ROLE of RESERVOIR HABITATS and POPULATIONS in the URBAN ENVIRONMENT

William H Robinson
Urban Pest Control Research and Consulting
2749 Market Street, #331, Christiansburg, Virginia 24073

Abstract Pest status of household and structural pests is based primarily on their persistence in the urban environment. Persistence of pest populations is determined by availability of reservoir habitats that harbor large and stable populations, which supply individuals to maintain small, local infestations. Success of pest species in the urban environment is dependent on a network of infestations and reservoir populations. Decline of pest species is linked to reduction or elimination of reservoir populations. The role of reservoir habitats and populations in the persistence of German and American cockroaches, old house borer, and American and European dust mites is discussed. *Blattella germanica* survives as a pest only indoors in local infestations and a limited number of urban reservoir populations. The importance of these populations is evident in the decline in abundance and reduced pest status of this cockroach. *Periplaneta americana* lives in local infestations outdoors and indoors, and is supported by reservoir populations in urban sewers. There is limited potential for reducing its reservoir habitats, and it is likely to maintain its pest status. A cerambycid *Hylotrupes bajulus* occurs only in local infestations of structural softwoods in urban and rural buildings, and in reservoir populations in lumber storage sites. Effective control of structural infestations and improvements in lumber storage have removed the key reservoirs needed for persistence of this pest. *Dermatophagoides* spp. dust mites depend on small, local populations to persist in the living space. Long-term pest status of these mites is expected because of the relative ineffectiveness of cleaning to remove enough of a pest population to achieve reduction, and the ease in which mites are carried to new sites or existing infestations.

Key Words Reservoir habitats reservoir populations metapopulations pest status

INTRODUCTION

Insect pests in the urban ecosystem can be characterized as species removed from their natural habitat, and able to adapt to variable conditions and resources in the urban environnment. Success of many household and structural pests is linked to the distribution of patches of favorable habitats, referred to as habitat islands or reservoirs (Simberloff and Abele, 1976; Davis and Glick, 1978). Persistence of these pests is maintained by a network of small infestations, or sink populations of Hanski (1998) connected to larger, reservoir populations. Species maintain their abundance by the infestation and re-infestation opportunities of this habitat and population network. Pest abundance declines and extinction occurs with spatial isolation of small infestations and the elimination of reservoir or source populations (Hanski, 1998; Stejskal, 2002).

The concept of specific or isolated habitats hosting reservoir populations of household pests, and for them to serve as foci for future infestations, was first proposed by Linsley (1944), and expounded by Hinton (1945), and Hatch (1953). For medically important insects, the concept of natural foci or zoonoses for diseases and disease vectors parallels that of household pest reservoirs. Disease foci may be small populations of their primary insect vectors or their host animals (Hudson, 1944; Audy, 1958). Other applications of the concept of urban habitats serving as refuges for pest and non-pest arthropods include suburban gardens (Owen and Owen, 1975), urban refuse dumps (Nuorteva et al., 1964; Boase, 1999), and urban highways (Lussenhop, 1973).

Presented here is a discussion of the role of reservoir habitats and populations in maintaining the abundance of household and structural pests. Four species will be used as examples of

Proceedings of the 4th International Conference on Urban Pests.
Susan C. Jones, Jing Zhai, and Wm H. Robinson editors. (2002)

long-term success or failure linked to a network of favorable habitats that support small infestations or reservoir populations. The species considered are the German cockroach, *Blattella germanica* (L.), American cockroach, *Periplaneta americana* (L.), a wood-infesting, cerambycid beetle, *Hylotrupes bajulus* (L.), and the house dust mites, *Dermatophagoides farinae* Hughes and *Dermatophagoides pteronyssinus* (Trouessart).

Cockroaches

Pest status of domiciliary cockroaches can be attributed to the continued presence of large numbers of individuals in or around the living space, and the psychological stress and social stigma attached to their presence (Wood et al., 1981; Thoms and Robinson, 1986; Robinson and Bao, 1988). Continued infestation is due in part to relative ineffectiveness of control measures, and the ability of reservoir populations to facilitate re-infestation. Control of infestations is often a recurring sequence involving insecticide treatment followed by a decline in the infestation, then gradual population recovery and an increase in the number of cockroaches, and treatment again. The recovery stage in the cycle is due to limited initial control, or re-infestation from outside, or both (Larter and Chadwick, 1983). Persistence of German and American cockroaches in the urban environment is based on a network of small infestations in relatively unstable habitats, and large, reservoir populations in stable habitats. Without reservoirs these cockroaches would not sustain the abundance necessary for pest status.

German cockroach. This species originated in southern Asia and lives primarily indoors where it occurs as a pest. Infestation sites include single- and multiple-unit dwellings, transportation vehicles, and food handling sites. Reservoir habitats with large populations include food warehouses, food retail stores, and large apartment buildings. Adults and nymphs of *B. germanica* crawl or are carried from reservoir habitats to initiate small infestations or to re-infest existing ones (Akers and Robinson, 1981, Bloomquist and Robinson, 1999). With the aid of a network of reservoir habitats and the ability to develop physiological resistance to insecticides, this cockroach has been a dominant household pest around the world for decades.

In the United States and countries in eastern and western Europe the abundance and pest status of *B. germanica* has declined in the last 5-8 years (Landau et al., 1999). In the United States it is no longer an economically important pest (Jenkins, 2001), and this status is expected in other countries that utilize modern toxic baits. The change in abundance is probably due to a combination of factors (Robinson, 1999), but the most important are the ability of toxic baits to reduce the number of individual cockroaches in an infestation in a short period of time, and the widespread use of baits in the urban environment, with the elimination of reservoir populations as a result.

Application of modern toxic bait for cockroach control kill a large number of adults and nymphs in populations in 3-4 days. This severe reduction in the population, perhaps taking it past a theoretical tipping point (Gladwell, 2000), prevents the recovery stage of the typical control sequence (Zeman et al., 1992; Zeaman, 1993). The widespread availability and use of baits has resulted in the elimination of local infestations, such as those in houses and apartments, and also large reservoir populations, such as those in large apartment buildings and warehouses.

As the network of local infestations and reservoir populations is decreased, the availability of individuals or groups of cockroaches for establishing or re-infesting sites eventually drops below a critical level. Habitats with suitable resources for *B. germanica* remain in the urban environment, but without an established network of populations there are few opportunities for them to become infested or re-infested. Breaking the cycle of treatment, recovery, and re-treatment has been possible because this species exists primarily indoors, and has limited dispersal between habitats. As the supply of recruits available from reservoirs or small infestations declines, control of local infestations results in elimination without recovery.

American cockroach. The tropical to temperate distribution of this species is attributed to its ability to adapt to various conditions, and to live and breed indoors and outdoors. Pest populations of *P. americana* occur in urban and rural environments around the world. Important reservoir habitats include urban landfills, food warehouse and distribution sites, and especially the sewer and rainwater disposal system of below-ground pipes found in urban and suburban areas (Eads et al., 1954; Jackson and Maier, 1955; Chadwick and Shaw, 1974; Rust et al., 1991; Zhai and Robinson, 1991). In the sewer system, resources and conditions are relatively stable year-round, and dispersal to other habitats is facilitated by sewer connections to buildings or street openings. Adults and nymphs move freely over a wide area through the interconnected system of pipes to establish or replenish infestations.

The abundance of *P. americana* in the urban environment is likely to remain unchanged in spite of modern insecticides and control programs. Key to the persistence of this cockroach is that reservoir habitats are not limited to indoor sites, and individuals disperse by walking and flying to new sites. Infested sites in most urban environments can be numerous, and long-term control or elimination is unlikely because of the opportunity for re-infestation from untreated sites. Extensive reservoir habitats supporting large populations, and the ability for *P. americana* to live outdoors and disperse to new habitats, will likely sustain this species as a peridomestic pest. Prevention methods and improved building construction may be successful in limiting its access to indoor habitats, but outdoor infestations will remain and re-establish when conditions become suitable.

Wood-Infesting Beetles

Pest status of wood-infesting beetles, such as powderpost (Anobiidae, Bostrichidae, Lyctidae) and longhorned beetles (Cerambycidae), is based on cosmetic damage to wood, and loss of structural integrity of timber pieces used in building construction. The continued presence of these insects in structural wood is due, in part, to ineffective control methods and the availability of natural populations in undisturbed areas, or reservoir populations in urban environments.

Larval development of anobiid and lyctid pest species is slow and infestations may be undetected for several years. This characteristic of their life history increases the amount of cosmetic and structural damage they cause, and their pest status in the urban environment. Persistence of a cerambycid beetle *Hylotrupes bajulus*, the old house borer, is based on household infestations and a limited number of reservoir populations in the urban environment. The audible feeding sounds of late-stage larvae contribute to the pest status, and assist in the detection of this beetle.

Old house borer. Larvae infest seasoned softwoods (pine, spruce, fir) commonly used in building construction around the world. This cerambycid probably originated in the forests of northwest Africa, but now is distributed in eastern North America, northern Europe, and South Africa (Durr, 1954; Becker, 1979). Pest status is linked to feeding by the larvae, and the large volume of wood consumed during the long larval stage (Cannon and Robinson, 1981). Old and new buildings infested with this beetle form a network of usually small populations in urban environments. From these sites female beetles fly to infest or re-infest structures, or larvae are carried to other sites in infested wood. Reservoir populations occur where supplies of lumber for building construction or repair are manufactured and stored for professional or homeowner use (Cannon and Robinson, 1982). From these storage facilities infested wood is transferred to new construction sites.

The network of structures and lumber storage sites that maintained *H. bajulus* in the urban environment has undergone significant change. The status of this beetle as a structural pest has declined in the United States, and may be doing the same in parts of Europe. The decline in abundance is probably due to effective control methods and materials (Baker and Berry, 1980;

Proceedings of the 4th International Conference on Urban Pests.
Susan C. Jones, Jing Zhai, and Wm H. Robinson editors. (2002)

Powell and Robinson, 1992), which reduced local infestations, and lumber yard sanitation which reduced reservoir populations. This species depends on artificial habitats for survival in most of the regions where it occurs as a pest, and does not occur in natural populations. Without adults moving to new sites or the availability of infested lumber, distribution is expected to decline to isolated patches with limited pest status (Lea, 1976).

House Dust Mites

Pest status of the house dust mites *Dermatophagoides farinae* and *D. pteronyssinus* is based on their role as human allergen producers, which results in their contribution to chronic respiratory asthma and allergic rhinitis worldwide (Voorhorst et al., 1964, 1967). Their continued presence indoors provides an allergen load in the living space and potentially long-term health problems. Dust mites inhabit household fabrics and floor coverings, and feed on debris that accumulates there. Persistence of allergen producing mites in the living space is due in part to the ineffectiveness of chemical and nonchemical controls, and the potential for re-infestation from reservoir populations throughout the urban environment.

American and European Dust Mites. These mites are the most common house dust mites in the urban environment, occurring in living spaces around the world. All stages live on fabric and carpet surfaces indoors where they feed on micro-organisms associated with human and pet skin scales that are found in house dust (Bronswijk and Sinha, 1973). Although some other domiciliary mite species also occur in outdoor populations, there are no apparent natural populations for *D. farinae* or *D. pteronyssinus.* They seem to be restricted to indoor, domestic habitats. Reservoir habitats of these mites are indoor sites with suitable humidity (75% RH) and temperature (27°C), and availability of human and pet skin scales (Arlian, 1989). House dust mites typically are found on or under upholstered furniture such as chairs, couches, and beds, and also on carpeting at these sites. Mites are capable of dispersing from reservoir habitats on clothing and other fabric, and can be carried to other indoor locations (Mollet and Robinson, 1996).

Abundance of *D. farinae* and *D. pteronyssinus* is likely to remain unchanged, due to problematic control and abundance of local or reservoir populations (Lang and Mulla, 1977; Fernandez-Caldas et al., 1990). Control generally includes application of chemicals to kill mites or neutralize allergens, regular vacuum cleaning of infested substrates, and reducing use of upholstered furniture and carpeting. These strategies result in limited long-term control because of the relative ineffectiveness of chemicals and cleaning regimens (Mollet and Robinson, 1993). Important to the success of this pest is the potential for re-infestation from other sites. There is widespread infestation in the urban environment, including living and working spaces, and transportation vehicles. Mites can be transported on clothing to fabric surfaces in automobiles, then to the work place or other living environments (Mollett and Robinson, 1993).

DISCUSSION

Reservoir habitats provide consistent sources of individuals or groups that can replenish local infestations and establish new ones. They are essential to the persistence that establishes pest status for many urban insect and mite pests. Reservoirs influence the design, expectations, and outcome of programs for control or management of pests. Urban pests are successful because of their ability to adapt to new or varied conditions, and to persist with the support of local infestations and reservoir populations (Stejskal, 2002). Based on characteristics of movement and dispersal, and the foundation of habitats and populations, urban pest species can be assigned to either the pest management or pest control program strategy.

Pest Management Strategy

Management programs for reducing pest abundance or infestations to low levels may be effective on species with extensive reservoir habitats and populations, and the ability to freely disperse in the urban ecosystem. The majority of domestic and peri-domestic pests are supported by a network of habitats, which make localized suppression or management the most practical and economic strategy, and the expected result. The American cockroach and *Dermatophagoides* dust mites are examples of pests in this category. They have a broad base of reservoirs, they utilize a variety of foods and harborages sites, and they are capable of dispersing to new habitats and replenishing existing populations. There are few aspects of their life cycle, habits, or distribution that make them vulnerable to long-term suppression by chemical or non-chemical control strategies.

Persistence of other urban pests is due to reservoir habitats and populations within urban and suburban areas, or proximity to populations in natural or undisturbed habitats. These include species of flies, wasps and ants, dermestid and powderpost beetles, stored food moths and beetles, cat flea, several species of cockroaches, and termites. Reduction or elimination of these populations is impractical since it would require drastic changes to indoor living conditions or the destruction of urban habitats with a rich flora and fauna, such as parks, urban trees, gardens, and other green spaces (Owen and Owen, 1975; Davis, 1978).

Pest Control Strategy

Programs with the goal of long-term suppression and elimination of pests from large areas are applicable for species with limited dispersal abilities, and a small number of reservoir populations (Robinson, 1996). However, there seem to be relatively few urban pests with characteristics that fit this category. The German cockroach and old house borer serve as the best examples. Their life cycles have features, such as survival that is limited to indoor habitats or develop on a narrow range of food sources, that make them particularly vulnerable to chemical and non-chemical control strategies. Reduced abundance (Landau et al., 1999) and localized elimination of these economically important pests has been achieved primarily by a combination of effective chemicals and delivery system.

Pests with similar characteristics and with the potential for significant changes in abundance include brown-banded cockroach, *Supella longipalpa* (Serville), domestic species of silverfish, and some food-infesting insects that may not have natural populations. These insects occur primarily indoors and are usually linked to a specific food source. Reduction or elimination of pest populations of species in this group is feasible, and begins with delimiting their reservoir habitats and defining the links these have to local infestations. The concept of reservoir habitats and populations has an important role in management and control of urban pests.

ACKNOWLEDGMENTS

Thanks to Clive J Boase, Pest Management Consultancy, Suffolk, United Kingdom; Susan C. Jones, Ohio State University, Columbus, OH; Larry Pinto, Pinto and Associates, Mechanicsville, MD USA, for reviewing and improving the manuscript. Vaclav Stejskal, Research Inst. Crop Protection, Praha, Czech Republic provided helpful suggestions.

REFERENCES

Akers, R.C., and Robinson, W. H. 1981. Spatial pattern and movement of German cockroaches in urban, low-income apartments (Dictyoptera: Blattellidae). Proc. Entomol. Soc. Wash. 83: 168-172.

Arlian, L.G. 1989. Biology and ecology of house dust mites, *Dermatophagoides* spp. and *Euroglyphus* spp. Immunol. Allergy Clin. 9: 339-356.

Audy, J.R. 1958. The localization of disease with special reference to the zoonoses Trans. Roy. Soc. Trop. Med. Hyg. 52: 308-328.

Baker, J.M., and Berry, R.W. 1980. Synthetic pyrethroid insecticides as replacement for chlorinated hydrocarbons for the control of wood-boring insects. Holz Roh-Werkstoff 38: 121-127.
Becker, H. 1979. Die Verbeitung des Hausbockk¬fer (*Hylotrupes bajulus* (L.)) Serville (Coleoptera: Cerambycidae).Sonderdruck Prakt. Sch¬dingsbek¬mpfer 31: 3-19.
Bloomquist, J., and Robinson, W. H. 1999. Prevalence and magnitude of resistance to cyclodiene and phenylpyrazole insecticides in *Blattella germanica* and *Drosophila melanogaster*. In: Robinson, W.H., Rettich, F., and Rambo, G.W., eds. Proc. Internat. Conf. on Urban Pests, 1999, Prague, Czech Republic
Boase, C.J. 1999. Trends in urban refuse disposal: a pest's perspective. Proc. Internat. Conf. on Urban Pests 1999: 83-98.
Bronswijk, J.E.M.H. van, and Sinha, R.N. 1973. Role of fungi in the survival of *Dermatophagoides* (Acari: Pyroglyphidae) in house-dust environment. Evniron. Entomol. 2: 142-145.
Cannon, K.F., and Robinson, W.H. 1981. Wood consumption and growth of *Hylotrupes bajulus* (L.) larvae in three environments. Environ. Entomol. 10: 458-461.
Cannon, K.F., and Robinson, W.H. 1982. Notes on the biology and distribution of *Hylotrupes bajulus* (L.) (Coleoptera: Cerambycidae) in Virginia. Ent. News 93: 173-176.
Chadwick, P.R., and Shaw, R.D. 1974. Cockroach control in sewers in Singapore using bioresmethrin and piperonyl butoxide as a thermal fog. Pestic. Sci. 5: 691-701.
Davis, B.N.K. 1978. Urbanisation an the diversity of insects. In: Diversity of Insect Faunas, Mound, L.A. and Waloff, N., eds., Symp. Roy. Entomol. Soc. London, No. 9. Oxford: Blackwell Scientific Pub.
Davis, A., and Glick, T.F. 1978. Urban ecosystems and island biogeography. Environ. Conserv. 5: 299-304.
Durr, H.J.R. 1954. The European house borer *Hylotrupes bajulus* L. (Coleoptera: Cerambycidae) and its control in Western Cape Province. Bull. Dept. Agric. Union of South Africa, No. 377.
Eads, R.B., Von Zuben, F.J., Bennett, S.E., and Walker, O.L. 1954. Studies on cockroaches in a municipal sewerage system. Am. J. Trop. Med. Hyg. 3: 1092-1098.
Fernandez-Caldas, E., Fox, R.W., Bucholtz, G.A., Truedaeu, W.L., Ledford, D.K., and Lockey, R.F. 1990. House dust mite allergy in Florida, mite survey in households of mite-sensitive individuals in Tampa, Florida. Allergy Proc. 11: 263-267.
Gladwell, M. 2000. The Tipping Point. Boston: Little, Brown and Co.
Hanski, I. 1998. Spatial structure and dynamics of insect populations. In: Insect Populations in Theory and in Practice, Dempster, J.P. and McLean, I.F.G., eds. Dordrecht, Boston, London: Kluwer Academic Pub.
Hatch, M.H. 1953. The origin and evolution of household insects. Biologist 35: 57-66.
Hinton, H.E. 1945. A monograph of beetles associated with stored products, vol. 1. London: British Mus.
Hudson, E.H. 1944. The role of the reservoir host in tropical disease. Am. J. Trop. Med. 24: 125-130.
Jackson, W.B,. and Maier, P.P. 1955. Dispersion of marked American cockroaches from sewer manholes in Phoeniz, Arizona. Am. J. Trop. Med. Hyg. 4: 141-146.
Jenkins, R. 2001. Battling a common enemy. Pest Control 69 (Supplement): S10-12, 16.
Landau, I., Muller, G., and Schmid, M. 1999. The Urban Pest Advisory of Zurich (Switzerland) and the situation of some selected pests. Proc. Internat. Conf. on Urban Pests 1999: 67-72.
Lang, J.D., and Mulla, M.S. 1977. Distribution and abundance of house dust mites, *Dermatophagoides* spp., in different climatic zones of southern California. Environ. Entomol. 6: 213-216.
Larter, R.J., and Chadwick, P.R. 1983. Use of a general model to examine control procedures for a cockroach population. Res. Pop. Ecol. 25: 238-248.
Lea, G. 1976. House longhorn beetle survey. BRE Information IS 14/76, Princes Risborough Laboratory.
Linsley, E.G. 1944. Natural sources, habitats, and reservoirs of insects associated with stored food products. Hilgardia 16: 187-222.
Lussenhop, J. 1973. The soil arthropod community of a Chicago expressway margin. Ecology 54: 1124-1137.
Mollett, J.A., and Robinson, W.H. 1993. The biology and distribution of house dust mites. Pest Control 61: 51-56.
Mollett, J.A., and Robinson, W.H. 1996. Dispersal of American house dust mites (Acari: Pyroglyphidae) in a residence. J. Med. Entomol. 33: 844-847.
Nuorteva, P., Kotima, T., Pohjolainen, L., and Räsänen, T. 1964. Blowflies in the refuse depot of the city of Kuopio in Central Finland. Ann. Entomol. Fenn. 30: 94-104.
Owen, J., and Owen, D.F. 1975. Suburban gardens: England's most important nature reserve. Environ. Conserv. 2: 53-59.
Powell, P.K., and Robinson, W.H. 1992. Penetration and permanence of permethrin in four softwoods. J. Econ. Entomol. 85: 1818-1821.
Robinson, W. 1996. Integrated pest management in the urban environment. American Entomologist 42(2): 76-78.
Robinson, W. H. 1999. The changing status of the German cockroach in the urban environment. Proc. 52nd N.Z. Plant Protection Conf. 1999: 16-21.

Robinson, W. H, and Bao, N. 1988. The pest status of *Periplaneta fuliginosa* (Serville) (Dictyoptera: Blattidae) in China. Proc. Wash. Entomol. Soc. Wash. 90: 401-406.

Rust, M.K., Reierson, D.A., and Hansgen, K.H. 1991. Control of American cockroaches (Dictyoptera: Blattidae) in sewers. J. Med. Entomol. 28: 210-213.

Simberloff, D.S., and Abele, L.G. 1976. Island biogeography and theory and conservation. Science 191: 285-286.

Stejskal, V. 2002. Metapopulation concept and the persistence of urban pests in buildings. In: Jones, S.C., Zhai, J., and Robinson, W. H., eds. Proc. Internat. Conf. on Urban Pests, Charleston, S.C.

Thoms, E.M., and Robinson, W.H. 1986. Distribution, seasonal abundance, and pest status of the oriental cockroach (Orthoptera: Blattidae) and evaniid wasp (Hymenoptera: Evaniidae) in urban apartments. J. Econ. Entomol. 79: 431-436.

Voorhorst, R., Spieksma-Boezeman, M.I.A., and Spieksma, F. Th.M. 1964. Is a mite (*Dermatophagoides* sp.) the producer of the house dust allergen? Allerg. Asthma 10:329-334.

Voorhorst, R., Spieksma, F.Th.M., Varekamp, H., Leupen, M.J., and Lyklema, A.W. 1967. The house dust mite (*Dermatophagoides pteronyssinus*) and the allergens it produces: identity with the house dust allergen. J. Allergy 39: 325-339.

Wood, F.E., Robinson, W.H., Kraft, S.K., and Zungoli, P.A. 1981. Survey of attitudes and knowledge of public housing residents toward cockroaches. Bull. Entomol. Soc. Amer. 27: 9-13.

Zeman, P. 1993. Management of a German cockroach population with a juvenoid bait formulation: computers simulation. Entomol. exp. appl. 67: 31-39.

Zeman, P., Kyselova, M., Rupes, V., Wimmer, Z., and Vrba, Z. 1992. Management of a German cockroach population with a juvenoid bait formulation: an experiment in residential buildings. Entomol. exp. appl. 62: 47-53.

Zhai, J., and W. H Robinson. 1991. Cockroach distribution in urban buildings. Pest Control Technology 19: 36-40.

Proceedings of the 4th International Conference on Urban Pests.
Susan C. Jones, Jing Zhai, and Wm H. Robinson editors. (2002)