URBAN ENTOMOLOGY: PAST AND PRESENT

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Abstract - Urban entomology has grown dramatically in the last 25 years and has attained a disciplinary status within the entomological and pest management community. As urban centers have grown throughout the world, the importance of the control of arthropods and insects associated with humans and their structures has taken on new significance. By the year 2010, nearly 56.5% of the world's population will live within urban areas. Increased commerce and travel between urban centers have resulted in the widespread dispersal of exotic pests such as the Formosan subterranean termite, Africanized honeybee, Asian tiger mosquito and German yellowjacket. In the last 10 years, the concept of Integrated Pest Management (IPM) has drawn more attention. In addition to chemical applications, supplemental recommendations such as cultural control methods, sanitation, alternative technologies, and more environmental sensitive insecticides are now often considered. Our use of chemicals to control urban pest will continue, however, the development of specific formulations and use patterns to reduce exposure to non-target organisms and the environment will continue. In the future, we will utilize molecular biology to assist in the identification of populations of exotic insects and their origin, construct lethal elements to be incorporated in to pest populations, and examine and combat insecticide resistance mechanisms. The 21st Century promises to bring exciting new changes and developments to urban structural pest control.
Key words - Integrated pest management, exotic pests, insecticide resistance

INTRODUCTION

As the new millennium nears, it seems appropriate that we review the events and developments that have lead to the evolution of urban entomology as a discipline and legitimate area of study. The 3rd International Conference on Insect Pests of the Urban Environment is a testimony to the progress that has been made in urban entomology. While household and structural pests have always been of importance, they attracted very little attention during the first 50 years of the 20th Century compared with agricultural or medical insect pests. The classic reference by Arnold Mallis, The Handbook of Pest Control, was first published in 1945. This original text has undergone 8 revisions and still remains one of the most useful texts for urban entomologist worldwide. Other texts such as Ebeling's Urban Entomology, Bennett's and Owens' Advances in Urban Pest Management, Hadlington's and Gerozisis' Urban Pest Control in Australia, and Robinson's Urban Entomology Insect and Mite Pests in the Human Environment are examples of more recent contributions to the general topic of urban entomology. Throughout the last century there have been certain events and discoveries that have been pivotal to the development of urban entomology as we know it today. I would like to review some of these developments and their impact on the direction of urban entomology. Finally, I will try to look ahead to the next 20 years and speculate on possible advancements and their impact on the future direction of urban entomology.

In many ways, the development of urban entomology and pest management is also the story about the growth of urban centers and the introductions of exotic pests. By 1900, the urban populations of Germany, France and the United States had reached 56, 41 and 40%, respectively. In 2010, greater than 80% of the residents of these countries will live in urban areas. World urbanization continues to grow at an alarming rate, an estimated 56.5% of the world's population will be living in urban centers by 2010, the fastest growth occurring in developing countries (Robinson, 1996). The major pest species of ants, cockroaches, fleas, flies, lice and mosquitoes have spread from one urban center to another. Even remote islands are not immune to introductions of urban pests, the American cockroach, *Periplaneta americana* (L.), and German cockroach, *Blattella germanica* (L.), being introduced into the Galápagos in 1877 and 1920, respectively (Peck *et al.*, 1998). When urban centers were isolated by large distances and long travel times, the spread

Proceedings of the 3rd International Conference on Urban Pests.
Wm H. Robinson, F. Rettich and G.W. Rambo (editors). 1999.

of many exotic pests was greatly retarded. At the turn of the 19th century, travel from Europe to North America required a minimum of 7 to 10 days by sea. However, today it is possible to fly from New York to Prague in < 24 hours. The short duration of travel and improvements in shipping make it possible for many exotic pests and vectors of disease with short life cycles and very specific environmental demands to make these journeys. For example, the Asian tiger mosquito, *Aedes albopictus* (Skuse), is believed to have entered the United States in shipments of used automobile tires. From 1978-1985, over 11 million used tires from 58 different countries were imported into the United States (Reiter and Sprenger, 1987).

The past century has been marked by numerous introductions of exotic pests and it is certain that this trend will increase especially with implementation of international trade agreements such as NAFTA (North American Free Trade Agreement) and GATT (General Agreement on Tariffs and Trade). Some of the important introductions are listed in Table 1.

At the turn of the 20th Century, inorganic insecticides such as borax, boric acid, sodium fluoride, phosphorus, and thallium sulphate were being used to control cockroaches, ants and other household pests (Cornwell, 1976). Paul Müller's discovery of the insecticidal properties of DDT in 1940 signaled a new era of the use of synthetic chemistry to control insects. By 1955, 100 million pounds of technical DDT was being produced annually (Cornwell, 1976). With the aid of chemists it was possible to develop insecticidal compounds capable of killing cockroaches, lice, fleas, ticks, flies, and mosquitoes. Within 15 years following World War II, chlorinated hydrocarbons such as chlordane, aldrin, dieldrin, and lindane; carbamates such as propoxur and carbaryl; and organophosphates such as malathion, dichlorvos, and fenitrothion were registered and used for pest control in and around structures. Environmental concerns raised by Rachel Carson's The Silent Spring would begin an environmental awareness that would ultimately lead to the cancellation of uses of the chlorinated hydrocarbons in the United States. The debate of the environmental impact of pesticides continues today and many of the standard insecticides used in the 1960's and 1970's have been replaced. In fact, it is likely that methyl bromide will be largely replaced as a fumigant in urban settings within the next 10 years. Today it is rarely used against drywood termites and wood-boring beetle infestations in California.

The widespread use of synthetic insecticides to control urban insect pests would create a number of paradigms, some of which persist today. For example, chlordane would have a major impact on urban entomology in several ways because chlordane provided an inexpensive way to treat soil and protect wooden structures from subterranean termites. The residual activity of treated soils appeared to be indefinite and in fact, some of soils treated at those original test sites remained active for 30 years or more (Kard *et al.*, 1989). Chlordane and the use pattern that was adopted by the pest control industry would dominate the way in which subterranean termite control was conducted until its cancellation in the United States in 1987. With the need to register other organophosphates and pyrethroids the paradigms generated during the preceding decades when chlordane was used would be challenged and changed. In addition, there was other dramatic changes in application technology such spray tips and fully contained pesticide systems and foams that also occurred. The success of chlordane as a soil preventive and remedial treatment in some ways probably stifled basic research on subterranean termites for nearly 40 years. For example, Ebeling and Pence (1957) reported that the western subterranean termite, *Reticulitermes hespersus* (Banks), was unable to tunnel through sand barriers consisting of particles between 16 to 18 mesh. This finding went unnoticed until Tamashiro and co-workers at the University of Hawaii conducted tests with basaltic gravel and Formosan subterranean termites (Tamashiro *et al.*, 1987). The loss of chlordane created an atmosphere conducive to the development of baits and more integrated approaches to controlling termites and the basic research needed to support such treatments. It is likely that the changes we have recently seen in termite control industry would not have occurred if chlordane had not been canceled in the United States.

Chlordane and the carbamate, propoxur, would also influence treatment strategies and methodology for the control of the German cockroach, *Blattella germanica*, for the 30 years. For the first time, pest control operators had liquid formulations of insecticides that could be applied to surfaces and provided

Proceedings of the 3rd International Conference on Urban Pests.
Wm H. Robinson, F. Rettich and G.W. Rambo (editors). 1999.

long-term residual activity against German cockroaches. The use of the compression sprayer and liquid formulations permitted applications to surfaces inside kitchens, food-preparation areas, bathrooms and areas likely to harbor *B. germanica*. An entire industry was established around this practice and as the importance of German cockroaches spread so did its acceptance. Additional carbamates and organophosphates were registered and used for the next 30 years. In 1966-67, the pyrethroid insecticides of allethrin series and some of resmethrin series were introduced (Wickham, 1995). Since then, a number of pyrethroids that showed good residual activity, moderate knockdown, and high mortality such as cyfluthrin, cypermethrin, deltamethrin, and permethrin would gain wide usage. Advances in formulation chemistry such as wettable powders, microencapsulated formulations, suspended concentrates, and flowable concentrates helped increase their bio-availability and residual activity. In the late 1970's, treatment practices were modified to also incorporate crack-in-crevice treatments with aerosol formulations. The application of insecticide sprays to control German cockroaches would remain the principle method of control until the early 1990's when the use of slow-acting baits would become increasingly more important in the United States (Reierson, 1995).

Although many insecticides are extremely promising in clinical laboratory studies, Ebeling *et al.* (1966) demonstrated that *B. germanica* avoided residual deposits of certain insecticides. Cockroaches surviving exposures to repellent deposits formed a nucleus for reinfestation. A direct relationship between contact activity and repellency exists. As knockdown activity of residual deposits increases, repellency also increases (Rust, 1995). To counteract repellency, Ebeling (1995) proposed the use of boric acid powder and a concept referred to as "built-in pest control." The use of boric acid powder to treat wall voids, sub-cabinet voids and areas likely to harbor cockroaches still remains one of the most effective strategies even against strains of *B. germanica* that have developed broad spectrum insecticide resistance. Until this ground-breaking research, little attention had been given to behavioral modifications of household insect pests caused by exposure to insecticides. Over the next 30 years, numerous laboratory tests would be devised to explore the relationship between inherent insecticidal toxicity and avoidance with cockroaches and other household insects.

The widespread use of synthetic chemicals with long-residual activity to control household and structural pests also signaled the beginning of insecticide resistance. Probably one of the best documented cases is the development of resistance in the German cockroach. Within 7 years after the introduction of chlordane, the first case of insecticide resistance in *B. germanica* was reported by Heal (1953). This was quickly followed by reports of resistance to carbaryl, diazinon, malathion, and lindane as reviewed by Cornwell (1976). The development of cross-resistance also affected the use of other carbamate and organophosphate insecticides. For example, the development of resistance to chlorpyrifos and diazinon conferred cross-resistance to the carbamate bendiocarb. Cochran (1989) reported resistance to a wide variety of organophosphates, carbamates, pyrethrins, and pyrethroids. In addition to physiological resistance, Silverman and Bieman (1993) documented behavioral resistance in certain strains of *B. germanica* that avoided toxic baits containing glucose, but were attracted to baits with fructose. Over the last 40 years, German cockroaches have developed physiological resistance to almost every new class of insecticide that has been extensively used against them.

The development of resistance is not limited to *B. germanica*. Resistance has been reported in other urban pests such as cat fleas, head lice, house flies, mosquitoes, and stored grain pests. The development of insecticide resistance and the failure of chemical applications to provide outstanding control are probably one of the major reasons that urban entomologists have recently proposed more integrated approaches to pest management. Nearly 30 years would pass after Stern *et al.* (1959) proposed the concept of Integrated Pest Management (IPM) to control agricultural pests before it would begin to gather favor with urban entomologists. IPM is based on three fundamental concepts: 1) the manage resource is a component of a functioning ecosystem, 2) the presence of an organism does not necessarily constitute a pest problem, and 3) consideration of all possible pest control options before any action is taken (Flint and van den Bosch, 1981). One very important distinction between IPM in agriculture and

Proceedings of the 3rd International Conference on Urban Pests.
Wm H. Robinson, F. Rettich and G.W. Rambo (editors). 1999.

urban environments is that eradication of the pests is typically the goal in an urban control program. One very important similar goal is to ultimately reduce the amount of insecticide applied. This has certainly become an important consideration for the registration on insecticides in the last decade.

In a recent survey in the United States, 76% of the respondents were very concerned or somewhat concerned about using pesticides in and around the home to control insects. This increased to 86% when respondents were asked about applying pesticides in and around a child's school. Approximately 43.8% of these respondents thought that pesticides (in general) cause cancer. Even though the public is concerned about pesticides, only 1.4% of the respondents knew that the letters IPM stand for Integrated Pest Management and 3.8% knew what Integrated Pest Management was (Potter and Bessin, 1998). It is evident that a major extension effort is still needed if IPM is going to be realized in urban settings.

The ineffectiveness of many sprays, the development of resistance, and the fortuitous discovery that hydramethylnon provided outstanding control of *B. germanica* when formulated as a bait renewed the interest insecticidal baits. In the 1930's and 1940's various baits containing arsenicals, sodium fluoride, and thallium sulfate were used, but they were largely ineffective (Rust, 1986). Baits containing organophosphates and carbamates provided rapid knockdown, but were repellent to some insects. The search for bait toxicants to kill red imported fire ant, *Solenopsis invicta* Buren, would shift our thinking to slow-acting toxicants that were not repellent and active over a broad concentration range (Stringer *et al.*, 1964). The discovery of slow-acting toxicants such as hydramethylnon and insect growth regulators such as fenoxycarb, pyriproxyfen, and hexaflumeron would stimulate new research for ant, cockroach and termite baits. The full impact on urban pest management of many of these baits has yet to realized.

In an effort to use less insecticides, especially in environmentally sensitive areas, alternative control strategies such as the use of extreme temperatures, modified atmospheres, and structural modifications such as termite sand barriers and stainless steel screen are being used. Conservators at museums have used low temperatures for many years to kill pests infesting artifacts and objects. Within the last 10 years, the use of high temperatures has been successfully used to kill wood-destroying insects as well as cockroaches. Temperatures in excess of 49 °C for 60 min will kill all stages of the western drywood termite, *Incisitermes minor* (Hagen). Naked larvae of the powderpost beetle *Lyctus planicollis* LeConte died from a 60-min exposure to 51.7 °C (Rust and Reierson, 1998). Heat treatments of food handling facilities provided outstanding control of German cockroaches (Zeichner *et al.*, 1996). Modified atmospheres containing < 0.1% O_2 provided complete kill of 12 different species of insect found in museums within 48-72 hours (Rust *et al.*, 1996). The egg and pupal stage of the cigarette beetle requiring about an 8-day exposure to provide complete kill. This technology is now gaining wide acceptance by conservators (Selwitz and Maekawa, 1998) and is readily adaptable to structural pest control, especially treating sensitive objects such as medical equipment, computers, and electronics.

As we begin the new century, insecticides will continue to be an important tool in our efforts to control urban pests. However, their use patterns will be greatly modified. The broad spectrum insecticides will be replaced with more species specific and environmental friendly materials. Broadcast applications will be phased out for site specific and prescription types of treatments. Fumigants will be gradually phased out. The interest in new natural products and insecticides and non-chemical alternatives will continue. The use of classical biological control agents such as predators and parasites will primarily be limited to outdoor situations involving pests of ornamental plantings.

Molecular techniques will become important tools of urban entomology researchers in the next century. In our battle with exotic insect pests, molecular tools can provide answers as to the origins of these exotic pests. Molecular biology also promises new control tools by transposing and inserting lethal genetic material into pest insects. The next advances in the continuing battle against insecticide resistance are likely to be the result of molecular research. Great progress has been made in the last 25 years in urban pest management and the future looks even more promising.

Proceedings of the 3rd International Conference on Urban Pests.
Wm H. Robinson, F. Rettich and G.W. Rambo (editors). 1999.

Table 1. Some important exotic urban insect pests and the date of introduction into various countries.

Common name	Scientific name	Country	Date of Introduction	Reference
Africanized honeybee	*Apis mellifera scutellata*	Brazil	1957	Winston 1992
		Venezuela	1976	
		Panama	1982	
		Mexico	1987	
		United States	1990	Visscher *et al.* 1997
Argentine ant	*Linepithema humile*	United States	1891	Passera 1994
		Australia	1939	
		South Africa	1908	
		Europe	1904	
Asian cockroach	*Blattella asahania*	United States	1985	Koehler and Patterson 1987
Asian tiger mosquito	*Aedes albopictus*	Hawaii	1830-1896	Rai 1991
		Guam	1944-1948	
		United States	1985	
		Brazil	1986	
Formosan subterranean termite	*Coptotermes formosanus*	Japan	<1700	Mori 1985
		South Africa	1925, 1958	Su and Tamashiro 1985
		Hawaii	1907	
		United States	1966	Beal 1985
German yellowjacket	*Vespula germanica*	New Zealand	1960	MacDonald *et al.* 1980
		United States	1968	
		South Africa	1976	
		Brazil	1976	
		Australia	1977	
West Indian powderpost termite	*Cryptotermes brevis*	United States	1919	Banks and Synder (1920)
		South Africa	1918	Croaton 1948
		Australia	1946	Gay 1969

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Proceedings of the 3rd International Conference on Urban Pests.
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