February 1962

ECTOPARASITE CONTROL IN PUBLIC HEALTH

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INTRODUCTION

The inclusion of a chapter on ectoparasite control in a work otherwise devoted to vertebrates has a great deal of justification; the ecologies of vertebrates and their invertebrate parasites are inseparable, thus, the vertebrate control specialist is brought into intimate contact with ectoparasites and ectoparasite problems. In many cases, the need for vertebrate and ectoparasite control problems is one, and knowledge of techniques in both areas is required.

The term "ectoparasite" groups a broad array of invertebrate animals externally parasitic on larger animals, many of them blood feeders in at least one stage of their life cycles. The ecological relationships between them and their hosts may be exceedingly complex, involving ectoparasites as vectors of parasitic micro-organisms, and in some cases as reservoirs of infection as well. In their role as vectors and also as bloodsucking parasites, they have a great impact on the ecology of animal and human populations.

The importance of many ectoparasite species, especially fleas, ticks, mites, and lice, to human welfare cannot be overemphasized. The roles of fleas in the transmission of plague and murine typhus are well known, as are those of ticks in a variety of viral, rickettsial, spirochaetal, and bacterial diseases, trombiculid mites in scrub typhus and lice in epidemic typhus. In addition, man may be exposed to painful bites resulting in direct pathological effects, both from wild animal ectoparasites or from others more directly associated with man and domestic animals.

The need for adequate ectoparasite control methods is manifest. Ectoparasite control ranks with control of vertebrates and with immunology and clinical treatment as a potent tool in protecting man from zoonoses. In many cases, the ectoparasite is the most susceptible link in the chain of man transmission of diseases from sources in nature to man. In others, control of ectoparasites is capable of immediately alleviating potentially dangerous situations until more lasting control measures can be carried out. It should be borne in mind that human discomfort from ectoparasites and vector-borne disease stems from a complex ecological situation and can be solved ultimately only by environmental management practices in which ecological factors are separated, analyzed, related, and adjusted in favor of man. The decision of how to control or whether to control ectoparasites should be based on a knowledge of these factors.

In the following, it is possible only to touch on immediate solutions to some ectoparasite problems encountered in the United States. Papers on control of lice (Barnes and Keh, 1959) and on control of the domestic fleas, *Ctenooephalides felis* and *canis*, and *Pulex irritans* (Keh and Barnes, 1961) are available on request from CALIFORNIA VECTOR VIEWS, California Department of Public Health, Berkeley 4 California.

FLEAS AND FLEA CONTROL

Fleas as adults are obligate bloodsucking parasites. As larvae, they are general feeders on debris and other materials in and about the environment of the host. The larvae of rodent fleas are closely adapted to the nest or burrow conditions of the host; larvae of the dog and cat fleas (*Ctenocephalides oanis* and *C. felis*) and of the so-called human flea are more broadly distributed about the host habitation. While adult fleas are often found on the host in considerable numbers, far more are usually found in the nest or about the habitation. Some species are more prone to remain in the nest than others. These have been termed "nest fleas" by flea students, though the distinction is one of degree rather than a sharply discrete difference.

It is apparent that different control measures are necessary to deal with rodent fleas than to deal with domestic fleas. In addition, the habits of various rodent groups makes necessary variations in control measures against their fleas. Whatever the case, it is necessary to reach the fleas in the environment as well as those on the host in order to achieve control. In the following, control measures for fleas about the home and for fleas of wild and domestic rodents are discussed.

Control of domestic fleas

These fleas are important pests of man and domestic animals due to discomfort caused by their bites. In North America the most frequent complaint is caused by the cat flea, _Ctenocephalides felis_ and the dog flea, _C. canis_. In California, _Pulex irritans_, the so-called human flea, was long considered to be the most important flea biting man, but in recent years at least, the cat flea has been much more frequently encountered. Domestic fleas, particularly the human flea, have been considered important vectors of plague by some authors in various parts of the world (e.g. Baltazard, 1960) in the United States they are controlled solely because they bite man.

Adult cat or dog fleas are commonly found on the pet; the eggs, larvae, and pupae where the animal sleeps. The infestation of adults, however, may spread throughout a home, into the yard area, and may include a whole neighborhood. Even though no cat or dog is known to occupy a residence at the time of infestation, infestations can invariably be traced to pets. Often, a family without dog or cat may move into a dwelling and find it infested, or a family with a pet returns from vacation and finds the home infested with fleas. In these cases, adult fleas have matured and may have been able to survive as long; as several months without food.

Successful control depends on first identifying the species involved, locating the focus of infestation, then applying appropriate control measures. The cat or dog flea is usually found in greatest numbers about the immediate living quarters of the pet, but may frequently be more widespread. The human flea is associated directly with man. Operators searching for sources of fleas should examine pets and their living area for <u>Ctenocephalides</u> and primarily the bedroom for the human flea. One clue as to which species may be involved is the location of bites: bites about the ankles often mean the dog or cat flea; about the waist, the human flea.

Flea infestations in homes may be controlled with several insecticides, including lindane, methoxychlor, and DDT. A 0.5 to 1.0 percent spray of lindane in petroleum distillate is extremely effective, as is 2.5 to 5 percent methoxychlor. Cats should not be treated with lindane. Where cat or dog fleas are involved, the sleeping area of the cat or dog should be examined for larvae and eggs. If found, they should be vacuumed if possible and the area treated with insecticide. Treatments for the control of the human flea should include bed-clothing, mattresses, and padded furniture if infested.

In treating outdoor areas for cat fleas, a water emulsifiable spray of 2 percent malathion, 1 percent lindane, or 1 percent Diazinon sprayed at the rate of 1 gallon per 1000 feet is effective.

In a number of instances, resistance to DDT and to chlordane by the cat flea has been reported. Laboratory tests have failed to bear this out. Nevertheless, in field usage, the organo-phosphorus compounds are now being used more extensively. Diazinon is reported by World Health Organization (Tech. Rept. Series, 1960, No. 191) as most effective. Control of Fleas on Wild Rodents

These fleas form the essential rodent-to-rodent link in the ecology of sylvatic or campestral plague; occasionally man is involved when bitten by them. Despite the obvious importance of fleas in plague ecology, it has only been in recent years that control of wild rodent plague by means of flea control has been suggested. Tests were made on the control of ground squirrel fleas as early as 1938 (Stewart and Mackie), later Ryckman, Ames and Lindt (1953) tested burrow dusting techniques using several insecticides on fleas of the California ground squirrel. Miles and Wilcomb (1953) tested simulated aerial application of DDT dust to control fleas of Neotoma spp. in an enzootic plague area. Kartman (1958) and Barnes and Kartman (1960) have successfully tested a bait-box control method for fleas on small cricetine and microtine rodents, the true reservoirs of plague, and against chipmunks and golden-mantled squirrels in the Sierra Nevada of California. This method has the advantage of using the mammal as a vehicle to carry insecticide back to the nest.

Nevertheless, no instance is known in the literature wherein enzootic plague has been quelled by use of flea control methods; rather, rodent control has been the only means extensively used. In the Soviet Union spectacular success has been reported in eradicating plague over 17.3 million acres by rodent control, primarily of the suslik or sisel

(<u>Citellus pygmaeus</u>) through poisoning programs (Fenyuk, 1960). However, Russian workers found early in the program that: (1) fleas congregated at the mouths of burrows after rodent control, (2) these fleas were able to survive over one year, and (3) that rodent control alone temporarily increased rather than decreased human exposure to potential plague. They concluded that rodent control programs in plague areas should be combined with ectoparasite control (Gonchar, 1956; Fenyuk, 1960) if plague is to be reduced as an immediate hazard to humans. This view is widely supported by plague control authorities quoted in Pollitzer, 1961.

The control of wild-rodent plague, in the ultimate sense, calls for management of host populations, holding them below a level at which plague is not a possibility, but this level is not known. It is doubtful that eradication programs as extensive as that carried out in the Soviet Union are economically feasible elsewhere, or even possible in a practical sense, since in most plague enzootic areas an array of rodent species distributed over tremendous areas is involved, some of them far more resistant to control measures than others. In such situations, plague control becomes a matter of special, localized, and intensive measures in situations where human hazard is involved (Kartman, 1956). Available ectoparasite control methods or combined ectoparasite-rodent control offer the most rapid, effective and economical means of achieving this end.

Recommendations for the control of wild rodent fleas involve the use of two techniques: burrow dusting for colonial burrowing rodents and the DDT bait-box technique as developed by Kartman (1958) and Barnes and Kartman (1960). Each of these methods is most suitable under particular circumstances. Both of them are selective and offer little hazard to human or wildlife populations. Area treatment is not recommended except under circumstances where very large areas must be treated. In these cases, area treatments as recommended for hard-shelled ticks (p.) are appropriate.

DDT bait-box technique: The DDT bait-box is remarkably simple in construction. It consists of a ½ inch-thick pine floor board, 12 inches long by 8 inches wide, covered by a "u"-shaped roof made by removing both ends from 9½ by 12½ inch lard can, then splitting it lengthwise. Bait pans consist of sardine tins or similar containers tacked or screwed to the center of the floor board. In use, the metal roof is placed over the floor board and its edges worked into the soil or nailed to the board. Bait pans are filled with approximately 100 grams of rolled oats. Approximately 25 grams of 5 or 10 percent DDT dust is then ridged up at each end of the floor board. Stations are rebaited twice weekly or more often as bait is removed.

Rodents investigate and use the bait-boxes immediately. In the Sierra Nevada tests (Barnes and Kartman, 1960) flea populations were reduced strikingly within *24* hours. When baited twice weekly for 28 days then removed, fleas remained low for at least 42 days. Kartman (1958) observed an effective residual control of 132 days against fleas of Microtus.

For effective control some knowledge of the distances moved by hosts is necessary in order to arrive at optimum spacing of the bait-boxes. With chipmunks and golden-mantled squirrels in the Sierra Nevada, bait-boxes were placed 100 feet apart, but 200 feet would probably have been adequate. With Microtus, a less widely ranging host, 30 to 50 foot spacing is required. Other wild rodent hosts could be expected to fall between these extremes.

Burrow dusting: This method is used against fleas of colonial burrowing rodents, e.g. the California ground squirrel (Citellus beecheyi). It has several of the same advantages as the bait-box technique.

Ryckman, Ames and Lindt (1953) tested four chlorinated hydrocarbon insecticides against fleas of the California ground squirrel: aldrin (2.5 percent), dieldrin (2.0 percent), heptachlor (2.5 percent), and DDT (5.0 percent), all as dusts. Effective control was achieved by placing 30 grams of any of these materials in each burrow entrance. The Bureau of Vector Control, California State Health Department, effectively controlled fleas of ground squirrels in Kern County, California during a plague epizootic in 1956 by application of 10 percent DDT dust at burrow entrances. Within *24* hours, heavily-infested burrows were free of fleas and the potential plague hazard to man from infected fleas, eliminated.

Where it is desirable to eliminate both fleas and rodents in one operation Cyanogas is an effective material, placed in the burrow and covered with soil. In the Russian work previously referred to (Gonchar, 1956; Fenyuk, 1960) "black cyanide" was used in a vast eradication program to eliminate the suslik (Citellus pygmaeus) and its fleas. Control of fleas on domestic rodents

Xenopsylla cheopis, the principal transmitter of both plague and murine typhus, is readily controlled in the United States and many other parts of the world by application of 5-10 percent DDT dust to runways and burrows. Patch dusting of runways and burrow entrances is cheap and extremely effective. This method has the same advantage as the DDT bait-box technique; the insecticide is carried back to the nest where immature stages and many of the adults are found.

The pest control operator who controls rats has the responsibility of sampling for ectoparasites prior to killing rats. In the absence of hosts on which to feed, rat ectoparasites are much more likely to bite humans in the vicinity. Where rat ectoparasites are present, patch dusting or DDT bait-box treatment in conjunction with anticoagulant baiting is both highly feasible and desirable. This approach costs the operator little and produces a much more thorough job.

LOUSE CONTROL

In many parts of the world, the human louse (Pediculus humanus) still constitutes an important problem. Heavy infestations carry with them the danger of epidemic typhus. In the United States, infestations are infrequent due to high standards of sanitation. However, the occurrence of the crab louse (Phthirus pubis) is probably more frequent than is commonly acknowledged. Outbreaks of head lice (Pediculus humanus, form capitis) occasionally occur in schools and institutions,

WHO (Tech. Bull. No. *191)* recommends the use of 10 percent DDT dust for mass delousing treatments, about 30 grams of powder per person. DDT-resistant lice have been encountered in Korea, where 1.0 percent lindane was substituted. Lice and eggs on clothing are susceptible to dry-cleaning solvents, temperatures over 122° F. for ½ hour, and to fumigation by methyl bromide.

For head lice, DDT is often objectionable since it temporarily discolors the hair. Barnes and Keh (1959) present a table of commercially available materials for use against head and crab lice, A desirable pediculicide should kill both lice and their eggs in one treatment, be easy to apply, and be available without prescription. These conditions are met by A-200 Pyrinate, containing synergized pyrethrins, Cuprex with tretralin and copper oleate, and Bornate, containing isobornyl thiocyanoacetate. Use of these materials requires careful reading of manufacturer's instructions.

MITES AND MITE CONTROL

The mites most often subjected to control for public health reasons are the chiggers (*Trombicula* and *Eutrombicula* spp.), the tropical, rat mite (*Ornithonyssus bacoti*), and the house mouse mite (*Allodermanyssus sanguineus*).

Chiggers

The chigger or red bug (*Trombicula alfreddugesi*) is often extremely troublesome in the eastern and southeastern United States through Mexico and in South America. Two closely-related species, *Trombicula splendens* and *T. batatas*, also attack man. *T. alfreddagesi* parasitizes a wide variety of vertebrate hosts; man is apparently an accidental host. They attach themselves to human hosts in regions of the body constricted by clothing such as ankles, waistline, and armpits. Their bites are extremely irritating} the irritation is probably an allergic response to salivary secretions of the mite.

Control measures against chiggers involve treatment of infested areas such as lawns, yards, and shrubbery. Application of DDT, chlordane, toxaphene or dieldrin at 1 to 2 pounds of technical material per acre, or of lindane at 0.5 per acre gives relief for up to 30 days. Sprays (suspensions or emulsions) or dusts give similar results. Where chiggers are encountered on shrubby vegetation, 50 gallons of spray or 40 pounds of dust are required; on lawns or grassy areas, half that amount. These amounts of technical material per acre are hazardous to wildlife and care should be taken in their use.

Repellents are frequently used in chigger-infested areas. The materials used as tick repellents (p.265) are also effective against chiggers.

Tropical rat mite

This mite is associated with rat infestations in the southern United States and Southern California. Much of a mite population will be found in the rat's nest, rather than on the rat itself. When rats are poisoned without concurrent ectoparasite control, hungry mites wander in search of a host. They migrate from nest or burrow, frequently using water or sewer pipes to reach higher levels in a building. The mites will bite man, causing a dermatitis-like reaction. Since the mites are very small and frequently aren't seen by the victim, the dermatitis is frequently ascribed to another cause. One victim in California was thought to be suffering from entomophobia because of a prolonged but unseen infestation of tropical rat mites following control of a very small roof rat infestation in her home. The mites followed the water pipes into the bathroom.

Control of these mites is best achieved by use of 5-10 percent DDT patch dusting as with the oriental rat flea. DDT used in patches about about anticoagulant bait stations is a simple, economical, and efficient means of control. Mites that have already invaded a building are easily controlled by 5 percent DDT or 1.0 percent lindane sprays. The house mouse mite

Allodermanyssus sanguineus is the vector of rickettsial pox. The mite is widespread and occurs on rats as well as Mus musculus. It is best controlled by ridding the premises of mice. The effectiveness of DDT dusts on runways and in burrows has not been tested, but should prove effective. Invading mites are susceptible to the same treatment as the tropical rat mite, namely by sprays of 1.0 percent lindane or 5.0 percent DDT.

Ticks and tick control

Ticks are obligate bloodsucking parasites that bite practically all terrestrial vertebrates, including man. Their role as transmitters of disease is thoroughly documented, beginning with the work of Smith and Kilbourne between 1889 and 1893 when the ability of a tick, *Boophilus annulatus*, to transmit the protozoan agent of Texas cattle fever, was first demonstrated.

Since that time, ticks have been shown to serve as vectors, and in some cases as reservoirs also, of five types of disease pathogens: (1) *Rickettsia*, causing spotted fever; (2) bacteria, e.g., tularemia (3) spirochaetes, e.g., relapsing fevers; (4) viruses, e.g., Colorado tick fever and the tick-borne encephalitides; and protozoa, e.g., Texas cattle fever. The list of diseases transmitted by ticks both to animals and man is by no means complete the above merely serve as categorical examples.

Ticks, simply by their action as blood-sucking parasites, play a significant role in the ecology of their vertebrate hosts. Cooley and Kohls (1938) state that one adult female of *Dermacentor andersoni* is capable of extracting a blood meal of 1.7 to 2.0 grams; Herms and James (1961) give an example wherein a large number of horses died of exsanguination due to heavy infestations of *Dermacentor albopictus* in California.

Ticks vary greatly as to habits, habitat, and life cycle. Since these variations affect control measures taken against them, they are more fully discussed for ticks than for other groups.

Ticks and man

Ticks, though many species have extremely broad host preferences, are not naturally parasitic on man, but on animals in nature. Tick adaptations include not only those involving hosts, but also a broad spectrum of other ecological factors, including particularly temperature, humidity, shelter, and often appropriate vegetation on which they climb to await a host. Civilized man has largely removed himself from nature; it is only when he intrudes his person into tick habitat (or allows tick habitat to come to him) that he is bitten. When this occurs, reaction is often severe; man is not adapted to the bite of ticks or to the micro-organisms they transmit, so is susceptible to disease from the latter and to toxic reaction from tick bites, including tick paralysis and systemic disturbances.

Taxonomy

Ticks are members of the suborder Ixodoidea of the order Acarina. The suborder includes two families: Ixodidae (hard ticks) and Argasidae (soft ticks). Hard ticks are characterized by marked sexual dimorphism, and possession of a scutum or dorsal shield covering the entire dorsum of males, but only about the anterior one-third in females; in soft ticks the sexes are similar and there is no dorsal shield. Herms (1961) lists eleven genera of Ixodidae and four of Argasidae. Both families are world-wide in occurrence and have representatives from tropic to sub-arctic regions. The more important genera in Ixodidae are: _Derma_ _centor_, _Ixodes_ _Haemaphyalis_, _Rhipicephalus_, _Hyalomma_, _Amblyomma_, and _Boöphilus_. In the Argasidae, _Ornithodoros_ is by far the more important medically; _Argas_ is a group of avian parasites having great economic importance.

Life cycle

Mating usually takes place on the host (Ixodidae) or in and about the nest or living area of the host (Argasidae), after which the female lays the eggs in masses on or near the ground over a period of time.

As many as 18,000 eggs may be produced by one female; often 2,000 to 5,000. Eggs hatch in two weeks to several months, depending on conditions. The emerging larva is six-legged. This stage then awaits the passage of a host to which it may attach (Ixodidae) or actively seeks a host by scent (Argasidae). Mortality is usually high in this stage— due principally to starvation or dessication—but if successful in feeding, the larva transforms to an eight-legged nymph. In Ixodidae, there is only one nymphal stage; in Argasidae there are several. Among Ixodidae, some species, having found a host, remain on it during the entire life cycle) others drop off after each blood meal and must find a new host each time. The former are called one-host ticks, the latter multiple-host ticks. Multiple host ticks frequently take the larval and nymphal blood meal from small animals (rodents, rabbits); tine adult blood meal from larger ones (deer, dogs, etc.). Following the nymphal blood meal, ixodids transform to adults. The whole process in nature usually takes two years, but may take as long as four or five as ticks "wait out" exigencies of the environment. Loomis (l96l) has shown that the process may be shortened to a few months under favorable laboratory conditions.

Habits

Generally, multiple host hard ticks spend much of their life cycle on the ground or on vegetation awaiting hosts. They are apparently attracted to animal trails and pathways from considerable distances and are found on the apex of branches at or near knee height. Rhipicephalus sanguineus, the brown dog tick, however, is found in crevices about dog kennels. One-host ticks, of course, are found more frequently on the host.

Soft ticks are more closely associated with the nests of their hosts. Ornithodorus hermsi, the vector of tick-borne relapsing fever, is usually found in the nests of chipmunks built in snags and logs. 0. parkeri, a related species, is found in the burrows of its ground squirrel hosts, while 0. coriaceous is found in deer beds. These ticks may actively seek hosts in the vicinity of nests, thus when chipmunks are allowed to enter mountain cabins in California and to nest in or around them, man is exposed to Ornithodorus hermsi and tick-borne relapsing fever.

Control and avoidance of ticks

Control of ticks over a wide area is an extremely difficult and costly procedure; therefore control efforts are usually undertaken on a more local basis. In combatting ticks, the use of repellents, mechanical control, and area sanitation rank equally with insecticidal control. For persons continually exposed to ticks in Rocky Mountain spotted fever areas, a vaccine has been developed that is administered in two or three subcutaneous injections and gives an immunity for one year. Immunity may be renewed by a booster after one year.

Mechanical control

Keeping out of known tick infested areas is probably the best way to insure against tick bite. If this cannot be done, protection may be gained by keeping clothing buttoned and trouser cuffs closed by inserting into socks or boots. Bicycle clips have been suggested also. Clothing should be periodically inspected for ticks while in tick areas and upon leaving them.

If ticks do become attached, it is best to remove them immediately, especially in areas where Rocky Mountain spotted fever is known to occur.

There is some danger of mouthparts breaking off, especially with those ticks having long mouthparts, e.g., Ixodes pacificus in the west coast of the U. S. and Amblyomma americanum which occurs in the southeastern U. S. Ticks are best removed in the field by gently pulling the tick off with the fingers. The site of the wound should be treated with merthiolate *or* some other aseptic agent immediately.

Repellents

According to Pratt and Littig (l96l), no general tick repellemt is known to be effective against all species. Treating the body with, repellent is only briefly effective; therefore, treatments of clothing are suggested. The authors state that Indalone, diethyltoluamide, dimethyl carbate, dimethyl phthalate, and benzyl benzoate provide up to 90 percent protection. M-1960, the present military clothing treatment is effective primarily because of butyacelanilide, but also contains benzyl benzoate and butyl ethyl propanediol which are also moderately good repellents, according to them. Three pints of 5 percent solution of this material is sufficient to treat a complete outfit of socks, shirt, and trousers of cotton, denim or light wool and is effective against ticks for one week or until wet.

Control of ticks on vegetation

As previously pointed out, multiple host hard ticks (family Ixodidae) typically climb to the apices of shrubbery, grass blades and other vegetation along animal trails where they await passing hosts. Important species with this characteristic are Dermacentor variabilis in the eastern states, D. andersoni in the Rocky Mountain and Great Basin Region, D. occidentalis and Ixodes pacificus on the Pacific Coast, I. scapularis in the southeast, Amblyomma americanum in the southwestern U, S., und A. cajennense in parts of Texas and Mexico. These ticks generally occur on vegetation from very early spring into summer; the length of season probably depends on climatic factors. Since ticks are found throughout favorable habitat which may occur over many square miles, it is generally feasible to control them only in areas of high human exposure, e.g., near human habitation, in high use recreation areas, and campgrounds.

Pratt and Littig (1961) state that area control may be obtained by the use of DDT, chlordane, dieldrin, and toxaphene at the rates of one to two pounds of actual insecticide per acre. Dust, suspension, or emulsion formulations produce similar results. According to these authors, dusts are applied by airplane or power equipment, using 10 to 20 pounds of 10 percent dust, or 20 to 40 pounds of 5 percent dust, suspensions by orchard sprayer; emulsions are applied by mist blowers. The U.S.D.A. (1961) has recommended as much as 4 pounds of actual DDT per acre.

A more economical approach to tick control has been used against Dermacentor variabilis in Long Island, New York, where this species is the vector of Rocky Mountain spotted fever. Collins and Nardy (1951) taking advantage of ticks congregating on vegetation near pathways and along roadsides, treated only narrow strips along them. This method has the advantage of being much less hazardous to wildlife. The authors achieved very effective control with a 2.5 percent spray of DDT applied along a two-foot strip on either side of the road or trail or at the edges of fields. On trails and around homes, a 1 to 3 gallon pressure tank or knapsack garden sprayer was used; along roads, a power sprayer was used. By power sprayer, 24 gallons of 2.5 percent spray covered a strip two miles long; in more local situations, one quart covered 100 feet of vegetation two feet on either side. While this method covers the vegetation treated with more insecticide (approximately 4.5 pounds per acre), it considerably reduces the total area treated with consequent reduction of hazards to wildlife. The latter method would seem to have importance in California these ticks and their chipmunk hosts abound. A general program of both tick and rodent control may be necessary, and, as Hems states, rodent control without tick control is useless, for the hungry ticks soon turn to humans for blood meals. As area sanitation measures, the following are suggested: (1) yards, woodpiles, and trashpiles should be cleaned up; (2) rodent production should not be encouraged by feeding; (3) breeding niches of chipmunks and other rodents such as snags, stumps, and downed trees should be removed and destroyed by fire or other means; (4) buildings should be rodent-proofed and treated with 0.5 percent lindane.

The concept of area sanitation has not been attempted on a broad scale. However, its use seems perfectly reasonable for Ornithodoros hermsi and, perhaps to a lesser extent, for hard ticks as well. Adult hard ticks only become adults by obtaining blood meals as larva and nymph; in the case of many important species, (e.g., Dermacentor ander-soni, D. occidentalis) these blood meals are obtained from rodents. It seems reasonable to believe that a substantial reduction in rodent population would decrease the opportunity for the most vulnerable stage in the tick life cycle, larvae, to contact hosts. However, the rodent population would have to be kept at a low level, since gravid ticks would constantly be introduced by larger hosts, deer in the case of D. andersoni and D. occidentalis. Such a method would have to be tested thoroughly before recommended for general use.

DDT bait-box

This method, thoroughly tested against fleas of domestic rodents (Kartman, 1957), Microtus californicus (Kartraan, 1958), and against chipmunk and golden mantled ground squirrels (Barnes and Kartman, 1960), holds some promise for localized tick control as well, either for soft or hard ticks. However, it has not as yet been tested against ticks.

application in parks, recreation areas, and human habitations where *D. andersoni*, *D. occidentalis* , *Ixodes pacificus* and other hard ticks are a persistent problem.

Control of ticks in buildings

Two types of tick problems occur in human habitations: the invasion of homes by the brown dog tick (*Rhipicephalus sanguineus*) a hard tick associated with pets, and the infestation of dwellings by *Ornithodoros* spp. a soft tick associated with small mammals and their nests.

The cosmopolitan brown dog tick has probably been subjected to chemical control measures more than any other tick species. Chlorinated hydrocarbon insecticides such as 5 percent DDT, 3 percent chlordane, and 0.5 percent lindane are effective against this tick in many areas. However, in others, the tick has developed a strong degree of resistance to chlorinated hydrocarbons, consequently these have been replaced by residual applications of 0.5 percent diazinon. According to Pratt and Littig (1961), treatments of diazinon as emulsion or kerosene spray give effective control up to 12 weeks. DDT may be applied generally about the premises; the others recommended should be applied only as spot treatments to crevices, baseboards and other harborage sites. Severe infestations may require more than one treatment.

In the case of *Ornithodoros* spp., permanent control can only be achieved by complete rodent proofing of buildings. Following rodent proofing, ticks will remain and may be controlled by 0.5 percent lindane wettable powder or emulsion concentrate, taking care not to contaminate food and dishes.

Area sanitation

Professor Herms stressed the importance of area sanitation in control of *Ornithodoros hermsi*, the California vector of tick-borne relapsing fever (Herms, 1961 and earlier editions). In areas of recreational

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