the problem and to find possible ways to remedy the situation.

8. The tenant committee has done a good job in understanding the situation. I appreciate the idea of tenant involvement.

9. I thoroughly appreciate the efforts taken by those individuals who have volunteered to help deal with this problem.

10. I feel that the educational efforts of the committee have been excellent and very informative.

11. Although I appreciate the considerable effort these people have spent, I feel that little has been achieved.

12. I feel the success of the tenant committee has been rather poor since I started seeing cockroaches only after they began their work.

13. I think the cockroach committee has done a good job in keeping the tenants informed about the problem and in trying to find solutions which will please everyone.

14. I have been impressed with the attitude of the cockroach committee in the year that we have lived here.

15. The handbook published by the committee was excellent.

16. The cockroach committee has been doing a valiant job of getting things done.

17. The effort of the cockroach committee has been great and highly commendable. However, I do not think that many tenants have put forth much effort to follow the excellent suggestions of the committee.

18. I feel that the cockroach committee has done an excellent job. It is my experience that if people care about a problem, then it can be solved.

OTHER COMMENTS

1. Let's face it, they had a head start on us in evolution. This is one species man cannot eradicate. These critters certainly do provide "food for thought", so I am amazed that no one has capitalized on them for their culinary quality.

2. Cockroaches! I thought they were ants.

3. Have you tried lizards?

APPENDIX 3: COCKROACH MONITORING

Building-wide surveys using traps were carried out in fall 1980, spring 1981 and fall 1981. In addition to these, residents of all infested dwellings were asked to carry out their own monitoring on an ongoing basis.

Disposable sticky traps were dated and set out in all suites for two to four weeks. The first and second surveys used "Roach Tent®" brand traps (Cherry Blossom Co., Vancouver, B. C.). The third survey used "Mr. Sticky®" traps (DRG Stationery, Georgetown, Ontario).

Two traps, rather than one, were used during the third survey. Since trap location was known to have profound effects on trap capture rates, the data were taken from the trap with the highest count in each dwelling. Although increasing the number of traps in an apartment occasionally gave some useful information on distribution, in general it did not add significantly to the evaluation of the infestations. Traps were placed on the kitchen counter near the sink, but residents often moved them to other locations.

Capture rates were calculated as cockroaches per trap per week (c/tr/wk). This number was obtained by taking the total number of cockroaches in the trap and dividing it by the number of weeks that the trap had been in the apartment. The variance in trap capture rates was always quite high, and therefore values were always rounded to the next whole number since decimal values would not be significant. Nymphs

that had hatched from oothecae deposited by trapped females were not included.

A relative rating of the infestation was assigned to each suite on the basis of trap captures. Rating criteria were as follows:

0 cockroaches/trap/week	=	No permanent infestation
1 - 4 cockroaches/trap/week	=	Low
5 - 10 cockroaches/trap/week	=	Moderate
>10 cockroaches/trap/week	=	High

Surveys were carried out by groups of four to seven people who attempted to make personal contact with residents to solicit opinions, assess individual tolerances and collect observations on cockroach occurrence and distribution. Thirty man-hours of labor were needed to distribute and pick up traps for the building. In addition to this, about ten hours of planning and summarization were required.

Tables 10 to 12 detail the results of the three major surveys. These are summarized in table 13. The arrangement of data in the first three tables reflects the distribution of the cockroaches in the building. The capture rates are grouped into four pairs of columns (marked east, west, north and south) each representing the apartments that are serviced by one of the four pipe shafts that run vertically through the building and that are belived to be the major corridors through which the cockroaches moved between dwellings. Thus insects in suite 1102 could moved into suites 1101, 1201, 1202, 1001 or 1002 but could not move easily into suites 1103, 1203 or 1003.

A review of the location of the kitchens in figure 3 will show the reason for this. For a cockroach in the kitchen of suite 1102 to get to

Table 10: FIRST SURVEY OF COCKROACH POPULATIONS (Fall 1980)

suite / floor	01	02	03	04	05	06	07	00
13	9	0	0	17	0	0	0	1
12	0	17	0	1	0	24	1	2
11	0	8	4	18	13	1	0	3
10	0	0	0	0	2	10	1	30
9	0	0	0	0	4	14	3	?
8	0	0	13	2	0	0	5	0
7	0	0	0	22	0	8	4	3
6	1	0	7	?	0	0	0	1
5	0	0	13	30	0	0	0	0
4	0	0	?	2	0	1	1	0
3	0	0	0	10	0	0	0	0
2	5	0	0	0	0	10	0	0
1	?					1	0	30
	east		north		west		south	

* Numbers represent the number of cockroaches captured per trap, per week, measured over a four week period. Unsurveyed suites are marked with a question mark (?).

Table 11: SECOND SURVEY OF COCKROACH POPULATIONS (Spring 1981)

suite / floor	01	02	03	04	05	06	07	00
13	5	13	1	2	0	1	0	0
12	2	18	3	0	0	1	0	1
11	1	1	1	14	5	1	0	1
10	2	1	11	18	1	15	1	0
9	0	4	1	?	6	0	0	0
8	0	0	18	1	1	0	1	0
7	0	1	0	2	0	0	1	1
6	0	0	4	1	?	0	0	0
5	0	0	0	1	0	0	0	1
4	0	0	0	1	0	0	1	1
3	0	0	?	0	2	4	0	1
2	0	0	0	0	0	1	26	0
1	0					1	1	1
	east		north		west		south	

* Numbers represent the number of cockroaches captured per trap, per week, measured over a four week period. Unsurveyed suites are marked with a question mark (?).

Table 12: THIRD SURVEY OF COCKROACH POPULATIONS (Fall 1981)

suite / floor	01	02	03	04	05	06	07	00
13	1	0	2	14	0	1	0	0
12	0	2	3	18	0	1	0	0
11	3	1	5	25	6	1	0	0
10	0	18	13	16	12	2	0	0
9	12	8	5	6	9	12	0	0
8	6	1	7	0	14	9	0	0
7	6	5	0	1	0	14	0	0
6	0	1	2	2	1	0	0	1
5	0	3	0	0	0	1	3	0
4	1	1	0	0	2	0	1	0
3	0	5	0	0	0	2	1	0
2	2	0	0	0	0	0	25	0
1	0					0	1	2
	east		north		west		south	

* Numbers represent the number of cockroaches captured per trap, per week, measured over a four week period. Unsurveyed suites are marked with a question mark (?).

Table 13: PROGRESS OF THE INFESTATION AT ACADIA

Time of Survey	Infestation Category*			
	0 - 1 c/tr/wk** (none)	1 - 4 c/tr/wk** (low)	5 - 10 c/tr/wk** (mod.)	over 10 c/tr/wk** (high)
Fall 1980	58	20	11	11
Spring 1981	53	36	3	8
Fall 1981	46	30	12	12

* Percent of apartments in each of 5 catagories.
** Number of cockroaches captured per trap, per week during a four week survey. This rating system is explained on page 118.

suite 1103, it would be necessary for it to travel down the hallway and through the front door into the central hallway. In several years of monitoring, cockroaches were rarely found in the proximity of the doorway, and were never detected in the outer hallway. It is likely that some insects did occasionally move between pipe shafts in this manner, but it is not conceivable that this was a common migration route.

This point is important in acessing the significance of cockroach distributions at Acadia. For example, from table 10 it would be tempting to hypothesize that the cockroach problem in suite 1105 was due to migration of insects from apartment 1104. This is clearly not likely. It was, however, possible that the problem in suites 803, 804, 704, 603, 503 and 504 were interconnected, in this case probably because of large infestations in suites 504 and 704.

I believe that the difference in cockroach distribution and density reflected by these trap records represent normal population shifts at Acadia. As can be seen in table 13, the magnitude of the cockroach infestation did not change significantly between surveys and the number of high density suites was nearly constant. However, a comparison of tables 10, 11 and 12 shows that the distribution changed dramatically. Thus, of the 11 suites that had high populations during the survey of Fall 1980 (table 10) only 3 (1404, 1202 and 1104) still had high populations one year later (table 12). The percent of suites in which no cockroaches were trapped also remained constant. Generally the upper floors always had more cockroaches then the lower floors and the apartments serviced by the south pipe shaft were more infested than those serviced by the other three pipe

shafts.

During the study, most of the control efforts in the building were directed toward the high density suites that were identified by the survey. It was disappointing that whenever the population was successfully suppressed in one apartment, another apartment somewhere in the building would develop a high density infestation, and consequently the number of seriously infested apartments was never decreased.

APPENDIX 4: PESTICIDE USE AT ACADIA

Opposition to pesticide use in Acadia has been organized by tenants on several occasions, usually through surveys and petitions, but also by public meetings from which delegates took proposals to meetings with the management. In some cases individuals threatened not to cooperate with the spray preparations of pest control operators.

Included in the surveys conducted during the study were several questions designed to assess the attitudes of residents in Acadia toward the use of pesticides. The results of the survey taken in May 1982 are summarized in table 14.

On several occasions pest control operators indicated that they thought that those individuals who were most opposed to building treatments were usually those with the most severe infestations. Table 15 compares attitudes toward pesticides and cockroaches among the suites with the highest cockroach trap capture rate, and indicates that this hypothesis is not correct.

Public opinion on the issue of pesticide usage is both diverse and complicated. A synopsis of comments from residents at Acadia on the topic of pesticides appears in appendix 2. The reports given by the

Table 14: ATTITUDES OF TENANTS TOWARD PESTICIDES

		Percent
A.	Building wide treatments:	
	In favor	38
	Opposed	36
	Uncertain	28
B.	General attitude toward pesticides:	
	Positive	35
	Negative	56
	Uncertain	9

Derived from a survey of 184 residents of Acadia in May 1982.
Expressed as percent of 152 returned surveys for A and 147 for B.

Table 15: ATTITUDES OF RESIDENTS OF HIGHLY INFESTED SUITES TOWARDS THE USE OF PESTICIDES

Cockroaches[1]	Attitude Towards Pesticides[2]			
	Positive	Negative	Uncertain	Total
Less than one	5 (28%)	11 (61%)	2 (11%)	18 (100%)
1 to 5	4 (31%)	8 (62%)	1 (7%)	13 (100%)
6 to 20	3 (25%)	8 (67%)	1 (8%)	12 (100%)
More than 20	12 (52%)	9 (40%)	1 (8%)	22 (100%)
Totals	24 (37%)	36 (55%)	5 (8%)	65

1. Number of insects typically seen in the apartment in one week.

2. Represented by the number of responses (out of 65) from a survey in May 1982. The number in brackets represents the percent of responses from the density (horizontal) category.

media of "environmentalists versus the chemical industry" did not accurately describe the situation since most of the people involved do not belong to either of these groups. The public has little knowledge of pest control or toxicology and although people seek out "expert advice" many of them do not believe it unless it confirms their prior convictions.

Concern over the use of pesticides has existed in Canada for many years. Frankie and Levenson (1978) who studied attitudes toward pest control in the United States indicate that people's opinions have been largely formed by the adverse image of chemicals presented by the media. A significant portion of the public today is skeptical of the purported safety of industrial chemicals and hardcore anti-pesticide lobbies exist in most strata of society. Their arguments are usually as follows:

1. If there is any risk, no matter how small, of the pesticide causing harm, then the product should not be used.

2. Since safe and effective alternative techniques exist they should be used instead.

3. Toxicological studies cannot be trusted. Because of the lack of information showing a product to be harmless it should be assumed that it is not.

Avoidance of pesticides is a goal to which some of these people have devoted much of their time and efforts and therefore suggestions that they should tolerate being exposed to insecticides are often not well received.

The arguments of other people who favor the use of pesticides in residential dwellings are usually as follows:

1. Exposure to pesticides has so far not affected me.
2. Everything in life is harmful and therefore it is not practical to try and avoid those things that might hurt us.
3. If it gets rid of the cockroaches, whatever risk is associated with it is worthwhile.

These people, who have great faith in pesticides, generally find it unacceptable that they should have to do without such an effective tool.

Although pesticide useage was never encouraged, some applications took place at the request of individual tenants. Records of all commercially applied insecticides were kept and the effectiveness of each was assessed.

During the two year period June 1980 to May 1982, crack and crevice treatments with chlorpyrifos were carried out on 28 occasions in 25 different suites (one quarter of the apartments in the building). Of these, 67 % (18 treatments) were done during the first six months of the study, perhaps indicating that as the work progressed confidence in the work of the tenant committee increased thus the need for pesticide treatments decreased.

APPENDIX 5: SANITATION TRIAL

Although tenants at Acadia were requlary encouraged to keep their apartments clean, this was not known to reduce the problem in any of the suites. It is not known how many people complied with these requests.

During the study, five suites were selected for supervised six month sanitation programs. A two week pre-trial survey using sticky traps indicated that two of the suites had high infestation levels, two supported a moderate cockroach population, and one had a low population. Attempts were made to increase the sanitary level of each suite to reduce food and harborage. For this purpose the following guidelines were established:

- No garbage stored under the sink. Trash emptied at least four times per week.
- No newspapers, rags or cardboard kept in kitchen cupboards.
- All food stored in insect proof containers.
- Number of items in cupboards and on counters reduced.
- Dishes washed right after use and not left overnight in the sink or on the counter.
- Counters and floor wiped of crumbs and spills after each meal preparation.
- Once a month everything in the bathroom and kitchen cupboards is to be removed and all the shelves wiped down.
- Floors washed twice a month.

Residents did all of the cleaning themselves and each suite was periodically checked. After one month, apartments were re-evaluated using a two week trap survey. The results are summarized in table 16.

Two of the five suites failed to follow the established guidelines of their apartment throughout the trial. The post-trial trap captures indicate that the population was not drastically reduced in any of the suites and seemed to be increasing in apartment #2. The tenants in this suite indicated that they had also seen more cockroaches than previously.

Although it would have been desirable to carry this trial on for a longer period, the amount of cooperation and goodwill received from the residents was deteriorating and consequently it was decided to discontinue the experiment. Because cockroaches can survive long periods without food or shelter, one month is probably not an adequate period to test the effects of improved sanitation. Since decline of the cockroach populations would take a long time, residents will not see the relationship between their efforts and the cockroach problem and therefore will not be motivated to continue.

Table 16: EFFECTS OF BETTER SANITATION AFTER ONE MONTH

Apartment	Pre-trial trap count*	Density Rating	Adhered to sanitation	Post trial trap count (c/t/wk)*	Density Rating
1	15	High	No	17	High
2	11	High	Yes	14	High
3	7	Moderate	Yes	5	Moderate
4	7	Moderate	No	4	Moderate
5	2	Low	Yes	1	Low

* Values represent number of cockroaches captured per sticky trap per week, averaged over a two week period. Density ratings are explained on page 119.

APPENDIX 6: TEMPERATURE REGULATION AT ACADIA

Several of the most densely infested apartments at Acadia were much warmer than other suites. Also the building locker and laundry rooms, which appeared to have sufficient humidity, harborage and food to support an infestation, never had any cockroaches. Temperature monitoring revealed that these utility areas maintained temperatures below 18 C throughout the winter months.

Several residents at Acadia reported great success in controlling cockroaches by reducing temperature in their apartment. Two cases were observed where populations completely collapsed when tenants reduced the temperature in their apartments from 26 to 20 C. Although a precise correlation was not established by experimentation, the evidence is very strong that reducing the temperature of apartments could be an effective means of reducing cockroach problems.

Outdoor temperatures in British Columbia are usually below 20 C for at least seven months of every year thus keeping the building cool during this period should not be difficult. The heat at Acadia is provided by hot-water baseboard radiators which originates from a natural-gas-fired boiler in the basement. The pipes run up the four central pipe chutes and enter the apartment underneath the kitchen cabinetry. The amount of hot

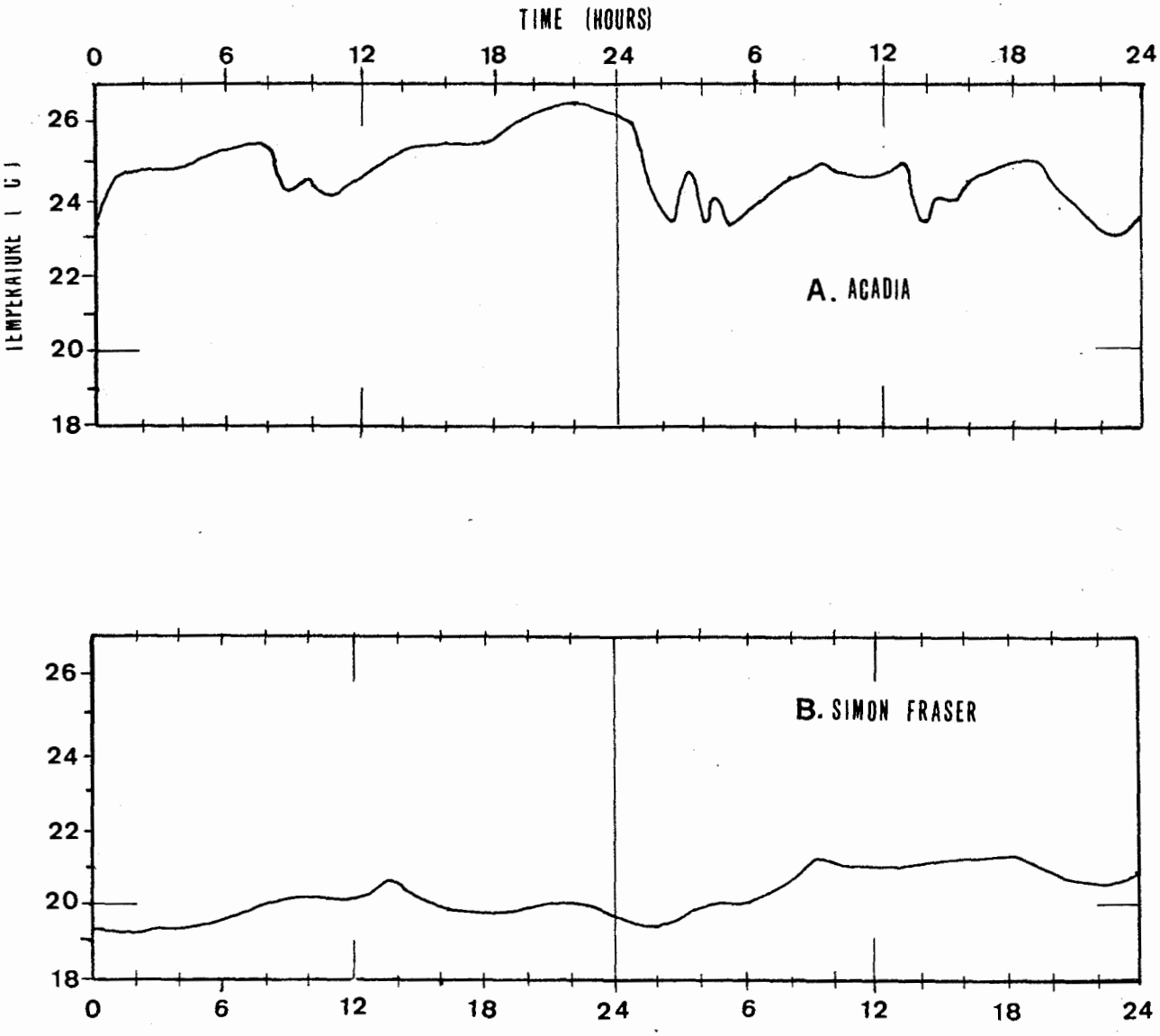
water entering the suite is controlled by a valve which is operated by the resident. Due to the design of the heating system, the temperature in the apartments was very uneven. The kitchen was always the warmest area in the suite (average 23.8 C) and the bedroom always the coolest (average 19.7 C).

Continuous temperature readings were taken in different areas of the several buildings using a thermograph. In figure 5 the records of measurements taken in a kitchen at Acadia (5A) is compared with the kitchen of a non-infested student family residence at Simon Fraser University (5B), about twenty miles away. Temperatures in the kitchen and bathroom areas at Acadia were always at least 21 C and were often much higher. Since heating pipes ran underneath the cabinets, the lower cupboards were usually 4 C warmer than the rest of the kitchen and consequently maintained a temperature around 27 C.

In figure 5A the mean temperature is about 24 C, although the actual temperatures range from 23 to 26 C. Generally temperatures were higher in the afternoon and evenings. The apartment windows were mostly closed during the first 24 hour period, but were left open from hour 18 to 22 of the second day resulting in lower than normal evening temperatures.

In figure 5B the mean temperature is about 20 C. Little change occured in the kitchen temperature throughout the day, and all temperatures remained within the range of 19 to 21 C.

Figure 5: TEMPERATURE RECORDS FROM THE KITCHEN OF AN INFESTED APARTMENT AT ACADIA AND A NON-INFESTED APARTMENT AT SIMON FRASER UNIVERSITY



During the work at Acadia, it was found that installation of a thermometer in the kitchen area of the apartment increased residents' awareness of the temperature and served as a reminder to keep the heat down. This tactic is simple and inexpensive and is strongly recommended for all urban cockroach control programs.

The normal way residents at Acadia reduced the temperature in their apartment was to shut off the radiator valve. However, even when the hot water was turned off most apartments were still too warm. In the suite where I lived the heat was off for two years and yet the kitchen was still always above 23 C. This would indicate that a large amount of heat in the apartment comes from the surroundings. Since to keep an individual apartment cool it was usually necessary to leave the balcony door open, an uncomfortable draft was often present. Furthermore, most people were afraid of their infants gaining access to the open balcony and so were usually unwilling to leave the door ajar. These factors all hampered efforts to use temperature reduction as a control technique.

Although many of the public areas of the building were overheated, none of these locations had cockroach infestations. Many residents suspected that heat from the core of the building was partly responsible for the apartments being overheated, however this was never substantiated. Based on numerous complaints about the temperature in the hallways, some efforts were made to reduce the heat. The warmth of this area seemed mostly due to heat generated from the lighting and from the furnace chimney combined with grossly inadequate air circulation. Despite extensive efforts to correct this situation the temperature never dropped below 25 C

and was often higher. Stairwell temperatures were a constant 27 C throughout the study.

Although any temperature reduction would be useful in an IPM program, the best results would be achieved if kitchen temperatures were maintained at below 20 C. If the cockroaches fail to find a harborage above this temperature, eggs will not hatch, oothecae will not be produced by the females and the time required to reach maturity will be doubled (Tsuji and Mizuno 1972).

Unfortunately this is slightly below the normal comfort range, 22 to 24 C, of most residents. At 20 C most people would find it chilly and would need to wear a sweater, particularly if they were inactive. Nevertheless, some people are willing to tolerate this condition, particularly if it were to eliminate the need for pesticide use in their suite. After a period of several weeks most people acclimatize to the lower temperature anyway. Even if it were necessary to set a higher temperature threshold, considerable benefit would still be derived.

Clearly, temperature management in the apartments would need to be approached on a building wide basis. As in most multiple dwellings in British Columbia, the cost of heating the apartments in Acadia is included in the rent and is not charged on the basis of consumption. Consequently, there is no economic incentive for people to keep the radiator turned down.

The most appropriate solution to the heat problem at Acadia would have been to reduce it at the source; the boiler room. The temperature of the water leaving the boiler was quite high (82 C) in order to assure that plenty of heat was available to all suites. This was unnecessary for most

of the year thus the temperature of the radiators could have been reduced by at least 15 C, and perhaps more. In addition to this, the boiler could have been shut off completely for a few hours every night using an automatic switching device. Experimentation would be necessary to determine the optimal combination of these two tactics and to be sure that temperatures in the residences did not become uncomfortably low.

No doubt a great deal of money would have been saved on fuel costs if these suggestions were adopted and this should have paid for the cost of making the changes. However, despite repeated attempts to encourage the management to initiate temperature reduction at Acadia, they could never be convinced of its value.

APPENDIX 7: SEALING OF APARTMENTS AT ACADIA

Many tenants in Acadia centered their control efforts on disrupting cockroach movement within or between apartments. Tremendous faith was put on "sealing" apartments as a cure to the cockroach problem. This seemed to be due to the residents' belief that most of the insects did not orginate from within their apartment but rather were continuously immigrating from elsewhere and in some cases this seemed to be true. The value of sealing to reduce harborages has already been mentioned.

Because of the enthusiasm expressed for sealing programs, considerable funds and efforts were directed toward making silicone glue and duct tape available to those tenants who wanted it, although in retrospect cheaper materials probably could have been used. Limited assistance and direction were also given on how and where to use these products.

Problems were encountered with tenants using the sealing compounds in such a way that they made the apartment appear unsightly. One resident went so far as to seal all of his cupboards and drawers permanently shut. Furthermore, most sealing efforts were only superficial since few residents actually crawled inside the cabinetry to reach where the water pipes entered the wall and where most of the cockroaches presumably entered the suite.

Some of the residents reported that their problem had significantly improved after sealing, however most people felt that it had not made much difference. Although no scientific evaluation was made of the value of this technique, it was observed that where populations were already very low, thorough sealing would often cause trap captures to decline to zero.

APPENDIX 8: MASS TRAPPING TRIALS

An experiment was carried out to evaluate the use of mass trapping. The test was carried out in a suite which was known to have had a high infestation for the previous 12 months. A two week pre-trial survey using one Roach Tent® in the kitchen area of the aparatment confirmed the presence of a large number of cockroaches (18 c/tr/wk[1]).

The experiment was carried out over 31 days. Initially six sticky traps (five "Mr. Sticky"® and one "Roach Tent"®) and three petroleum jelly jar traps baited with apple were placed in the apartment. After five days it was found that the jar traps required too much maintenance and that the tenants were disturbed by the cockroaches running freely inside them. The jars were removed and replaced by 7 sticky traps (Roach Tent®). Most of the fourteen traps were placed in the kitchen but some were put in the bathroom. It was found that this was the largest number of traps that could be used without being in the way of the residents.

At the end of the trial the traps were removed and one new Roach Tent® was deployed in the kitchen for four weeks. Table 17 summarizes the data. Although 1225 cockroaches were removed from the population, the density after the end of the trial was still high (14 c/tr/wk[1]). The residents said they did not notice much change in the level of infestation and the problem continued for many months after the trial.

1. Units are cockroaches per trap per week.
Note method of calculation described on page 118.

Table 17: FIELD TRIAL OF MASS TRAPPING

Trap	Type	Days Deployed	Captures*			Total	Capture Rate c/tr/wk**
			Ad	LN	SN		
1	Mr Sticky®	31	15	12	30	57	13
2	Mr Sticky®	31	20	22	13	55	12
3	Mr Sticky®	31	30	24	70	124	28
4	Mr Sticky®	31	35	29	27	91	21
5	Mr Sticky®	31	44	16	14	74	17
6	Roach Tent®	31	14	46	12	72	16
7	Roach Tent®	26	19	23	39	81	22
8	Roach Tent®	26	14	27	70	140	38
9	Roach Tent®	26	19	29	43	91	25
10	Roach Tent®	26	6	77	23	106	29
11	Roach Tent®	26	7	15	20	42	11
12	Roach Tent®	26	11	23	65	99	27
13	Roach Tent®	26	14	61	40	115	31
14	Jar Traps***	5	30	48	0	78	37

* Ad = Adults
LN = Large nymphs (mostly 1 - 3 instar)
SN = Small nymphs (mostly 4 instar or older)

** Capture rates measured in cockroaches per trap per week.

*** Trap captures from jar traps represent the data from three traps combined.

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