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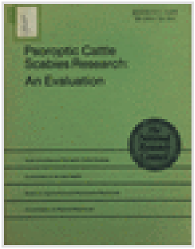

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Psoroptic Cattle Scabies Research: An Evaluation

A Report Prepared by the
Subcommittee on Psoroptic Cattle Scabies
Committee on Animal Health
Commission on Natural Resources
Board on Agriculture and Renewable Resources
National Research Council

NATIONAL ACADEMY OF SCIENCES
Washington, D.C. 1979

NOTICE: The project that is the subject of this report was approved by the Governing Board of the National Research Council, whose members are drawn from the Councils of the National Academy of Sciences, the National Academy of Engineering, and the Institute of Medicine. The members of the Committee responsible for the report were chosen for their special competences and with regard for appropriate balance.

This report has been reviewed by a group other than the authors according to procedures approved by a Report Review Committee consisting of members of the National Academy of Sciences, the National Academy of Engineering, and the Institute of Medicine.

This study was supported by the Animal and Plant Health Inspection Service of the U.S. Department of Agriculture.

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PREFACE

The alarming and costly increase of psoroptic cattle scabies during the 1970s motivated the United States Animal Health Association in October 1978 to adopt a resolution (No. 17) containing 11 points. Point number 9 read as follows: "Request the National Academy of Sciences--National Research Council to review present scabies research programs and make recommendations for needed research." The Association presented the resolution, Scabies Eradication, to the Secretary of the U.S. Department of Agriculture (USDA) who, through Animal and Plant Health Inspection Service (APHIS), made the request to the National Academy of Sciences (NAS). The Subcommittee on Psoroptic Cattle Scabies of the Committee on Animal Health (CAH), Board on Agriculture and Renewable Resources (BARR) was appointed and charged: (1) to review the status of research, (2) to review the adequacy of research, and (3) to recommend needed new research.

The Subcommittee convened on December 14 to 15, 1978, in Denver, Colorado; February 26 to 28, 1979, in Amarillo, Texas and at the U.S. Livestock Insects Laboratory of USDA/Science and Education Administration/Agricultural Research (SEA/AR), Kerrville, Texas; and May 30 through June 1, 1979, in Airlie, Virginia. The Subcommittee heard presentations from affected state and federal regulatory veterinarians, livestock association representatives, USDA representatives (from APHIS and SEA/AR), and from research scientists engaged in active projects. On one occasion it studied commercial treatment facilities and observed naturally infested cattle. During its tenure the Subcommittee reviewed much of the world's relevant literature and collectively prepared this report.

The Subcommittee wishes to acknowledge the help it received from federal and state scientists and cattlemen and their association representatives.

The Subcommittee wishes to thank Philip Ross, Executive Secretary of BARR, and Selma P. Baron, Staff Associate, BARR, for their help and guidance during the preparation of the report.

Rue Jensen, Chairman
Subcommittee on Psoroptic Cattle Scabies

SUMMARY AND MAJOR RECOMMENDATIONS

SUMMARY

In the 1970s in the western, midwestern, and southwestern United States, outbreaks of psoroptic cattle scabies, a dermatitis that causes harmful itching, crusting, scurfing, and depilitation, reached epidemic proportions. Nearly eradicated among cattle in the United States only 20 years ago, the disease is now spreading rapidly because new marketing procedures have brought unprecedented numbers of cattle into contact with each other in large feedlots. Efforts to diagnose and treat psoroptic scabies are thwarted by the difficulty of detecting scabies in the latent stage and by the transportation, merger, and redivision of cattle herds. A major reason for the inadequacy of formerly successful eradication programs to meet the new situation in the cattle industry is that not enough is known about psoroptic scabies in cattle to permit the development of improved methods of diagnosis and more effective acaricides and equipment for administering them.

Psoroptes ovis (Hering 1838) mites are the specific cause of common scabies in cattle. They also cause psoroptic scabies in domestic sheep and, probably, in the Rocky Mountain bighorn *Ovis canadensis* and the water buffalo and, possibly, in domestic equines. These mites rarely transfer between cattle and sheep under natural conditions. However, transfers have been successfully completed in experiments, and the transferability of aggressive strains merits investigation. The life history of the mite on sheep has been thoroughly studied, but its life on cattle has been examined only in a very preliminary manner. There are five distinct stages: (1) egg, (2) larva, (3) protonymph, (4) deutonymph male and pubescent female, and (5) adult male and ovigerous female. The complete life cycle requires approximately 10 to 12 days on sheep, but it may take longer on cattle. Usually, populations of these mites increase during autumn and winter, then recede in the spring and summer. A minimal over-summering population occurs in a condition known as "latency." There is disagreement among research workers as to the cause of latency and the distribution of mites on sheep during the summer; no research has been done on latency on cattle. Lesions of psoroptic scabies on both sheep and cattle usually become

enhanced in the fall and winter and abate during spring and summer. Mites separated from the host have been found to survive for as long as 60 days, but most data indicate that they survive for a few days to, at most, 1 month. Once separated from the host, mites are usually not able to reinfest sheep after 1 to 2 1/2 weeks. Very little research has been done on cattle on this very important practical consideration. *Psoroptes ovis* may not be able to reinfest cattle 3 days after separation from the host, but these data refer to only one particular set of conditions.

Following transmission of virulent mites to susceptible cattle, the clinical disease begins. The mites, proliferating, sustain themselves by feeding on the host, especially on the skin of the withers, rump, and back. Using their piercing chelicerae, the mites puncture the epidermis and, presumably, the corium. Puncture points become red and later turn into vesicles and pustules. The excess fluids mix with necrotic epidermis, hair, soil, and manure and coagulate to form gross lesions of dermatitis that may be moist and greasy or dry, scurfy, denuded, and wrinkled. The skin at feeding loci rapidly becomes unsuitable for further feeding, and the mites continually move to the lesion's periphery and feed on new skin. Thus lesions become large and, by coalescence of adjacent affected areas, infestations become general. The parasitized skin becomes severely irritated from mite movements, mite secretions, and immunopathologic reactions. Consequently, the frenetic cattle bite, kick, scratch, and eventually excoriate the itching parts. The injured skin may become infected with bacterial organisms and invaded by dipterous larvae. Parasitized cattle develop precipitating antibodies against mite antigens, but they do not become immune. Heavily infested cattle lose weight and some may die. What happens to specific organs in hosts is not known in detail and should be studied by light microscopy, electron microscopy, immune reactions, and biochemical changes. Information from such studies may assist in understanding the disease.

The diagnosis of psoroptic scabies currently depends on (1) finding typical clinical signs, (2) observing characteristic lesions, and (3) isolating and identifying causative mites. These procedures generally are efficient and accurate for diagnosing the active disease. Clinical signs attract attention to suspicious herds and skin lesions guide investigators to the locations of mite populations. The procedure for diagnosing latent infestations is inefficient and often inaccurate because both signs and lesions are usually minimal or absent. If diagnosticians knew the common hiding sites of latent mites, they could concentrate their searches there. A serologic test or a skin test that would identify infested herds is acutely needed. Such tests would obviate the treatment of clean herds.

The management of cattle and the epidemiology of scabies are closely associated. From the mid-1960s to the mid-1970s, two profound changes occurred in the cattle industry: (1) an increase in the concentration of breeding cattle in the southeastern states relative to the western states, and (2) an increase in the numbers of cattle fed in large southwestern feedlots relative to those fed in small midwestern feedlots. During that same period, the incidence of scabies surged from a few annual outbreaks to 313 in 1978, mostly in the large feedlots of the southwest states. Major sources of feeder cattle are small breeding herds throughout the southeast, midwest, and west. Those animals are assembled in crowded sales yards, transported in crowded trucks, and finished in crowded feedlots. These practices enhance the probability that latently infested cattle from enzootic areas will transmit the mites to clean cattle by direct body contact.

During all of the current century, acaricides have been used against psoroptic cattle scabies. Among the numerous acaricides developed and tested, four--lime-sulfur at 2-percent concentration, phosmet at 0.15-0.25 percent, coumaphos at 0.3 percent, and toxaphene at 0.5 percent--are currently registered and approved for official use. Phosmet and coumaphos are organophosphorus compounds and toxaphene is a chlorinated hydrocarbon. Toxaphene is highly effective and usually is recommended over the other compounds. All four acaracides are applied to infested and exposed cattle in dipping vats, hydraulic cage vats, and spray-dip machines. In both types of vats, the animals are completely submerged in the compuonds. In the spray-dip machines, each animal is placed in a closed box and sprayed continuously for 1 minute with prescribed nozzles at a standardized pressure. The swim vats are the preferred equipment because they can treat 600 or more cattle per day and are highly effective.

In the United States, several agencies currently conduct formal research on psoroptic cattle scabies. The U.S. Livestock Insects Laboratory of the USDA at Kerrville, Texas, conducts investigations under a project having 18 basic objectives and the equivalent of four full-time scientists. The Agricultural Experiment Station at New Mexico State University, Las Cruces, recently initiated a research program on the disease. Pest Consultants, Inc.--a commercial agency at Amarillo, Texas--conducts investigations under a project having seven applied objectives and the equivalent of one full-time scientist. Despite these efforts, more research is requisite for eradicating psoroptic cattle scabies.

The economic repercussions of scabies reach breeders, feeders, packers, and consumers. Dipping alone costs $1.00 per animal, and exposed herds are dipped at least once and infested herds twice. In 1975 the estimated cost of dipping, quarantine, and market discrimination against exposed and infested cattle was $65 million. The disease causes additional unmeasured losses to packers from damaged hides and trimmed carcasses and to consumers from diminished quantity and quality of meat.

The Subcommittee recognizes the value of the current federal-state program directed against psoroptic scabies in the United States and endorses its continuation. Based on its review of the literature and interviews with scientists, administrators, regulatory officials, cattle industry representatives, and others, the Subcommittee considers that a successful program to eradicate this disease would comprise:

1. early detection of the disease or its causative agent on cattle;

2. successful quarantine and treatment of infested cattle; and

3. tracing the origins of the identified cases, instituting programs to eliminate the source, and tracing forward to facilitate early detection of new infestations.

Major Recommendations

The Subcommittee makes the following major research recommendations, in general order of importance, to facilitate a more practical and effective program for the eradication of psoroptic cattle scabies from the cattle population of the United States:

- Research should be expanded on improvement of diagnostic methods.

- An intensive effort should be made to develop new treatment materials and simpler, more effective, and safer methods of applying them that will require less supervision.

- The question of hidden sources of *P. ovis*, including consideration of the southeastern United States, should be investigated.

- Understanding of the biology, pathogenicity, epidemiology, and host-parasite interactions of *P. ovis* was developed through research on sheep. Basic research should be undertaken using mites on or from cattle.

- Additional engineering research should be pursued to improve the efficiency and performance of treatment equipment, especially the spray-dip machine.

- Current research on test kits for vat-side analysis should be completed as soon as possible for all permitted acaricides.

- Standard methods should be developed for using hydraulic cage vats and portable vat dips.

- Transmission of psoroptic cattle scabies via contaminated environments should be studied using laboratory and field trials.

- The economic costs of cattle scabies and the eradication program should be compared to the benefits of the program to cattlemen, the livestock industry, and the consumer.

- Methods of tracing cattle movements should be studied, and the best method should be implemented.

- Standard methods and materials other than lime-sulfur should be developed for treating dairy cattle.

- Standard methods should be developed for treatment of infested premises, structures, trucks, and other materiel.

- The pathogenesis of bovine psoroptic scabies should be investigated with emphasis on the histopathology of moist and dry forms of dermatitis.

- Biological control agents, pheromones, and hormones should be sought.

- Research on lindane, whether from domestic or foreign sources, should be conducted to find formulations that will prevent excessive depletion of lindane from vats.

- Wild-host reservoirs should be studied, emphasizing cross-transmission between cattle and bighorn sheep. A survey should be made to determine whether any Psoroptes species are present on bison.

To accomplish the tasks outlined in these research recommendations, substantial funding will be required. Allocation of this funding should be designed to stimulate the best efforts of competent scientists at state, federal, and commercial institutions.

Meanwhile, a strengthened educational campaign should be conducted to inform producers, transporters, marketers, and regulatory personnel about the signs, treatments, and costs of psoroptic cattle scabies.

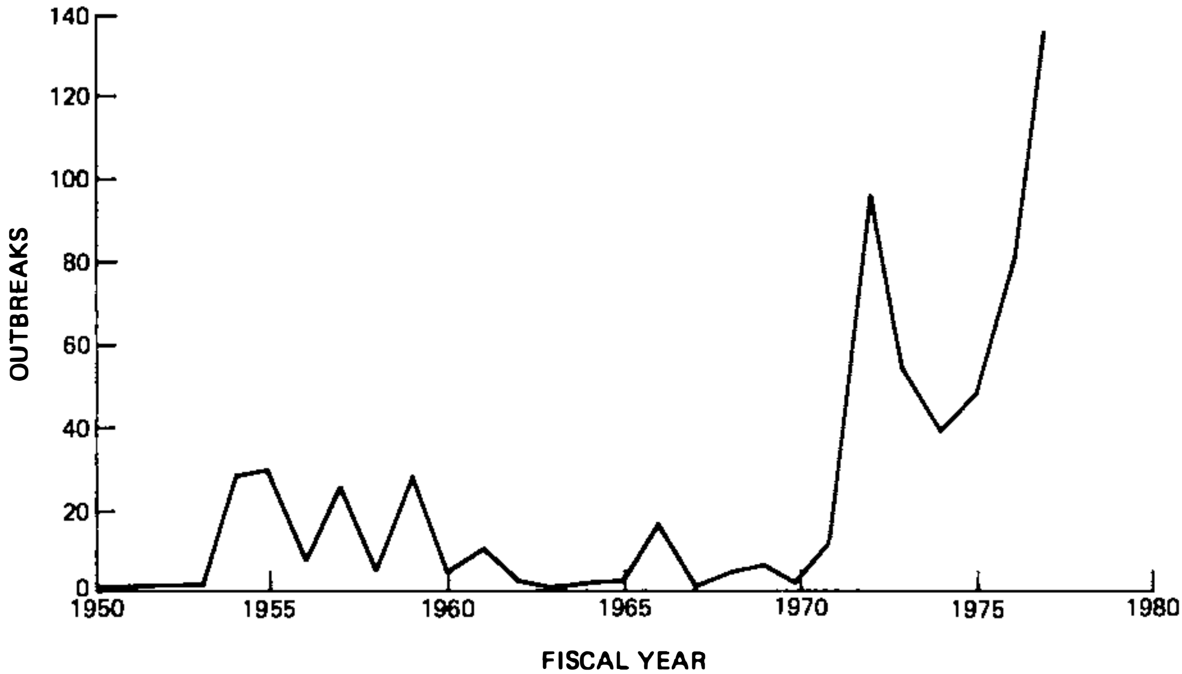
CHAPTER 1

STATEMENT OF THE PROBLEM

BACKGROUND OF THE CURRENT EPIDEMIC

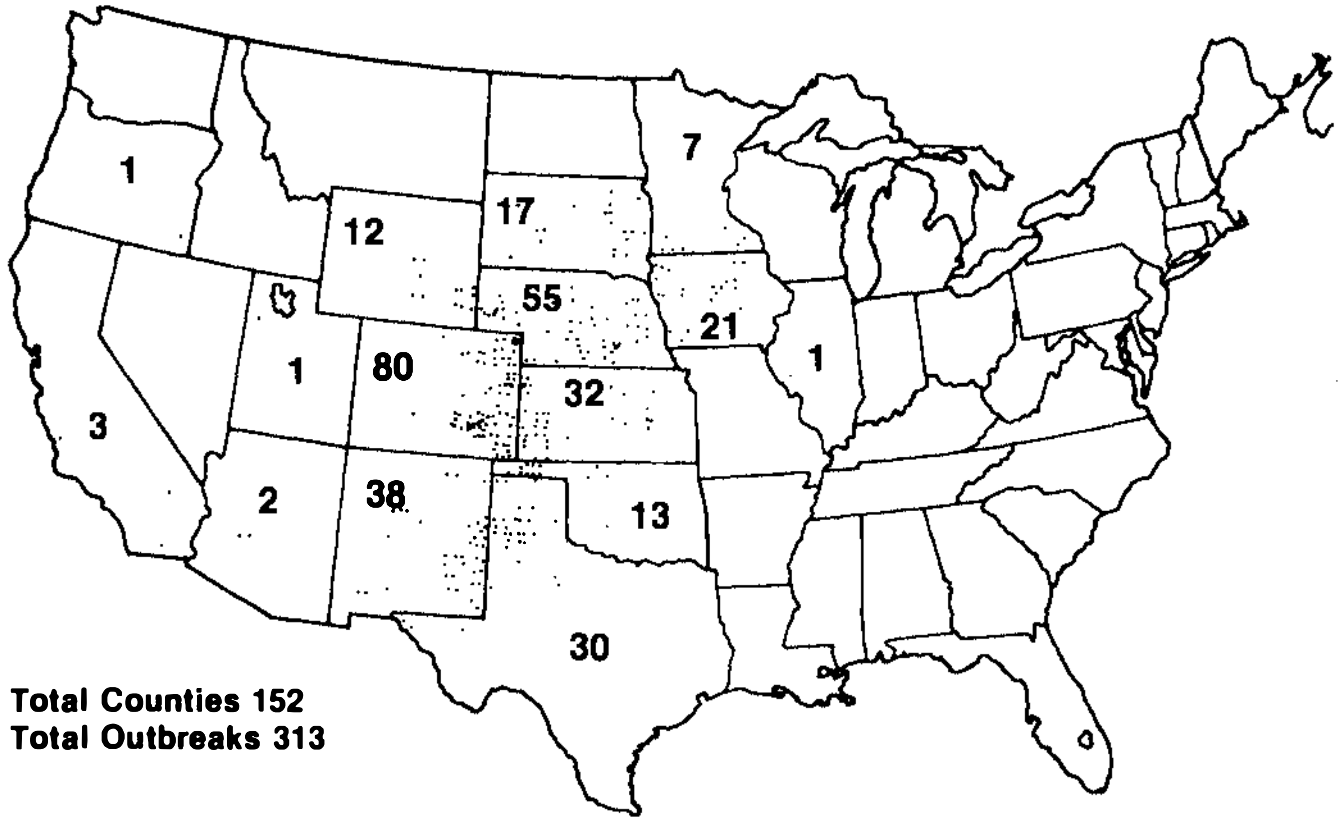
Despite an extensive, longstanding eradication campaign, since 1970 outbreaks of psoroptic cattle scabies in the western, midwestern, and southwestern United States have reached epidemic proportions. Psoroptic cattle scabies--caused by *Psoroptes ovis* (Hering 1838), an obligate parasitic mite--is an acute, subacute, or chronic contagious dermatitis characterized by itching, crusting, scurfing, and depilation. Unchecked, it spreads rapidly, reducing the rate of growth in cattle, lowering the quality of their hides, and eventually causing their death. The resulting economic losses to the cattle industry, the federal and state government agencies attempting to control the disease, and the consumer are significant.

Why is there an epidemic? Psoroptic cattle scabies is not a newly discovered disease. Cato the Censor wrote of the malady as long ago as 180 B.C., and in 1809 Walz demonstrated that mites are the cause of generic scabies. Methods to control infestation were sought, and around 1895 sheepmen in several parts of the United States started a program in which infested sheep and exposed flocks were dipped repeatedly in such compounds as lime-sulfur, sulfur, nicotine, arsenic, petroleum, cresol, and chloronaptholeum. Cooperative state and federal programs have been organized since 1905, and new and better insecticides, such as lindane and toxaphene, have been developed and used successfully on sheep and cattle mites. By 1970, psoroptic scabies in sheep in the United States had disappeared. There had been 872 outbreaks in 1961. For a time similar success was had in controlling psoroptic scabies in cattle. No cases were reported in the United States from 1950 through 1952, and only 49 herds were infested during the decade of the 1960s. Then, in the 1970s, outbreaks of the malady escalated (see Figure 1). In 1978, the number of outbreaks reported reached 313 in 15 states, affecting uncounted thousands of cattle (see Figure 2). During the first 9 months of Fiscal Year 1979, 224 outbreaks occurred in 16 states (see Figure 3). New outbreaks crossed Germany and France, too.



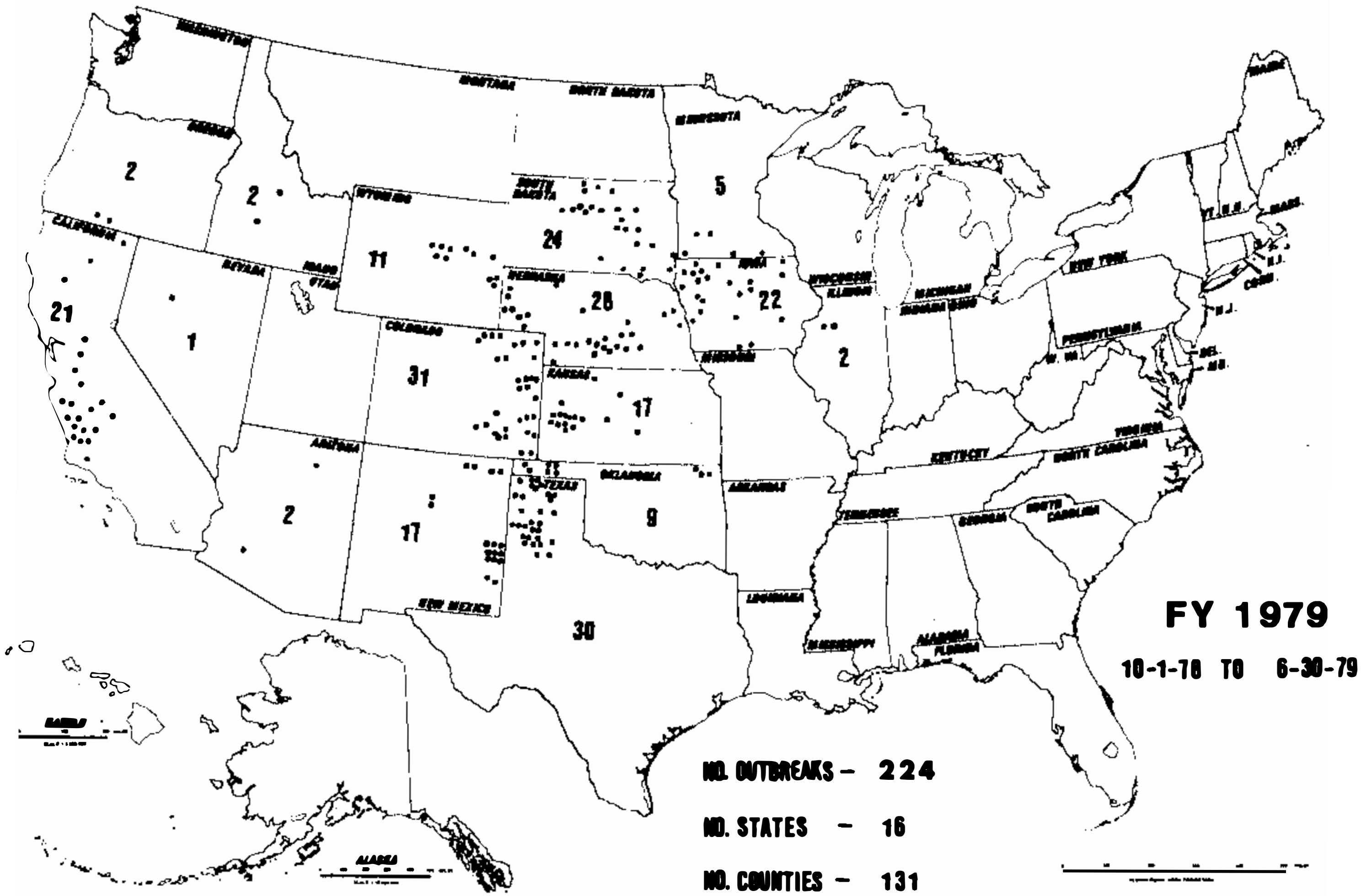
SOURCE: Courtesy of APHIS.

FIGURE 1 Reported outbreaks of psoroptic cattle scabies.



SOURCE: Courtesy of APHIS.

FIGURE 2 Reported outbreaks of psoroptic cattle scabies, FY 1978.



SOURCE: Courtesy of APHIS.

FIGURE 3 Reported outbreaks of psoroptic cattle scabies FY 1979 .

Three factors are largely responsible for the failure of the programs to eradicate psoroptic cattle scabies: (1) the current practices of mixing cattle from many sources, (2) crowding large numbers of cattle into small areas, as happens in the feedlot industry, and (3) ineffective acaricides and application methods. The trend since the mid-1960s has been away from small herds in the Corn Belt and toward large herds in the Texas Panhandle and the surrounding High Plains area, and away from small feedlots toward large feedlots. In New Mexico in 1977, the average number of cattle in each feedlot was 7,350. The average number of calves sold by farms in Georgia in 1974 was only 22 head of cattle. For the large feedlots to fill, cattle from many small operations must be brought together. The cattle are shipped in crowded trucks, enter crowded feedlots and then some are reshipped to crowded sales yards or dispersed to other crowded feedlots. This complex interstate and intrastate traffic facilitates the spread of psoroptic cattle scabies by bringing cattle infested with live mites into bodily contact with uninfested cattle. Federal and state regulations control the movements of cattle and usually require prior treatment of infested and exposed animals with approved acaricides, but some escape. Also, the permitted use of acaricides and application methods may not be completely effective under the varied conditions of practical use.

During the December 1978 meeting in Denver, the Subcommittee was presented with lists of research priorities by state and federal veterinarians and cattlemen's associations representatives. Emphasis was placed on:

1. Providing better diagnostic and inspection methods, more rapid confirmation of outbreaks, modernized methods for recording cattle movements and facilitation of trace-backs, and determining hidden sources of mites such as inapparent presence in the southeastern United States or on wild hosts.

2. Developing better acaricides (particularly those incorporating ovicidal action and lengthy residual action) and treatment methods, including improving or abandoning the spray-dip machine (Colorado veterinarians reported 9 failures out of less than 82 cases); creating treatments having real effectiveness with a single application; developing reliable, fast acaricide analysis methods for dip vats; reassessing toxicity to cattle with emphasis on baby calves; investigating drinking of dip, immediate trucking of wet cattle, and cold weather dipping; treating dairy cattle; and studying specific acaricide problems such as suspensibility of coumaphos, a replacement for toxaphene if registration is removed by the U.S. Environmental Protection Agency, and correctness of dipping interval (10 to 14 days) for toxaphene.

3. Gaining information on the biology of the psoroptic scabies mite of cattle on and off the host, including life cycle, host specificity, effect of climate and weather, latency (or inapparent infestations), and factors of susceptibility of cattle.

4. Meeting the need to thoroughly survey the literature and present an up-to-date summary.

5. Increasing funds for education, training, surveillance and portable dip vats.

6. Establishing a National Scabies Technical Commission to evaluate the eradication program and suggest improvements on a regular, continuing basis.

ECONOMIC LOSSES RESULTING FROM PSOROPTIC CATTLE SCABIES

The costs of scabies are high and are borne directly by the cattle industry and indirectly by consumers and taxpayers. Psoroptic scabies causes economic loss for producers by reducing rates of animal growth and requiring expensive treatments; for packers by diminishing quality of hides; and for the public by necessitating tax-funded research, eradication, and surveillance programs, and by increasing the price of meat.

A comprehensive economic analysis of the losses caused by scabies is needed but has not been done. Nevertheless, what data have been collected and analyzed show clearly that those losses are serious and need to be reduced.

Analyzing an experiment in a Colorado feedlot, Tobin (1962) evaluated the effects of scabies on feed consumption and weight gains in infested cattle. Daily feed consumption declined 21.5 percent and gain declined 0.53 lbs per day. Tobin also noted less obvious costs, such as losses from secondary infections, bruises, sale of "distressed merchandise," and restriction of market outlets.

Meleney and Roberts (1969) stated that the cost of maintaining quarantines against cattle scabies is estimated to be $4 million per year. Costs for dipping averaged $1 per head; however, some dips would control other diseases besides scabies.

During the scabies outbreaks in 1972 and 1973, which involved 53 ranches and feedlots in the southwest, nearly 40 million cattle were individually inspected and approximately 2.7 million cattle were dipped (Roberts 1975). Economists from the USDA estimated the cumulative costs of this outbreak to be $40 million, including cattle losses, treatment costs, and regulatory expenses. Costs of dipping and quarantine coupled with a decline of $1 per $100 in the sale value of cattle infested with or exposed to scabies in 1975 were estimated to have been $65 million.

At current retail prices for chemicals approved for scabies treatment, a single treatment for a 600-lb steer costs $0.39 for coumaphos, $0.23 for phosmet, and $0.16 for toxaphene. Estimated vat depletion and carry-out losses from spray-dips increase material costs 50 and 100 percent, respectively. Labor and facility charges must be added to these material costs. A major additional cost is salary and per diem for supervisory staff from state and federal regulatory agencies. For the 1976 epidemic of cattle scabies that occurred in California, Herron (1976) reported a total state retrievable cost of $498,211 (inspection, treatment, surveillance, epidemiology, administration, and enforcement). In addition, there were federal expenses of $37,000 for equipment and $9,711 for staff provided by the Animal and Plant Health Inspection Service (APHIS) and USDA State Services. The epidemic involved 11 infested herds, 131 exposed herds, 95 herds possibly exposed, and 50 herds inspected after traceback to originating herds. The total cost covered 678,118 cattle associated directly with the outbreak and 5,089,588 cattle inspected because of increased surveillance activities.

At a May 3, 1978 meeting in Denver, Colorado, APHIS presented to the livestock industry proposed changes in the National Eradication Program. The new Program incorporated an "eradication area" concept. The portions of the United States to be included in the plan are: southeastern Wyoming, all of Nebraska, eastern Colorado, western Kansas, the Oklahoma and Texas Panhandles, and approximately one-half of New Mexico. Texas Agricultural Extension Service specialists (Cope et al. 1978) estimated that for the cattle industry to comply it would have to spend $118,117,073 annually and that each year 21,698,540 head of cattle would have to be dipped under either federal or state supervision. According to their analysis, based on May 1978 market values, it would cost $4.90 to dip each beef cow, $5.36 for each replacement heifer, $6.45 for each stocker heifer and bull over 500 lbs, $6.00 for each stocker steer and heifer under 500 lbs, and $4.94 for each head of cattle placed in feedyards.

Federal funds allocated to APHIS to support scabies-related regulatory activities have increased from $1.78 million in 1977 to $5.37 million in 1979. The anticipated allocation for Fiscal Year 1980 is $5.28 million.

Obviously, to let the epidemic of psoroptic cattle scabies continue is to pay a heavy financial penalty. Prevention, early diagnosis and treatment, and--if possible--eradication are economically desirable.

Early eradication would immediately benefit the cattle industry economically and eliminate the need to spend millions of tax dollars on regulatory activities. Investment in research that will facilitate early eradication of cattle scabies should, therefore, be given high priority.

CONSTRAINTS TO ERADICATING PSOROPTIC CATTLE SCABIES

The two major causes of the new psoroptic cattle scabies epidemic--mixing cattle from many sources and crowding large numbers of cattle into small areas--exacerbate problems that have always been present in the eradication program but that until the new conditions arose seemed negligible. Those problems are: conflicting federal and state regulations, inadequate education about cattle scabies and its effects, unclear priorities within the eradication program, and--probably most significant--too little knowledge about the disease itself and the best methods for eradicating it. This last problem is discussed in Chapters 2 through 5.

Conflicts in Regulations

Regulations for the National Scabies Eradication Program emphasize diagnosing infested and exposed cattle, quarantining the premises, treating the animals, and tracing infested or exposed herds to locate all foci of the disease.

With few exceptions, the states have adopted the federal guidelines as their state regulations. The most frequently reported exceptions are: (1) Some states officially recognize only dipping in toxaphene instead of in all four federally permitted pesticides. (2) Some states require treatment of all cattle received from another state whether or not the cattle are being shipped from a quarantined area.

A summary of the federal regulations for the existing National Scabies Eradication Program is contained in Table 1. The complete regulations for the National Scabies Eradication Program (APHIS 1979) are presented in Appendix A. In addition to the regulations, the United States Animal Health Association has formulated Recommended Procedures for Cattle Scabies Eradication, and these are given in Appendix B. The acaricides and treatment methods permitted by APHIS (1972 to 1976, 1977), are presented in Appendix F.

The current eradication program is founded on the principle that infested and exposed cattle are to be treated prior to shipment except for shipment to immediate slaughter. Uninfested and unexposed cattle from

TABLE 1 Guide to Federal Requirements for the Interstate Movement of Cattle with Respect to Scabies

This Guide is NOT a Regulation and is NOT to be used as such. For detailed information relative to each type of Interstate Movement refer to the regulations which appears in Part 73 (as amended) of Title 9, Code of Federal Regulations.
Each State or portion of a State is classified in the regulation as a particular area or areas, namely, (1) Free Area, and (2) Quarantined Area

STATUS OF CATTLE	AREA OR PLACE OF ORIGIN	DESTINATION AND PURPOSE OF MOVEMENT	REQUIREMENTS OR RESTRICTIONS
A. Uninfected and Unexposed cattle	1. Free Area.	Any destination or for any purpose.	Are not restricted under Part 73, except that they lose their status as cattle of the free area: (1) When they move to an eradication or quarantined area or (2) are exposed to infected cattle or facilities.
	2. Quarantined Area.	Cattle moving interstate for any purpose, except immediate slaughter, into any area.	Inspected, treated once within 10 days prior to moving, so certified.[3,4]
		Cattle moving interstate for IMMEDIATE SLAUGHTER directly to a recognized slaughtering center in any area.	Treatment not required but must be inspected within 10 days prior to moving, found free from the disease and exposure thereto, and so certified. One treatment required if cattle not slaughtered within 14 days of arrival at destination.[2,3,4]
B. Exposed Cattle	1. Any Area.	Cattle moving interstate to any area for any purpose, except immediate slaughter.	Inspected and treated once within 10 days of movement interstate and so certified.[3,4,5]
		Cattle moving interstate for IMMEDIATE SLAUGHTER to a recognized slaughtering center.	Inspected within 10 days of movement, found scabies free, and so certified, if not slaughtered within 14 days of shipment, one treatment is required. Vehicles must be placarded.[2,3,4,5]
STATUS OF CATTLE	**AREA OR PLACE OF ORIGIN**	**DESTINATION AND PURPOSE OF MOVEMENT**	**REQUIREMENTS OR RESTRICTIONS**
C. Infected Cattle	1. Any Area.	Cattle moving interstate to any area for any purpose, except immediate slaughter.	Treated twice prior to moving interstate 10 to 14 days apart, and so certified.[3,4]
		Cattle moving interstate for IMMEDIATE SLAUGHTER to a recognized slaughtering center.	Treated once within 10 days of movement and so certified. If not slaughtered within 14 days, a second treatment is required. Vehicles must be placarded.[2,3,4]

1. Inspection, supervision of treatment, and certification must be made by a VS State Inspector or Accredited Veterinarian.
2. The cattle for immediate slaughter shall not be diverted enroute and upon arrival shall use facilities reserved for such cattle.
3. Inspection, supervision of treatment and certification must be made by a VS or State Inspector.
4. All treatments must be done in a permitted pesticide at a State and VS approved treatment facility. Cattle may be treated on farm in a facility approved by the VS or State Inspector involved.
5. If other than permitted lime-sulphur or toxaphene dips are used, two treatments rather than one treatment of exposed cattle are required.

SOURCE: United States Animal Health Association (1978).

nonquarantined and scabies-free areas may be shipped without restrictions.

Because of the increased incidence of scabies in Colorado during 1977, the Colorado Agricultural Commission adopted intrastate shipping regulations (Appendix C) that require dipping of all cattle to be shipped. Special emphasis was given to cattle moving from eastern to western Colorado because the majority of confirmed cases were reported in the eastern half of the state.

In an attempt to fully use available regulatory personnel, some states concentrate their resources into the areas where movement of cattle is greatest. For example, the Arizona Livestock Sanitary Board has formulated regulations (See Appendix D) for "certified feed yards."

The lack of uniformity among state regulations is a problem for members of the livestock industry and regulatory officials. So, too, is the complexity of both state and federal regulations, which creates confusion for producers trying to meet state-of-destination regulations for their interstate shipments. The establishment of uniform, simplified, federal regulations should be encouraged, and, in general, states should adopt the federal regulations.

Inadequate Education

Controlling and eradicating disease in livestock require that the public, the owners, veterinarians, scientists, and control officials understand the principles and benefits involved and collaborate. This requirement was discovered and applied during the campaign from 1887 to 1892 against contagious bovine pleuropneumonia--the first eradication program in the United States--and has been an essential aspect of all subsequent eradication and control programs.

Educational information about and evaluation of psoroptic cattle scabies have been provided to the general public and special groups by many agencies. The latter includes the USDA, State Agricultural Extension Services, Agricultural Experiment Stations, colleges of veterinary medicine, colleges of agriculture, departments of veterinary science, and professional associations. Diverse but related communications have been published in newspapers, magazines, special bulletins, scientific journals, and technical books, and spread by personal conversations. Through these media, thousands of bits of free information on the subject were provided to individuals.

Publications prepared by the USDA had primal significance in educating the public about psoroptic cattle scabies. Farmers' Bulletin No. 1017, "Cattle Scab and

Methods of Control and Eradication," by Imes was first printed in 1918 and revised in 1953 by Kemper and Peterson. Its illustrated contents were semitechnical and consequently comprehensible and utilitarian to cattlemen, veterinarians, and entomologists. Tens of thousands of copies were distributed on request to citizens of the United States as well as to individuals of other countries. Yearbooks of Agriculture--Keeping Livestock Healthy, 1942; Animal Diseases, 1956--also written by scientists of the USDA, were widely distributed and extensively used.

During the quarter century since Bulletin 1017 was last published, host metabolism and toxicities of acaracides have been extensively investigated and numerous new compounds have been synthesized, tested, and marketed. In addition, the incidence of infestation has dramatically fallen and risen, partially because of changes in management practices within the cattle industry. Consequently, Farmers' Bulletin 1017 should be revised to include all relevant old and new information, especially on psoroptic scabies, and should be published in two forms--one technical and the other nontechnical--for educational use by the general public and cattlemen as well as by entomologists, toxicologists, specialized veterinarians, ectoparasitologists, pharmacologists, biochemists, and pathologists.

An educational campaign should be conducted to inform ranchers, feedlot operators, and the general public about the disease. Films, slide sets, pamphlets, radio, television, and other media should be used by county agents, veterinarians, and USDA staff to inform the people they serve.

Unclear Priorities within the Eradication Program

For either regulations or education to be changed in ways that increase to the utmost the potential for eradicating psoroptic cattle scabies, it is necessary that the principles of disease eradication programs be understood and implemented. Without clearly defined principles and goals to direct the efforts of those people regulating the disease, indirection can severely limit the success of the regulatory activities.

A review of the adequacy of research on psoroptic cattle scabies should also contain a review of the principles involved in animal disease eradication programs, because a successful program cannot be based solely on research findings. These findings must be blended into a workable eradication program.

In 1973, a National Academy of Sciences workshop on Animal Disease Eradication: Evaluating Programs was conducted at the University of Wisconsin. The purpose of the workshop was to examine eradication programs and identify the principles that result in successful programs for control or eradication of animal diseases.

At the workshop, Clarkson (1973) stated that the following are essential elements of long-range planning for control or eradication of any animal disease: existence of a definable disease entity; epidemiological intelligence; empirical knowledge of the disease derived from practical experience; more precise knowledge of the disease derived from scientific inquiry; knowledge of the economic impact of the disease; public health considerations; workable procedures for control or eradication of the disease; resources to accomplish the task; and knowledge of public attitudes. In reviewing these elements, he stressed that it is necessary to keep in mind their interrelationships.

Riemann and Bankowski (1973) summarized as follows the important knowledge gained from disease eradication efforts:

1. It is impossible to legislate a disease out of existence.

2. Eradication should not be publicly stated as a goal unless its theoretical possibility has been established.

3. Police measures are seldom completely effective.

4. People must recognize the problem as their own and share in the efforts to correct it. Education is essential.

5. A program must take full advantage of supportive trends in the community and environment.

6. A program must enlist the support of the private segment of the veterinary profession, farm advisors, the Extension Service, and similar groups.

In addition to these elements, Riemann and Bankowski added that "the last phase, stamping out, is sometimes difficult to accomplish and some of the reasons are: (a) previously unknown facts about disease epidemiology show up; (b) flaws in the existing testing methods show up after the bulk of the reservoir has been removed; (c) the tracing of the last carriers is technically difficult and the cost is high; and (d) decrease in funds and interest."

Hourrigan (1978), who is senior staff veterinarian with the USDA and responsible for coordinating the National Scabies Eradication Plan, said about eliminating cattle scabies:

> There is no easy way to eradicate cattle scabies, no simple gimmick, no magic ritual. The disease can be eliminated and this has been proven many times. There is only one way to eradicate cattle scabies and that is to kill the scabies mites. And there is only one practical way to do this--find and dip the cattle harboring the mites. Other activities are merely supporting directly or indirectly, satisfactorily or unsatisfactorily, the direct attack on the scabies mite. There is no way to stay even with the disease. Either the program gains and the scabies mites lose, or the scabies mites win and the program loses. There is no negotiated peace, no negotiated settlement, no truce with scabies mites. If we think we are staying even, the scabies mites must be very happy because they are secretly winning.

In a presentation to the U.S. Animal Health Association, Tobin (1978) listed the following as keys to a successful scabies eradication program: (1) acceptance of the program and cooperation with it by the livestock industry; (2) surveillance and control of cattle movement--both interstate and intrastate; (3) vat management to ensure the quality of dipping; (4) proper management of outbreaks to prevent spread and rebreaks; (5) adequate epidemiological investigations to locate sources of scabies and notify other interested parties of possible spread from outbreaks.

Comparisons of the cattle scabies eradication program with other eradication programs may not be valid. For example, the sheep scabies program differed because there was a decrease in total sheep population and sheep are not commingled into concentrated herds as are cattle. Also, other animal disease eradication programs rely on fairly accurate, objective diagnostic techniques, such as the card test for brucellosis.

Some of the difficulties encountered by regulatory agencies in Great Britain in their efforts to eradicate psoroptic scabies from sheep are nicely summarized by Spence (1951):

> Inefficient, incomplete gathering [of animals to be treated or examined] . . ., inefficient dipping methods, inefficient dips, insufficient supervision, difficulties of diagnosis and detection, special phases of the disease resistant to treatment, and non-co-operation or even concealment of disease by . . . owners and inadequate propaganda constitute the main problems which faced those responsible for the control of the disease.

Other observations made by Spence are:

> No matter how good an insecticide might be, it cannot be magical, and few will kill parasites without contact with them. [Lay inspectors] . . . were of very great value and the discovery of many outbreaks was made by them. The training and appointment of large numbers of lay officers of this class is a very important point in any disease eradication campaign and will certainly prove necessary before we can bring such diseases . . . under control.

The Veterinary Laboratory, Ministry of Agriculture and Fisheries, Weybridge, England, wrote:

> No dips are passed for approval unless they give 100% cure of active, encrusted scab when used at half the normal bath concentration prescribed in the manufacturer's instructions. Most . . . [stockmen] can easily recognize [scabies] and its presence leaves many of them quite undisturbed. [In some situations] . . . the disease spreads very slowly, and the grudging dipping efforts imposed carelessly and inefficiently carried out, serves to keep the disease in a quiet, smoldering state which causes them no alarm. Even in infected [flocks] the incidence may be only a fraction of 1% so that it seems a very unimportant disease. Many . . . were much less interested in clearing the [flocks] of [scabies] than they were in finding some cure for footrot.

The current outbreaks of cattle scabies in the United States can be linked to many of the deficiencies enumerated by Spence (1951). The attitudes of many members of the cattle industry, unfortunately, closely parallel the attitudes mentioned by him as being common among hill-country stockmen where sheep scabies was endemic. That is, the members believe that the regulations and prevention are more costly to the entire cattle industry than the disease itself.

Cooperation from the cattle industry and additional financial support for regulatory agencies are essential if psoroptic scabies of cattle is to be eradicated from the United States. However, the Eradication Program should improve because federal funding increased from $1.78 million in Fiscal Year 1977 to $5.37 million in Fiscal Year 1979.

It is evident that accurate and practical diagnostic techniques are essential. Completely effective eradication procedures must be made available and must gain the support of industry to reach the goal of eradication.

CHAPTER 2

REVIEW OF THE CURRENT KNOWLEDGE ABOUT PSOROPTES MITES

Surprisingly little research has been done in recent years on the basic biology of the parasite causing scab in cattle, or any *Psoroptes* species. Scientists are dependent mainly on early work reported by Gillette (1897), Salmon and Stiles (1898), Hickman (1902), Neumann (1906), Stockman (1912), Stockman and Berry (1913), Bedford (1915), Shilston (1915), Imes (1918, 1927), Hirst (1922), du Toit (1923), Cameron (1925), Babcock and Black (1933) Downing (1936), Neveu-Lemair (1938), Lucas (1942), Snyder (1942), Fortushnyi (1942), Palimpestov (1944, 1947), Bauman (1946), Troitzkii (1947), Spence (1949), Najera and Mayer (1950), Palimpestov et al. (1950), Rocha et al. (1952), Kemper and Peterson (1953), Priselkova (1954), Dubinin (1954), and Roberts and Cobbett (1956). Nineteenth century research, mainly taxonomic, was reported by Bourguignon, Delafond, Canestrini, Gerlach, Hering, Megnin, and Railliet.

Much of this literature was reviewed by Sweatman (1958) in his work on the taxonomy and biology of *Psoroptes* mites. However, his was not a complete review, particularly of bionomics pointed toward practical questions related to control or eradication. Results of biological research since 1958 are scattered in many small papers in some American journals and many foreign journals for which, unfortunately, there are no English translations. The hiatus in Russian translation is particularly serious. No recent reviews exist. The most valuable recent research is that of W.P. Meleney and I.H. Roberts and their co-workers. Significant contributions have been made by Russian parasitologists. Only minor work has been done elsewhere on the biology of psoroptic scabies mites.

Most research on *Psoroptes ovis* has been done on sheep. The Subcommittee considers this research pertinent to cattle because the etiological agents are probably the same species. However, such extrapolation must be done cautiously because of parasite strain differences, host physiological differences, and great differences within the microenvironment of cattle haircoat and sheep fleece. The few reports on the biology of the bovine form of *P. ovis* include Hickman (1902), Imes (1918), Synder (1942), Baker

(1946), Kemper and Peterson (1953), Roberts and Cobbett (1956), Labie et al. (1975), Liebisch and Petrich (1977), and Liebisch et al. (1978). Most are reviews. Further biological research with *Psoroptes ovis* on or from cattle is needed urgently.

TAXONOMY AND HOST SPECIFICITY

In this report, the *Psoroptes* that causes cattle scabies is called *Psoroptes ovis* (Hering 1838), following the definitive research of Sweatman (1958). Sweatman synonymized *P. ovis* and *P. bovis* because he could find no morphological differences and there was evidence of transferability between sheep and cattle (Kemper and Peterson 1953, 1956). Sweatman also noted epidemiological coincidence in Australia, Canada, and New Zealand, where decline in bovine scabies incidence followed successful ovine scabies eradication.

The synonymy becomes:

Collections from sheep--*Psoroptes ovis* (Hering 1838); *Psoroptes ovis* (Gervais 1841); *P. longirostris* var. *ovis* (Megnin 1877); *P. communis* var. *ovis* (Railliet 1893); *P. equi* var. *ovis* (Neveu-Lemaire 1938).

Collections from cattle--*Psoroptes ovis* (Hering 1838); *Dermatodectes bovis* (Gerlach 1857); *P. longirostris* var. *bovis* (Megnin 1877); *P. communis* var. *bovis* (Railliet 1893); *P. bovis* (Canestrini and Kramer 1899); *P. equi* var. *bovis* (Neveu-Lemaire 1938).

The Subcommittee follows Sweatman in considering psoroptic scabies of cattle and sheep to be etiologically identical. More recently, Roberts and Meleney (1971) have confirmed the transfer of psoroptic scabies mites between sheep and cattle. Meleney (1967) initiated infestation by *P. ovis* in a rabbit by transfering mites from a steer. The mites prospered, causing severe scabies. The rabbit died. Mites from the rabbit were transferred to sheep and cattle, resulting in typical sheep scabies, but only transitory infestation in cattle. Because the results of this experiment were most unusual, they should be confirmed by further research. The mites originated from cattle but would not reinfest cattle, although they did infest sheep subsequent to the rabbit passage. Also, the mites were transferred into the rabbit's ears, where infestation occurred; only later did the infestation spread to nearby parts of the body. *P. ovis* is not ordinarily an ear mite (Sweatman 1958). Shilston (1915) failed to infest ears of rabbits with *P. ovis* from sheep. Delafond and Bourguignon (1856) could not infest a cow with *P. ovis* from sheep. Sweatman discounts this very old research, citing epidemiological evidence to support his conclusion that the agents causing psoroptic scabies in cattle and sheep are monospecific. He notes that in Australia, Canada, and New Zealand, bovine psoroptic scabies declined greatly following ovine scabies eradication campaigns.

Nykolsky and Tchablin (1973), however, consider Psoroptes mites to be host specific. They review Palimpestov (1956) and Nykolsky and Orlov (1958), noting that no disease occurred in animals during the invasion of Psoroptes from nonspecific hosts. They were unsuccessful in repeating the Meleney (1967) experiment on four rabbits. The cattle mites lived in rabbit ears for more than 28 days but did not cause scabies and were not propogated by serial transfer. Mites that were transferred from sheep to rabbits died in 7 to 10 days. Nykolsky and Tchablin (1973) concluded from serological experiments that allergic responses in hosts are related to specific Psoroptes species. They state that morphological and biological characteristics of Psoroptes mites, as well as the allergic responses of animals, indicate that cattle, sheep, and rabbit Psoroptes are distinct species.

Palimpestov (1961) greatly complicates the taxonomy. Using the old Megnin trinomials Psoroptes longirostris ovis, bovis, and equi, it was concluded from experimental results that one or another of these mites can infest horse, cattle, sheep, goat, pig, rabbit, dog, and chicken.

Sweatman, as noted above, used Australian epidemiological experiences to support the theory that scabies mites are monospecific. However, more recent epidemiological evidence supports the theory that they are polyspecific. Sheep scabies was introduced into Australia in 1788, control efforts commenced in 1831, eradication was successful in 1896, and scabies has not recurred (Roberts 1952; Endrejat 1957; Seddon 1964; FAO-WHO-OIE 1971, 1977). Roberts, writing in 1952, noted that cattle scabies was unknown in Australia. However, in more recent years it is reported as having a "low sporadic occurrence, treatment not required" (FAO-WHO-OIE 1971, 1977). More dramatically, the bovine form in the United States has increased catastrophically since 1970, despite completely successful ovine eradication after January 1970, with no recurrence (Meleney and Christy 1978). Meleney and Christy (1978) argue against polyspecificity because the cattle scabies outbreak that began in 1970 has been in the western United States only, where sheep seldom mingle with cattle. However, in the 1940s and 1950s in New York State and the northeast in general, sheep scabies was common while psoroptic cattle scabies was practically absent, even though cattle and sheep mingled in some pastures during summer and even in some buildings during winter (Matthysse, personal observation). The comparative worldwide distribution of the two diseases (see Table 8) does not support monospecific status. *P. ovis* is reported to affect sheep but not cattle in 12 countries, cattle but not sheep in 16 countries. A great difference in incidence of psoroptic scabies between the two hosts is reported by 23 countries.

Careful morphological studies may reveal new characters of taxonomic value. For example, Krishna Rao et al. (1974) add the bursa copulatrix of the ovigerous female as a character valid at the species level. They used it to differentiate *P. natalensis* and *P. cuniculi*. Further work is needed to determine the validity of the bursa copulatrix for the remaining species of *Psoroptes* and possibly for new species among them.

Understanding the nature of the differences between *Psoroptes ovis* on sheep and cattle is incomplete. Differences in aggressiveness and virulence among parasite strains (Roberts and Meleney 1971) and individual host susceptibility (Sweatman 1958) and immunocompetence, as discussed for *Sarcoptes scabiei* by Hancock and Ward (1974), Clayton and Farrow (1975), and Fain (1978), are undoubtedly involved. Successful transfer of a parasite to an exotic host species can require a particular strain, as has been demonstrated by adapting the human body louse, *Pediculus humanus*, to feeding on rabbits (Culpepper 1946). Culpepper's research further demonstrates that cross transfer of parasites among hosts is not an adequate species criterion. Conversely, initiation of infestation on the normal host can be difficult at times, as shown by Cameron (1925) for bovine psoroptic scabies.

The most reasonable conclusion is that transfer of *P. ovis* from one host species to another does not occur readily under natural farm conditions. Strain differences, probably host-induced, exist in the parasite population (Roberts and Meleney 1971, Meleney 1978), even if varietal or specific differences do not. Further work is needed to determine the taxon for this parasite, including research involving scanning electron microscopy, internal anatomy, genetics, physiology, biology, ecology, and immunology. Possibly, sibling species are involved. Cross-host transmission studies should be undertaken using single virgin forms of the two sexes mated in confinement on assuredly mite-free animals. Males of strain ovine crossed with females of strain bovine, and vice versa, should be tested with biological data taken during a complete generation, and longer if possible. Aggressive-virulent and nonaggressive, low-virulent strains (Roberts and Meleney 1971) should be tested. Obviously, such research is difficult, laborious, and expensive.

Horses, donkeys, and mules are the only North American domestic animals, other than sheep and cattle, that have been reported from other parts of the world as hosts for P. ovis. However, equines are questionable hosts for P. ovis. After stating that P. ovis infests cattle, Sweatman (1958) writes that "data on psoroptic mites from horses is less convincing." He concludes that horses are hosts for P. equi, P. cuniculi, P. natalensis, and possibly P. ovis. General experience is that work horses used among psoroptic scabby cattle or sheep do not become infested. Further research is needed on Psoroptes from horses, including world distribution of P. equi and its differentiation from P. ovis and P. cuniculi.

The most recent and most authoritative general manual of acarology (Krantz 1978) cites P. equi (Hering) as the psoroptic scabies mite of sheep and cattle. Evans et al. (1961) named Psoroptes forms according to host, using P. equi (Raspail) ovis, bovis, equi, cuniculi, and caprae. The Subcommittee sees no necessity for these ambiguous reversals. Hering described both species in 1838, naming them according to host, as no morphological criteria were known then. Undoubtedly the mite he named ovis, from sheep, was that which we know now as ovis. It is very unlikely that the mite from horses was that ovis, but rather equi or cuniculi (Delafond 1859). Evans et al. (1961) appear to have discounted the morphological differences among equi, ovis, and cuniculi.

The only American wild-animal host for P. ovis is the bighorn, Ovis canadensis, as will be discussed subsequently.

The species of Psoroptes, based on Sweatman (1958) and subsequent workers, are:

Body Mites

P. ovis (Hering 1838, Gervais 1841)--sheep, cattle, bighorn (Ovis canadensis), possibly horse, donkey, and mule, probably water buffalo (Bubalus bubalis). Cosmopolitan.

P. equi (Hering 1838, Gervais 1841)--horse, possibly donkey, and mule. England, South Africa according to Zumpt (1961).

P. natalensis (Hirst 1919)--cattle (Bos taurus and Bos indicus), Indian water buffalo (Bubalus bubalis), horse, African Cape buffalo (Syncerus caffer). Asia, Africa, South America, New Zealand, possibly France.

P. pienaari (Fain 1970)--African Cape buffalo. Africa.

Ear Mites

P. cuniculi (Delafond 1859, Canestrini and Kramer 1899)--rabbit, goat, sheep, horse, donkey, mule, Indian water buffalo, possibly *Gazella*. Also a temporary body mite of horse. Cosmopolitan.

P. cervinus (Ward 1915)--bighorn (*Ovis canadensis*), wapiti or elk (*Cervus canadensis*) (in the ears), mule deer (*Odocoileus hemionus*), and probably white-tailed deer (*Odocoileus virginianus*). North America.

Roberts et al. (1970) determined that mule deer (*Odocoileus hemionus*) were infested with *Psoroptes cuniculi*. Strickland et al. (1970) found *Psoroptes* on white-tailed deer (*Odocoileus virginianus*). They declined to apply a species name but suggested that these mites were *P. cuniculi*. Roe (1951) mentions mange on American bison (*Bison bison typicus*), but not even the genus was determined. Seton (1929) also noted mange on bison. Hepworth and Thomas (1962) were unable to transmit *P. cervinus* from elk to cattle or sheep.

Further recent references for *Psoroptes* on wild hosts in the United States are: *P. cervinus* on elk--Colwell and Dunlap (1975), Worley et al. (1969), Honness and Winter (1956); *P. ovis* on bighorn--Lange et al. (1979), Becklund and Senger (1967), Cowan (1951). Sweatman (1958) and Lange et al. (1979) cite other references supporting these determinations of *Psoroptes* species on wild hosts in North America.

In conclusion, several *Psoroptes* species infest American wild mammals, but the only probable wild host for *P. ovis* is the bighorn (*Ovis canadensis*) and its several subspecies. Lange et al. (1979) note that serious epizootics occur among bighorn. It is probable that bighorn initially acquired *P. ovis* from domestic sheep or cattle many years ago. Bighorn are potential reservoirs for psoroptic scabies of livestock. Although the habitat of bighorn is mainly remote mountainous areas, it overlaps that of range cattle and sheep.

As stated above, bighorn remain only a probable host for the *Psoroptes ovis* of sheep and cattle. As Lange et al. (1979) point out, proof awaits transmission studies. Current knowledge of speciation in *Psoroptes* is inadequate for reliance on morphological characters only.

Further data concerning bison are needed.

Outside North America, the domestic water buffalo, *Bubalus bubalis*, and the wild African Cape buffalo, *Syncerus* caffer, are hosts for Psorptes natalensis and possibly Psoroptes ovis (Sen and Fletcher 1962, Mohan 1968, Mohan and Gotts 1970, Zumpt 1961, Krishna Rao et al. 1974, Fain 1970, Basson et al. 1970). Shastri and Ghafoor (1974) add Bubalus bubalis as a host for ear infestations by Psoroptes cuniculi.

The Psoroptes on alpacas in South America has been stated to be Psoroptes communis var. aucheniae (Chavez and Guerrero 1965, Astrom and Alvarado 1966). Fain (1970) described Psoroptes pienaari taken from African Cape buffalo Syncerus caffer from Uganda and South Africa. There is no evidence that either species affects cattle or sheep.

The position of Psoroptes ovis within higher categories of Acarina, according to the most modern classification (Krantz 1978), is:

Phylum	Arthropoda
Class	Arachnida
Subclass	Acari
Order	Acariformes
Suborder	Acaridida
Supercohort	Psoroptides
Superfamily	Psoroptoidea
Family	Psoroptidae
Genus	Psoroptes
Species	ovis

Most scabies and mange mites of cattle and sheep are found in the supercohort Psoroptides. Two exceptions are Demodex and Psorergates, members of the suborder Actinedida, families Demodicidae and Psorergatidae, respectively. These mites are readily distinguished from Psoroptes by the anteriorly placed legs and annulate elongate form of Demodex and by the strong claws on all legs of Psorergates. Psorergates ovis and P. bos are very small mites with radially placed legs. They have been found at odd times in several states (Roberts and Meleney 1965, Roberts et al. 1965). Within Psoroptides, the superfamily Sarcoptoidea contains the cattle and sheep scabies mite Sarcoptes scabiei, which is distinguished from Psoroptes by its short legs III and IV, long unsegmented pedicles, and spined dorsum.

Within Psoroptidae, the genus Chorioptes contains the chorioptic scabies mite, C. bovis, of sheep and cattle. Although closely allied to Psoroptes, C. bovis is far less pathogenic because it feeds on skin products (scurf) rather than directly damaging the skin (Sweatman 1957, McEnerney 1953, Matthysse and Marshall 1963). C. bovis is common and widespread on cattle and sheep in the United States and is by far the most frequent cause of scabies, albeit usually mild (Matthysse and Marshall 1963, Roberts et al. 1964).

Chorioptes can be distinguished from Psoroptes by the short unsegmented pedicles I and II, short leg III of the female, and shape of the gnathosoma.

Fain (1975) gives a key to the genera of the subfamily Psoroptinae, including the domestic-animal mite genera Psoroptes, Chorioptes, and Otodectes. Georgi (1974) gives differentiating characters and excellent illustrations for these genera as well as for Sarcoptes and Notoedres.

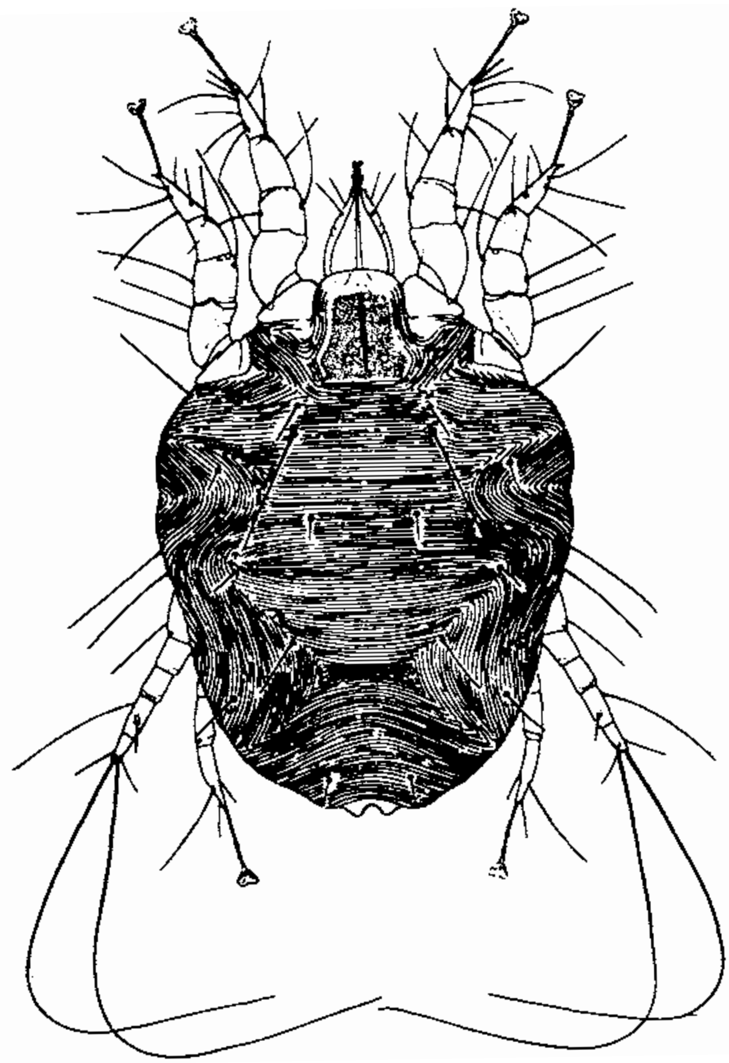
Dubinin (1954) presents for families and genera of mange and scab mites a key in which the superfamily Sarcoptoidea contains the families Acaridae and Psoroptidae. Although these taxons are at variance with Krantz (1978), the key characterizes genera very well.

Sweatman (1958) includes a key to the species of Psoroptes based on adult males. Only two characters are used: length of the outer opisthosomal seta and the location of the infestation on the host.

LIFE HISTORY

According to Sweatman (1958) and all recent workers, psoroptic scabies mites develop through five stages: egg, larva, protonymph, deutonymph or pubescent female, and adult or ovigerous female (Figure 4). The ambivalence in terms for the last two stages results from the unusual circumstance that fifth stage males (adults) attach to fourth stage females (deutonymphs) that molt to become ovipositing fifth stage females. The Subcommittee follows Sweatman in using the terms "deutonymph" for fourth stage males, "pubescent" for fourth stage females, "ovigerous" for fifth stage females, and "adult" for the fifth stage males. Sweatman (1958) reviews the usage of these terms by various authors and the discrepancies in the number of male stages reported.

Evans et al. (1961) use "tritonymph" for pubescent females. Fain (1963) agrees, noting that the deutonymphal stage is absent in five ectoparasitic families of Acaridiae, including Psoroptidae. Among Acarina in general, tritonymphs are advanced stages that molt into adult males and females. Sexual distinctions may be present. Thus, the third motile stage of Psoroptes should be named "tritonymph." Fain (1963) describes the nymphal stages of Psoroptidae and discusses their development, noting that only in Psoroptes and Chorioptes is there sexual differentiation among protonymphs as well as tritonymphs. His scheme is simple: (1) egg, larva, protonymph female, tritonymph female, adult female; (2) egg, larva, protonymph male, tritonymph male, adult male. He does not use "ovigerous" or "pubescent." Fain's terminology is



SOURCE: Courtesy of APHIS.

FIGURE 4 *Psoroptes ovis* (female).

authoritative, but, to be consistent with current usage, the Subcommittee will continue to use the Sweatman (1958) terminology--deutonymph, pubescent, and ovigerous--in this report.

Sweatman (1958) describes and illustrates each stage of P. cuniculi in great detail. Except for body size and length of the outer opisthosomal setae, these descriptions are correct for P. ovis, which is described and illustrated by Downing (1936) and by taxonomists (cited in the Taxonomy and Host Specificity section of this report). The egg is elliptical, opaque initially, and shiny white with two bosses on the same side towards one end. The larva is elongate, oval, soft-bodied, grayish brown, with three pairs of moderately short legs. No sexual dimorphism has been noted. The protonymph is similar except that it is larger, has additional setae, and possesses four pairs of legs. The only sexual difference noted was the presence of a pair of posterodorsal suckers on the female protonymph. The deutonymph male and pubescent female are similar to their respective protonymphs except for larger size and additional setae. The pubescent female is differentiated from the deutonymph male by her possession of posterodorsal suckers. The adult male differs strongly from earlier stages in that it has setae of the idiosoma, large opisthosomal lobes, setation and caruncles on legs III and IV, possession of copulatory suckers, and visible reproductive apparatus. The ovigerous female is more similar to the immature stage than is the adult male. However, in contrast to earlier stages, a vulva is present between coxae II and posterodorsal suckers are absent. Insemination occurs upon molting from pubescent to ovigerous female. A quiescent period occurs at the end of each immature stage, prior to molting.

It is unfortunate that little research has been done on the life history of P. ovis on or from cattle. The following information on P. ovis is derived from research on sheep.

Table 2 summarizes data on the length of egg incubation and one complete generation of Psoroptes ovis on sheep, reported by Babcock and Black (1933), Downing (1936), Gerlach (1857), Gillette (1897), Imes (1927), Kemper and Roberts (1950), Kemper (1952), Lucas (1942), Palimpestov and Goncharov (1960), Priselkova (1954), Roberts (1975), Shilston (1915), Stockman (1910), and Stockman and Berry (1913). Table 3 presents more detailed results, including duration of all stages, from the experiments of Downing (1936), Lucas (1942), and Shilston (1915). These workers used similar techniques in which aluminum, glass, bolting-cloth, or muslin cells containing Psoroptes ovis were cemented to the skin of sheep.

TABLE 2 Days Required for Incubation of Eggs, and for One Complete Generation, *Psoroptes ovis* (Ovine)

Egg Incubation	Cycle (Egg to Egg)	Source
1-3[a]	10-12	Downing (1936)
2-3[a]	10	Lucas (1942)
2-3[a]	11-13	Shilston (1915)
3.2-3.7[b]	17-18,[b] 30-90[c]	Priselkova (1954)
3-4[a]	14-15	Gerlach (1857)
3-4[a]	10-12	Stockman and Berry (1913)
3.5-6.4		Palimpestov and Goncharov (1960)
4-5[d]		Downing (1936)
4-5[d]		Shilston (1915)
4-7[e]		Stockman and Berry (1913)
4-7	14-19	Kemper and Roberts (1950)[i]
-9[f]		Gillette (1897)
<7	<17-19	Roberts (1952)[i]
6-8[g]		Shilston (1915)
to 10[h]		Downing (1936)
10-17		Palimpestov and Goncharov (1960)
	10-12	Imes (1916)[i]

[a]On the skin.
[b]*In vitro* at 36-37°C, >85% R.H.
[c]*In vitro* at low temperature and low R.H.
[d]Separated from skin by scab or debris.
[e]*In vitro;* temperature not stated.
[f]Carried in vial in a pocket.
[g]Two inches from the skin.
[h]Up to 10 days in tags of wool attached 2 inches from the skin.
[i]Not original research.

TABLE 3 Life History of *Psoroptes ovis* (Ovine) Confined Near the Skin of Sheep

Developmental Stage (in days)	Shilston (1915)	Downing (1936)	Lucas (1942)
Eggs			
Number		126	16
Minimum	2	2	2
Maximum	3	3	3
Mean		2.7	2.7
Larvae			
Number		66	12
Minimum	2	2	2
Maximum	3	3	3
Mean		2.2	2.2
Nymphs[a]			
Number		34	11
Minimum	3	2	2
Maximum	4	3	3
Mean		2.3	2.1
Deutonymphs (♂)[b]			
Number		4	8
Minimum	∿1	5	1
Maximum		5	1
Mean		5	1
Pubescent (♀)			
Number		25	8
Minimum		2	2
Maximum		4	3
Mean	∿3	2.2	2.5
Preoviposition			
Number		10	
Minimum		1	1
Maximum		2	1
Mean	∿1	1.3	1
Cycle (♀)[c]			
Number			
Minimum		9	9
Maximum		15	13
Mean		10.7	10.5

TABLE 3 (Continued)

Developmental Stage (in days)	Shilston (1915)	Downing (1936)	Lucas (1942)
Cycle (♀)[d]			
Number		4	1
Minimum	11	10	10
Maximum	13	12	10
Mean		11.0	10

[a]Downing data include female protonymphs only; Lucas data include both sexes.
[b]Downing data include male protonymphs plus male deutonymphs; Lucas data include male deutonmyphs.
[c]Cycle derived from periods for each stage.
[d]Cycle observed for individual mites through one generation.

According to most workers, the complete life cycle, egg to egg, for mites close to the skin of normally fleeced sheep usually requires 10 to 12 days. Incubation of eggs usually requires 2 to 3 days. Sweatman (1958) suggests that these may be minimum periods because the eggs used in the experiments were not necessarily newly oviposited. However, Downing, Lucas, and Shilston all described experimental methods which ensured that the eggs were less than 12 to 24 hours old. Downing and Lucas used a large number of eggs from which they derived an average incubation period of 2.7 days.

Eggs further from the skin and therefore at lower temperatures in the gradient from skin temperature to ambient air temperature require more time to hatch, even up to 10 days (Table 2--Downing, Stockman and Berry). Thus, the complete life cycle could extend through 3 weeks. Kemper and Roberts give the life cycle as 14 to 19 days, which is probably longer than normal. Their statements are derived from the data of other workers and are made without reference to their source.

In vitro experiments (Priselkova, Stockman and Berry, Gillette) yielded longer incubation and life cycle periods, but conditions probably were not optimal.

Extremes of weather could cause variations in the life cycle because skin temperature and humidity are affected by the temperature and humidity of ambient air and by sunlight (see the section on Bionomics).

In Palimpestov and Goncharov's experiments on mites from sheep at temperatures between 25 and 33°C and relative humidity between 20 and 25 percent, eggs took a long time to hatch: 3.5 to 6.4 days. At lower relative humidity, 10 to 12.5 percent, the development time increased to 10 to 17 days. However, Downing (1936) concluded that "there is no evidence to show that the life cycle varies in the different seasons of the year." He obtained a cycle of 10 to 12 days on sheep in February, April and May, July, October, and December in England. This conclusion may not be true in countries with more rigorous climates.

The temperatures inside the cells used by Downing, Lucas, and Shilston were never recorded. It is possible that reduced ventilation caused higher-than-normal temperatures and thus shortened development periods. Future research should include measurements in this microenvironment.

Table 3 presents the duration of each stage in the development of *Psoroptes ovis* near the skin of sheep, as determined by Downing, Lucas, and Shilston. Shilston added that pubescent females appeared 5 1/2 days after hatch, males 6 days or more, "copulation" (attachment) occurred within 7 days of hatch, duration of attachment was 1 to 2 days, and oviposition began 9 days after hatch.

Hickman (1902), Imes (1918), Cameron (1925), and Snyder (1942) report on the time required for development of _P. ovis_ on cattle. According to Imes, the eggs require 3 to 4 days to hatch and the mites take 10 to 12 days before ovipositing. The egg-to-egg cycle is thus 13 to 16 days. These data indicate a longer cycle on cattle than on sheep, caused mainly by slower development after eclosion. However, the reports are not original research, but reviews of data. To confirm these reports, further research is needed in which similar techniques are used on both hosts and microenvironment temperature and humidity are recorded. _In vitro_ data should be obtained.

Sweatman's (1958) report of results with _Psoroptes cuniculi_ held at 35°C and 80 percent relative humidity was vague: the incubation period for eggs lasted up to 4 days, quiescent mites took up to 30 hours to molt, motile periods were longer than quiescent periods, and additional time was needed for the preoviposition period. Altogether, a complete cycle could take up to 3 weeks. The 3-week cycle for _P. cuniculi_ is considerably longer than that for _P. ovis_, reflecting the artificial conditions of Sweatman's experiments with _P. cuniculi_ and possibly a species difference.

The two most important biological factors affecting timing strategy for acaricidal treatments are incubation and single-generation periods. Shilston suggested an interval of 10 days between dippings on the basis that minimum generation time is 9 days, that sheep remain wet for some time after dipping, and that egg incubation requires less than 9 days even when the eggs are 2 inches from the skin. Downing (1936) concurs in suggesting a 10-day interval. Current United States Regulations accept a 10 to 14 day interval as discussed in detail in the Treatment and Prevention section. Fourteen days appears to be a long interval considering that new eggs may be laid within 9 to 10 days of hatch.

There is little biological data from research with _P. ovis_ on cattle related to timing acaricidal treatments. Life history research is needed urgently. It should include experiments in various seasons and climates on cattle having different types of haircoats. Skin temperature and humidity readings should be taken both within the cells or other devices used to confine the mites and, for comparison, nearby in the normal temperature gradient of the haircoat.

The behavior of each stage of _P. ovis_ on sheep is described by Downing (1936). The larva begins to feed immediately after hatching, causing a typical vesicle to form on the host. During the last 12 to 24 hours of this phase the larva ceases to feed and becomes quiescent, assuming a characteristic position. The female protonymph feeds, then enters a quiescent period lasting 24 to 36 hours. Downing's male "nymphal" quiescent period of 72 hours is in error because he did not distinguish between the protonymph and deutonymph stages of males. The pubescent female feeds for a short time before a male attaches to it, and may feed during attachment. Molting occurs during the last 24 hours of attachment and is followed by insemination. Finally, the female is freed to prepare for oviposition. Pubescent females will neither molt nor lay eggs unless males are present. In the absence of males, pubescent females will live as long as 49 days on a sheep without reproducing (Shilston 1915). Shilston reported that males survive for 22 to 34 days. Palimpestov and Goncharov (1960) determined that at unfavorable temperatures eggs seldom survived for more than 22 days, either on sheep or in the laboratory.

Downing observed 1 male fertilize 5 females within 48 hours, and Shilston observed 1 male fertilize 6 females. The ovigerous female feeds soon after emergence and oviposits soon after engorgement.

Psoroptic scabies usually is spread by direct contact (Babcock and Black 1933, Imes 1927, Kemper and Peterson 1956). Animals can contract the disease from contaminated quarters, fences, etc., as discussed in the Bionomics section. Kirkwood (1977) discusses the possibility that the disease is spread by birds such as starlings that carry tags of wool some distance. Salmon and Stiles (1898) mention distribution by crows.

The rabbit ear mite, Psoroptes cuniculi, has been transmitted experimentally by the housefly Musca domestica (Holz 1955). Therefore, it is conceivable that flies could transmit bovine psoroptic scabies. The face fly Musca autumnalis is a likely candidate for this research since it is attracted to wounds, blood, and watery secretions on the bodies of cattle and is very mobile within and among herds (Ode and Matthysse 1967).

Blake et al. (1978) described the mouthparts of P. ovis and how they function in feeding. The skin of sheep is abraded by the shearing action of the toothed, chelate chelicerae. Serous exudates are siphoned through a suctorial cup formed from the subcapitulum, into a preoral cavity, thence into the pharynx. The pharynx acts as a pump. Salivary glands were not observed. The absence of salivary secretions may bear on the lack of development of antibodies in the host.

Maydell (1961) and Priselkova (1954) described the general morphology of *Psoroptes*, and Buxton (1920) presented details of the capitulum. Mayer (1960) worked on the morphology of *P. equi*. Najera and Mayer (1950) described the morphology of *P. cuniculi*. Jones (1957) reported on the size of *Psoroptes* eggs. Fain (1963) described and illustrated morphological features of value in taxonomy of Psoroptidae, including for *Psoroptes* the chaetotaxy, legs, epigynium, and attachment organs. Krishna Rao et al. (1974) described the bursa copulatrix and other copulatory organs of *P. cuniculi* and *P. natalensis* and discussed the methods of attachment and insemination.

BIONOMICS

Four types of environmental factors affect permanent, obligatory ectoparasites such as *Psoroptes ovis*: (1) physical factors (particularly temperature and humidity); (2) host factors (particularly nutrient supply, reactions and modification of physical factors); (3) biotic factors (pathogens, predators, parasites, and competitors); and (4) human factors (animal husbandry practices operating through the first three factors). These factors alter the microenvironment of the haircoat of cattle, within which *P. ovis* lives close to the skin. Exceptionally, for very brief periods when the mites transfer from one host to another, these factors directly affect the mites. The physical factors of climate and weather affect *P. ovis* secondarily by altering the temperature and humidity in the haircoat and by causing host reactions that change this microenvironment. For example, direct summer sunlight can raise skin temperature to lethal levels for cattle, sheep, and horse lice (Matthysse 1946; Murray 1957b, 1963). Shilston (1915), Cameron (1925), and Spence (1949) have shown that *P. ovis* is rapidly killed upon exposure to sunlight or dryness. Summer heat can cause cattle to sweat, raising skin surface humidity to high levels that affect mite and lice reproduction and movement (Butler 1968a, Mock 1974).

Cattle ectoparasites exist in a desiccating environment during cold weather (Matthysse 1946, Mock 1974, Butler 1968a). A temperature and humidity gradient exists in the haircoat from beyond the hair tips down to the skin. Ambient air is warmed in this gradient, but there is only minor change in absolute humidity since little moisture passes through the skin of cattle in cold weather. The result is a steep gradient in saturation deficiency because saturation humidity is high for warm air. Murray (1975a) plotted the temperature gradient accurately for sheep fleece. Scurf feeders such as *Chorioptes* probably produce metabolic water (Butler 1968a); *P. ovis* may require watery exudates to survive.

Scabies mites themselves are responsible for changes in their microenvironment that result from the reaction of the host to the feeding activities of the mites and to antigens produced by the mites. Changes in microclimate humidity and temperature are to be expected as a result of impairment of skin function, serum exudation, and erythema.

Almost no research that has been done on the bionomics of *P. ovis* on cattle includes the aforementioned microenvironmental factors of the haircoat. Downing (1936) has provided valuable data for ovine psoroptic scabies, but the microclimate within fleece is obviously different from that of the bovine haircoat. Nelson et al. (1975, 1977) thoroughly reviewed the general subject of host-ectoparasite relationships, including distribution on the host, feeding mechanisms, the effects that the nutrition and endocrine state of the host have on the ectoparasite, toxins produced or secreted by the ectoparasite, pathogenesis, immunology, resistance, and genetics. They included no references on *Psoroptes*, which indicates the present state of knowledge concerning the effects the host has on the cattle scabies mite. Nevertheless, this general statement by Nelson et al. (1975) is pertinent:

> Distribution of ectoparasites on an animal appears to be dictated primarily by their requirement for a suitable microhabitat in which to complete one or more stages of their life cycle. Host factors such as self and mutual grooming, thickness of skin, hairiness, and resistance may also restrict the distribution of parasites, as may atmospheric conditions. The distribution pattern is a result of long association between ectoparasite and host that has allowed the survival of both animals.

In general, ectoparasites such as Anoplura, Mallophaga, Hippoboscidae, and Acariform Acarina, which infest livestock in the temperate zone, develop large populations and cause most injury during the winter, then subside to low numbers during the summer and cause minimum injury (Craufurd-Benson 1941, Matthysse 1946, Scott 1950, Roberts 1952, Murray 1955, Roberts and Cobbett 1956, Sweatman 1956, Nelson and Qually 1958, Murray 1963). *P. ovis* is no exception (Downing 1936, Roberts et al. 1971). Blachut et al. (1973) summarize further references on seasonal population fluctuations of *P. ovis* as well as of other ectoparasites. Parasitological theory suggests that our livestock species and their permanent, obligatory ectoparasites evolved in warm climates. The long association between host and ectoparasite produced an equilibrium in which small parasite populations existed in harmony with hosts that experienced only minor injury. The equilibrium was upset when man moved livestock into the cooler climate of the Temperate Zone where wintertime ectoparasite outbreaks alternated with summer remission.

No complete explanation of the mechanism for this phenomenon has been postulated or proven. Seasonal changes in haircoat microclimate are thought to be factors in the case of lice and mites, including *P. ovis* (Matthysse 1946; Spence 1949; Butler 1968 a,b; Mock 1974). Nelson and Qually (1958), Nelson (1962 a,b), Nelson and Bainborough (1963), and Nelson and Hironaka (1966)--all working with the sheep ked (*Melophagus ovinus*)--have implicated the age and nutrition of host populations coupled with seasonal development of immunological resistance. No detailed research has been done on the factors involved in this important practical problem with any *Psoroptes* mite.

Butler (1968a) proposed a model for mite-host interaction based on the psoroptid *Chorioptes bovis*. His model integrated seasonal changes in the microclimate of the haircoat, water balance of the mites, damage done to the skin of the host by large ectoparasite populations, antibody development by the host, sweating above thermal thresholds, lethal temperatures induced by sunlight, migration of mites to and from oversummering sites, and mortality of mites. He did not include changes in the reproductive rate or longevity of mites.

Several workers have cited effects of weather on development and reproduction of *P. ovis*. Shilston (1915) observed in Natal, South Africa, that there was little difference in the length of time required for a complete life cycle, provided that air temperature was the only variable present. He noted that it was previously believed that seasonal changes in temperature affected development. His explanation was that the thermal insulation provided by the very efficient fleece during the winter months made it "doubtful whether the temperature of the skin is then much lower than in the summer when the fleece is short." He stated that in mid-winter the complete life cycle, as observed under a cover (his confinement cells on the skin) never occupied more than 10 days and in the great majority of cases occurred in a little over 9 days. In summer, the period was constantly 9 days. However, Natal does not have the extremes of temperature found in much of the northern part of the North Temperate Zone.

Shilston (1915) found that rainfall or humidity affected strongly the rate of egg production. During the long dry season very little oviposition occurred (mean of 0.3 eggs per day). Immediately after heavy rains, one female produced 24 eggs in 2 days and 6 to 7 per day subsequently. This was not an isolated event.

Downing (1936) did not report that weather affected the development of motile stages. He disagreed about the effect of weather on oviposition, saying that the lower the minimum temperature (frosty nights), the greater the oviposition rate and the shorter the life of the ovigerous female. Rainfall did not appear to have much influence on oviposition. He observed a 10-day cycle in July, similar to that of April and May and only one day shorter than that of October, December, and February (another February observation was 2 days longer). Possibly under more severe winter conditions this 1- to 2-day difference would increase into significance.

More drastic effects of weather are discussed below, in relation to latent scab.

Of course, temperature (and possibly humidity) controls the rate of development of *P. ovis*, as it does of all poikilothermic animals. As discussed previously, this is demonstrated by slower development of mites at a distance from the skin and by *in vitro* experiments. That the development rate for *P. ovis* on sheep is independent of the ambient temperature must be explained by the constancy of the skin temperature. Unfortunately, there are no relevant biological data for the very different circumstance of haircoat of cattle infested with *P. ovis*. Research is needed on cattle, including experiments comparing *Bos taurus* and *Bos indicus*, beef breeds and dairy breeds, winter coats and summer coats.

The phenomenon of "latent" scabies is very important in controlling and eradicating the disease. Psoroptic scabies of cattle and sheep usually regresses in the summer to partial or complete remission of symptoms and very low numbers of mites. In the autumn, the mite population on these animals increases, resulting in scabies outbreaks in late autumn and winter (Stockman 1909 and many subsequent authors). Eradication efforts can be foiled if inspections fail to detect scabies in the latent condition. There is evidence that acaricide treatments are less effective in summer, possibly because of the protected nature of the oversummering sites of the mites (Downing 1936, Kirkwood 1977).

Downing (1936) and Spence (1949) are in general agreement on the behavior of *P. ovis* during latency and the causes of latency. The theory is that warm temperature, lower humidity, and more sunlight accentuated by sheared fleece, cause mortality, migration, and a reduced rate of reproduction. Also, the host reaction changes, resulting in difficult feeding by the mite and possibly further lowered humidity in the microclimate. Spence (1949) described the normal pathology, explaining that "after each mite has fed, a minute inflamed tumor developed, followed by vesication, rupture, and exudation of serum. Generally these vesicles were transformed into pustules which increased in size before rupture and discharge." Thus, food for siphoning (Blake et al. 1979) by the mite is readily available and the microenvironment is moist. Spence then described the pathology seen as summer approached: ". . . on these sheep the minute reddened tumors occasionally returned to normal without vesication, or if vesication did take place, the vesicle did not rupture but became desiccated and detached from the skin as a minute scab," reducing the availability of food and lowering the humidity, causing the mites to die or migrate. Butler (1968b) discussed migration of the psoroptid mite *Chorioptes bovis* to oversummering sites in response to changes in humidity and temperature within the microenvironment. Spence (1949) did not discuss the cause of the modified host reaction. One could speculate on immunological involvement as shown for the seasonal population cycle of *Melophagus ovinus* by Nelson and Qually (1958) and Nelson (1962).

There is no evidence for aestivation by the mites. No morphological differences have been noted. Rather, slow breeding occurs by mites in protected sites. Shilston (1915) commented that large amounts of wool grease produced by the host retarded the life cycle of *P. ovis*.

Downing (1936) stated that during latency, there is no appreciable lengthening of the life cycle, but rather a reduced reproduction rate. His evidence was the high ratio of adults to immature stages and eggs. Spence (1949) concurs. Latent populations in ears and infraorbital fossae averaged 55 ovigerous females to 2.5 to 3.5 males, pubescent females, or nymphs and 9 to 12 larvae or eggs. There were 0.2 eggs present per female. Spence (1949) calculated a ratio of 4 to 5 eggs per female in normally breeding winter populations. Downing (1936) and Spence (1949) both found that longevity of ovigerous females was inversely related to oviposition rate. Spence (1949) reported that one female in a sheep's ear lived 69 days, from July 10 to September 17. Such longevity is related to continuation of infestation through the inclement summer period.

Shilston (1915), Downing (1936), and Spence (1949) related the low oviposition rate to decreased humidity. However, saturation deficiency (the criterion for the effects of desiccation) will be less in summer than in winter in the microclimate close to the skin, as discussed previously. Lower humidity may occur nevertheless because of dryness of lesions.

Shearing is important. Both Downing (1936) and Spence (1915) observed continuation of the active phase on some unshorn sheep despite the onset of warm weather.

Spence (1949) summarized by saying that "mites are rapidly killed on exposure to sunlight or to dryness and the change in these climatic factors in shorn or denuded sheep appears to offer an adequate explanation of the virtual extermination of mites from exposed lesions."

During latency, mites survive in the infraorbital fossae, inguinal folds, perineum, scrotum, and tail (Downing 1936). Spence (1949) included the interdigital fossae, vulvar furrows, ears, and folds of the thickened body skin. Consistently, the most frequently infested protected loci were ears and infraorbital fossae (Spence 1949).

Downing (1936) in England found that latency was initiated in March, that mites were difficult to locate from April into August, and that the mite population increased and caused active scabies in September. He showed that latency was induced by rising average minimum temperatures above about freezing and that active scabies resumed when average minimum temperatures decreased below about 47°F.

The only intensive research on latency done within the American bovine psoroptic scabies outbreak climatic region is that of the USDA Parasite Research Laboratory, Albuquerque, N.M., which is continuing now at Kerrville, Texas. To date, published reports have been on ovine psoroptic scabies and their results on oversummering sites have differed radically from those noted by European and South African workers. Roberts et al. (1971) concluded that _P. ovis_ survives the summer primarily on the major body surfaces where serous encrustrations and the wool umbrella provide adequate summer shelters. Live mites occurred on the major skin surfaces of 32 percent of the sheep; only 7 percent of the sheep harbored mites in hiding places. These "hiding places" were the anatomical locations where Downing (1936) and Spence (1949) found the preponderance of oversummering mites. The bulk of the data, _but not all_, referred to sheep kept inside buildings or to an abnormal, highly virulent strain of _P. ovis_ that did not become latent. Roberts and Meleney (1971) discussed this strain that maintained populations on about 50 percent of the sheep throughout the summer and continued to cause active scabies. Also, Roberts and Meleney found correlation between the virulence of sheep strains and their ability to infest cattle.

Blachut et al. (1973) reported on the population structure of _P. ovis_ on sheep throughout the year at Albuquerque, N.M. Their results were at variance with those of European and South African workers. The infection during the summer possibly fits the category of "active scab in summer" defined by Downing (1936). Blachut et al. (1973) state that "the number of active lesions on sheep was much lower in summer"; whereas Downing (1936) reported practically complete absence of active lesions during summer latency. Downing (1936) and other workers commented on shearing as one factor in latency and that mites on scabrous unshorn sheep may not go latent. W.P. Meleney (U.S. Livestock Insects Laboratory, Kerrville, Texas, personal communication, 1979) believes that the Blachut sheep were not shorn.

Blachut et al. (1973) concluded that no seasonal differences occurred in stage composition of the mite population. Averages for one year were 20 percent ovigerous females, 17 percent males, 28 percent larvae, 4 percent male deutonymphs, 9 to 12 percent in each nymphal stage.

Unfortunately, eggs were not counted so that the rate of oviposition cannot be calculated by the Spence (1949) method. Nevertheless, comparison of summertime counts is striking, leading to the conclusion that either the scabies condition at Albuquerque was "summer active" or latency in the United States is a different phenomenon than that in Europe. Table 4 presents this comparison of stage frequencies, excluding eggs from the calculations. Frequency of ovigerous females was about 5 times greater in Spence's (1949) observations. A high percentage of long-lived, ovigerous females is characteristic of latency according to Spence (1949).

Latency (defined as the reduction of P. ovis almost to zero and the almost complete remission of scabies symptoms) did occur in many years during the summer at Albuquerque on many flocks and groups of sheep (Roberts et al. 1971, Roberts and Meleney 1971). Perhaps the research of Blachut et al. (1973) involves a strain mixture of enhanced virulence, including genes from the Missouri strain (Roberts and Meleney 1971) introduced into the laboratory prior to this research.

Bovine psoroptic scabies also passes into latency during the summer (Snyder 1942, Roberts and Cobbett 1956, and many others). No intensive research has been done on cattle. Extrapolation from sheep data may be misleading because haircoat and fleece are so different. Also, loss of haircoat in cattle is a natural prolonged shedding controlled by the environment rather than a sudden extreme event controlled by the sheep shearer. Meleney (personal communication) noted that most cattle brought from Albuquerque, New Mexico to Kerrville, Texas, at the time of setting up the Scabies and Mange Research Unit, lost their mites and lesions over the summer. Meanwhile, infested sheep at Kerrville maintained obvious lesions even during the hottest months.

TABLE 4 Motile Stage Composition of *Psoroptes ovis* Populations on Sheep during the Summer (percentage in each stage)

Location	Ovigerous Females	Males	Larvae	Pubescent Females	Nymphs
Britain (Spence)	76	5	12	3	4
Albuquerque[1]	16	13	34	12	26

[1]Data are averages for May through August from Blachut et al. (1973: Table 1).

Research on latency should involve cattle with different hair and skin conditions: *Bos taurus* and *Bos indicus*, dairy breeds and beef breeds, winter coats and summer coats.

Latent scabies in cattle is a topic of great current interest because of suspicion in the United States cattle industry that latent or asymptomatic scabies has occurred in the Southeast for many years without developing into symptomatic scabies. The theory is that southeastern cattle harboring mites asymptomatically are shipped westward, particularly to the Texas Panhandle and other High Plains areas, where they break out into symptomatic scabies in proper season. Thus, new loci for spread are formed.

There are no data from prior work on latency to support this theory. Latency is part of an annual cycle that includes active scabies in the autumn and winter. In most cases investigated, mites can be found by very diligent search, and these mites are active; they feed and they cause pathogenic effects, albeit extremely minor. Also, there are large areas of the Southeast, particularly moderately high altitudes, where subfreezing weather is common so that latent scabies should become active and readily diagnosed.

Finally, psoroptic cattle scabies is reported from many tropical and subtropical countries, including Gambia, Ghana, Togo, Nigeria, Cameroon, Zambia, Malawi, Angola, Madagascar, Mauritius, and Brazil (FAO-WHO-OIE 1957), where climate is warmer year round than in the southeastern United States and where there are no cold highlands. Van Volkenberg (1934) reported that in Puerto Rico psoroptic scabies of cattle is comparatively common, but "in the climate of Puerto Rico it rarely becomes a serious disease. However, heavy infestations have been found among animals which were crowded together in small enclosures."

Information on the ability of *Psoroptes ovis* to survive off the host is of great importance to the success of eradication efforts. This mite is an obligate parasite that cannot feed off the host; thus, its survival time is limited by starvation, desiccation, or other causes of mortality. Research has supplied two types of information: the length of time the parasite remains alive off the host and the mite's functional survival time, assessed by its ability to infest host animals. The latter is of greater practical import. To date practically all research has been done with mites from sheep.

Shilston (1915) and subsequent authors have observed the ovigerous females to be the most resistant motile stage. Palimpestov et al. (1950) noted that quiescent stages and eggs were more resistant to cold than were motile stages and that among motile stages adults were the most and larvae the least resistant. Under warm conditions some eggs will hatch off the host, but larvae die quickly (Stockman 1911, Shilston 1915, Zolotarov 1956, Tarry 1974).

Wilson et al. (1977) thoroughly reviewed prior research. They discounted early publications suggesting that sheep pens, buildings, and pastureland could remain infective for 1 to 5 years (Imes 1916, Salmon and Stiles 1903, Dill 1920, Wheeler 1921). By 1935, Imes had changed his opinion, believing then that pens, etc. could remain infective only up to 30 days.

Tables 5 and 6 summarize information based on experimental evidence rather than the desultory field observations noted above. Imes (1918) is the only authority in these tables who discusses P. ovis from cattle, and he did not do original research. Wilson et al. (1977) refer to an unpublished 1929 report by Kemper about his extensive research over a 3-year period on the survival of P. ovis from cattle in New Mexico. Cattle became infested when placed in corrals that had been vacated by scabby cattle for not more than 48 hours. The number of positive infestations was low but definite. No new infestations occurred when the corrals were vacated by scabby cattle for 3 days or more.

P. ovis can survive for long periods off the host, particularly under cool, moist conditions. There are several reports of survival for more than 30 days. Wilson et al. (1977) reported survival for 28 days under winter conditions in New Mexico. The survival period is much shorter when mites are exposed to the sun, dryness, or warmer temperatures. Several of the reports in Table 5 show the surprising ability of P. ovis to withstand subfreezing temperatures. The Palimpestov and Zolotarov data in Table 5 are useful if cold or heat is employed to kill P. ovis.

The most recent research in the United States is that of Wilson et al. (1977). As shown in Table 6, they were able to infest sheep with mites kept off hosts for as long as 17 days, provided that the mites were kept at low temperature. However, they were unable to infest sheep by placing them in infested pens that had been empty of sheep for more than 3 days.

Wilson et al. (1977) combined data from their literature reviews and their own results to conclude that enclosures suspected of being contaminated with P. ovis should be vacated for at least 2 weeks and if possible for 1 month before occupancy by clean sheep. They concluded also that their observations are very closely applicable to cattle corrals and vehicles as well.

Further research is needed on cattle to confirm the conclusions of Wilson et al. (1977). This is a complex problem because there are so many variables of season,

TABLE 5 Off-Host Survival Rate of *Psoroptes*[a] Assessed by Complete Mortality

Conditions	Longevity	Source
Crusts, wool, skin at medium temperature	10-20 days	Neuman (1892)
Dry atmosphere	10-14 days	Railliet (1893)[b]
In a stable	20-30 days	
	20 days	Gillette (1897)
Egg hatch	8 days	Stockman (1911)
	31 days	Stockman (1912)
Crusts, wool in jars, room temperature, high R.H.	20 days	Shilston (1915)
Incubator, 37°C	7 days	
Desiccator, room temperature	6 days	
Ice box, 0°C	4 days	
Egg hatch, room temperature	8 days	
Egg hatch, ice box	10 days	
Eggs in mild weather, moist, protected	14-28 days	Imes (1918)[c]
Eggs and motile stages, dry places in sunlight	a few days	
Wool in boxes, shade 70 to 80°F	38 days	Babcock and Black (1933)
Wool in boxes, caves 70 to 72°F, ∿96% R.H.	20 days	
Wool in open boxes, under glass, in sun	3 hrs.	
Wool fastened to fence outdoors, 15 min.	5 days	
Reproduction in wool in boxes (see text)	17 days	
Hides under shed, -5 to -15°C, 87 to 95% R.H.	4-6 days	Palimpestov et al. (1950)[d]
P. cuniculi, -5°C	6 days	
P. cuniculi, -10°C	5 days	
P. cuniculi, -15°C	4 days	
P. cuniculi, -20°C	2 days	
Dry air, 50°C	<90 min.	
Dry air, 60°C	42 min.	
Dry air, 70°C	5 min.	
Dry air, 100°C	0.5 min.	

TABLE 5 (Continued)

Conditions	Longevity	Source
In buildings, 6 to 8°C, 85 to 100% R.H.	60 days	Zolotarev (1956)[e]
On grazing grounds	35 days	
-2 to -12°C	4 days	
-25°C	6 hrs.	
Newly laid eggs, 7°C	40 days	
"Developed larvae," 7°C	12 days	
Eggs on pasture	4-8 days	
In scrapings, 20°C	14 days	Hepworth and Thomas (1962)[f]
In scrapings, 4°C	35 days	
Eggs hatched in patches of wool	4-5 days	Nuallain (1966)
Closed jar in winter	23 days	Tarry (1974)
"Eggs may hatch after"	21 days	
Jars, winter outdoors, Albuquerque[g]	28 days	Wilson et al. (1977)
Jars, incubator, 35°C, 75 to 80% R.H.	9 days	
Jars, room temperature, 22 to 24°C	10 days	
Jars, refrigerator, 2 to 6°C	21 days	

[a] *P. ovis* from sheep unless otherwise stated.
[b] Mites from horses, probably *P. ovis*.
[c] *P. ovis* from cattle.
[d] The hides were from sheep infested with *P. ovis*; *P. cuniculi* from rabbits were held in a refrigerator at 85 to 95% R.H. or in "natural winter environment."
[e] Host not specified; cattle, sheep, or horses.
[f] *P. cervinae* from elk.
[g] Temperature as low as -7.8°C.

TABLE 6 Off-Host Survival of *Psoroptes ovis* (Ovine) Assessed by the Ability to Infest Sheep

Conditions	Survival Time (days)	Source
Pens	8	Stockman (1912)
Manure from infested pen	16	Shilston (1915)
Pens	9	Bedford (1915)
Pens	17	Du Toit (1923)
In paper, cold room (quotes Guenther)	56	Opperman (1929)
Pens	1	Babcock and Black (1933)
Pens plus exposed wool tied on[a]	10	(ibid.)
Mites "starved" (kept off sheep)	13	(ibid.)
Not stated; not original work	42	Tarry (1974)
Pens[b]	3	Wilson et al. (1977)
Jars, winter outdoors, Albuquerque[c]	12	(ibid.)
Jars, room temperature, 22 to 24°C.	10	(ibid.)
Jars, refrigerator, 2 to 6°C.	17	(ibid.)
Sheep quarters[d]	42	Liebisch et al. (1978b)

[a]Bags of infested wool were put into pens coincident with the removal of infected sheep. This wool was later tied onto principals when they were put into the pens.
[b]Pens in barns and pens exposed to weather were tested, but results were not reported separately.
[c]Temperatures as low as -7.8°C.
[d]Taken from pens, folds, fences, scratching posts, and farm implements in Germany. No supporting research cited.

weather, altitude, and type of pastures, ranges, barns, holding facilities, and vehicles. The problem is compounded by the difficulty of initiating infestations artificially, even though field experience has shown the disease to be highly contagious.

It has been stated frequently that the condition and plane of nutrition of cattle and sheep are related to their susceptibility to infestation by *Psoroptes ovis* and to the course of psoroptic scabies. For example, Imes (1918) noted that unthrifty cattle usually are the first members of the herd to contract the mite and that the disease develops much more rapidly on weak or poorly nourished animals of low vitality. He remarks further that cattle in good condition and given green, succulent food seldom contract scabies. Cottereau (1976) points out that calves in large fattening units in France are fed a mineral-rich diet supplemented by vitamin injections, which is said to minimize the hazard of psoroptic scabies. Holtenius (1961) mentions a relationship between scabies and vitamin A. Liebisch et al. (1961) state that an inadequate nutrient supply during the winter and late summer contributes to the incidence of severe infestations by *P. ovis* on sheep. Meleney (U.S. Livestock Insects Laboratory, Kerrville, Texas, personal communication, 1979) is conducting research on nutrition and has not as yet been able to demonstrate a relationship between plane of nutrition and psoroptic scabies in cattle.

No precise information exists on the relation of host condition or nutrition to susceptibility to *P. ovis*, populations of the parasite, or course of the disease. Nelson et al. (1975, 1977) present an up-to-date, thorough review of the general subject of host-ectoparasite relations, but no references to *Psoroptes* are included. They discuss the implications of vitamin deficiencies, protein level in the diet, mineral intake, and other factors. These nutrients may be involved directly since ectoparasites obtain their supply of them from the host. Nutrients may also be involved indirectly, as for example through the role of vitamin A in skin function and immunocompetence. Nelson et al. (1975) reviewed research supporting the thesis that host nutrition plays a major role in the population dynamics of ectoparasites. However, this subject remains in disarray because other workers have not been able to demonstrate similar effects.

Stress factors may affect susceptibility and course of psoroptic scabies, but no concrete evidence has been reported. Stress is major during shipment, sale, and early feedlot handling of cattle, a period of prime importance in the spread of *P. ovis*.

That the age of the host affects its susceptibility to disease and the severity of a disease once it has been contracted is well known. No intensive research has been done on this subject with P. ovis. Imes (1918) states that psoroptic scabies develops more rapidly and is more severe in old animals and that they are the first members of the herd to contract the mites. No supporting evidence was presented. Downing (1936) found that lambs only four days old were susceptible to P. ovis. It appears that cattle and sheep of all ages may contract psoroptic scabies, but it is not known if age is important to relative susceptibility.

Obviously, research is needed on the relation of the age, condition, nutrition, and stress of cattle and their susceptibility to psoroptic scabies.

POPULATION DYNAMICS

The available information on biotic potential and mortality rates for Psoroptes ovis is inadequate for population dynamics calculations or for construction of life tables.

Table 7 gives the oviposition rates and longevity of adult females. The reproductive rates of 10 to 30 or 15 to 24 eggs per female stated by Roberts (1975), Snyder (1942), Miller (1942), or Kemper (1952) have not been included because these reports do not state the sources of their data. A remark by Shilston (1915) may be pertinent: that Gerlach's (1856) report of 15 to 24 eggs per female referred to Sarcoptes scabiei, but was often misquoted as referring to Psoroptes ovis. Obviously, reproductive rates depend on the temperature and humidity of the microenvironment. Downing (1936) concluded that the higher the minimum ambient temperature, the lower the oviposition rate but the greater the longevity of Psoroptes ovis ovigerous females.

Life history data were presented earlier.

Sex ratios (males:females) are 1:2 (Gerlach 1856), 1:3 or 4 (Shilston 1915), 1:1.2 (Blachut et al. 1973), and 1:15 (Spence 1949). The ratio determined by Spence (1949) was for latent scabies in summer.

Mortality rates are completely unknown. Causes of mortality include host reaction, inclement physical environmental factors, chemical factors, biological control agents, and intrinsic factors. Host reactions include biting, scratching, and rubbing; immunological reactions (discussed subsequently); and pathological changes in the dermis (discussed subsequently). Biological control of obligatory ectoparasites results from reaction by the host rather than from predators or parasites. For example, the sensitivity of human skin to Sarcoptes scabiei results in scratching that limits the population of this parasite

TABLE 7 Longevity of Ovigerous Females of *Psoroptes ovis* and Their Oviposition Rate on Sheep

Number of Females Observed	Longevity (days)	Oviposition Period (days)	Eggs per Female	Rate[a]	Source
			15[b]		Gerlach (1857)
	8	8	15 to >30[c]	<3.0	Stockman and Berry (1913)
	30-40		56-93	4-7[d]	Shilston (1915)
2	42	29	35	1.2	Downing (1936)
3	11-15	11	40	3.6	Downing (1936)
1	11	7	39	5.6	Downing (1936)

[a]Eggs per female divided by period during which oviposition occurred.
[b]Quoted from Stockman and Berry (1913). Species may be questionable.
[c]Obtained only for the period of initial oviposition until the next generation of females emerged.
[d]Highly variable: approached zero under adverse weather conditions (drought) but increased during the rainy season.

(Mellanby 1944, Fain 1969). Bell et al. (1962) demonstrated the role of self-grooming in controlling louse populations on mice, and stanchioning, which prevents cattle from grooming with their rough tongues, is said to predispose cattle to chorioptic scabies (McEnerney 1953).

Physical factors in the mortality of mites, discussed previously, include lethal effects of high temperature on the skin and decreased reproductive rate during latency in the summer. Chemical factors include skin secretions such as wool grease or "yolk" or lanolin in sheep, which Shilston (1915) found to be important in limiting P. ovis populations. Nothing is known of the effects of skin secretions on bovine psoroptic scabies. Obviously, pesticides affect populations of mites.

Animal parasites or predators of P. ovis are unknown except for the predaceous mite Saintdidieria sexclavatus mentioned by Roberts and Meleney (1971). This rare mite has not been shown to have any significant effect on populations of scabies mites. No diseases of Psoroptes are known.

There is no useful information on intrinsic mortality factors such as ageing. Downing (1936) and Spence (1949) noted an inverse relationship between egg production and longevity of ovigerous females. Intrinsic variations among strains will affect population dynamics. For example, the virulent strain of Roberts and Meleney (1971) maintained populations through the summer.

Speculation on the rate of population increase is possible by arbitrarily selecting a model from pertinent data from Tables 2 and 7: the period for one generation is 11 days; the oviposition period, 10 days; eggs per female, 40; sex ratio (see above), 1:3. The result is a "guesstimate" of 1 million P. ovis produced in a bit more than 2 months. Over 100 years ago, Gerlach (1856) calculated on the basis of 15 eggs per female and a developmental period of 15 days that 1 pair could produce 1.5 million mites in 3 months. Kirkwood (1977) gives an offhand figure of 1 million P. ovis produced in 12 weeks. Obviously, mortality factors reduce such productivity. Nevertheless, a rapid increase in population during favorable autumn weather can arise from a few survivors of latency or from a few mites introduced into a flock or herd in the winter. Thus, acute scabies can develop rapidly. Many authors have noted that mite populations increase rapidly on newly infested, susceptible animals in proper season. But population increases may also be slow. There are many documented cases in the literature of several months elapsing between infestation and manifestation of obvious symptoms. Wilson et al. (1977), Babcock and Black (1933), and Stockman (1910) reported prolonged periods of 89, 176, and 77 days between infestation and obvious symptoms, in contrast to as little as 2 to 3 weeks for rapidly developing cases. Factors involved in reduced reproduction rates during warm weather have been discussed previously.

The speculation presented on the rate of population increase is based on data from ovine *P. ovis*. That bovine psoroptic scabies mites, during favorable weather, develop large populations a little more slowly is indicated by the life history parameters reported by Imes (1918). In winter, the development period on cattle may be longer than on sheep because of lower skin temperature on cattle than on sheep in full fleece. Murray (1957) reported that the skin temperature on sheep in summer was 37.5°C when the air temperature was 24.5°C. Butler (1968a) reported that the skin temperature on dairy heifers ranged from 37.2 to 37.8°C in August when the air temperature was 28.9°C. But when the air temperature was 7.2°C in March, Butler found that the skin temperatures on the escutcheon and tailhead of dairy heifers measured from 28.3 to 33.3°C. Since it is a rough biological rule of thumb that the development rate doubles for every 10° temperature rise, *P. ovis* could require considerably longer development time on cattle than the time presented previously for sheep, particularly on exposed body locations with thin haircoat or with lesions. Nevertheless, from a few mites maximum populations in the millions could develop on cattle within 2 to 3 months.

Further research on cattle is needed to begin a basis for determining the population dynamics involved in bovine psoroptic scabies. The haircoat of different cattle breeds and its microenvironment through the seasons must be considered. Basic information on the skin and haircoat of cattle and their microclimate can be found in Hammel (1955), McDowell et al. (1961), McLean (1963), Treager (1966), Berry and Shanklin (1962), Bennett (1964), Taneja (1959) and in references cited previously in the Bionomics section.

GEOGRAPHIC DISTRIBUTION

The haircoats of cattle and sheep apparently provide acceptable microclimates for *P. ovis* throughout the range of these hosts. Undoubtedly the parasite has been transported to all continents and many islands by man's movement of livestock to new lands. The FAO-WHO-OIE *Animal Health Yearbooks* (1971, 1977) document the current or past infestation of sheep and cattle on all continents and most countries of the world.

Psoroptic scabies is a serious disease in the Temperate Zone, but is of much less importance in the tropics and subtropics. Apparently the parasite generally does not develop as large populations nor cause as much injury in the tropics as in colder climates, despite being present in a large number of tropical countries. Parasitological theory suggests that livestock species and their permanent obligatory ectoparasites coevolved in warm climates. The long association produced an equilibrium in which low parasite populations existed in harmony with hosts that experienced only minor injury. The equilibrium was upset when man moved livestock into cooler Temperate Zone climates where ectoparasite outbreaks occurred in winter and then remitted during summer.

The data in Table 8 are based on Veterinary Department Reports that originate through field location of P. ovis following expression of symptoms. The data show that mites reproduce in enough numbers to cause obvious symptoms in warm climates, even at low elevations and high humidity, as attested to by the presence of psoroptic scabies in many African countries and tropical and subtropical islands (FAO-WHO-OIE 1971).

The distributional data in Table 8 do not support the thesis that psoroptic scabies has greater importance in the Temperate Zone. The table shows that sheep and cattle psoroptic scabies are absent from many European and North American countries. However, the absence from many temperate countries is due not to naturally low incidence, but to control efforts, particularly for sheep scabies. Norway and Finland, for example, have given it notifiable-disease status, and require quarantine, compulsory treatment, and even slaughter. One of the authors of this report (personal communication) has examined large numbers of cattle in Zambia, where sporadic occurrences of psoroptic scabies are reported, and neither saw nor heard of psoroptic scabies outbreaks, even though these cattle were never treated with insecticides and no scabies control program existed. Psoroptic scabies of cattle generally is not reported to be an important problem in tropical countries except possibly at higher elevations.

It is unfortunate that, since 1971, the FAC-WHO-OIE Yearbooks have lumped together all types of scabies and manges. Information on psoroptic and sarcoptic scabies is lost because of the abundance, ubiquitousness, and uncontrollability of demodectic mange (Smith 1961). However, several studies have shown that, although psoroptic scabies is present in tropical and subtropical climates, the incidence is so low that the disease does not cause serious problems. In Tanzania, a tropical country, McCulloch and Tungaraza (1967) found Demodex bovis on 84 percent and Sarcoptes or Psoroptes on only 0.004 percent of the cattle hides they examined. Bwangamoi and DeMartini (1970) found mites on 33.9 percent of Kenya cattle hides, with 33.1 percent affected by Demodex and only 0.2 percent by Psoroptes. Demodex bovis caused major losses by hide

TABLE 8 Occurrence of Psoroptic Scabies[1]

Country	Bovine[2]	Treatment	Ovine	Treatment
North Africa				
Morocco	Sporadic	Compulsory	Sporadic	Compulsory
Algeria	Sporadic	Compulsory	Seasonal	
Tunisia	Sporadic	Voluntary	Seasonal	Compulsory
Libya	Sporadic	Voluntary	Widespread	Compulsory
Egypt	Moderate	Compulsory	Moderate	Compulsory
Saharan and Western Africa				
Sudan	Present	Voluntary	Not Recorded	Quarantine
Chad	Not Recorded	(Notifiable)	Not Recorded	
Niger				
Upper Volta				
Mali	Sporadic		No Information	
Mauritania	No Information		Widespread	Compulsory
Western Sahara			Not Recorded	
Senegal				
Gambia	Sporadic	Voluntary	Widespread	Voluntary[3]
Cape Verde				
Guinea (Bissau)	Not Recorded		Not Recorded	
Guinea				
Sierra Leone	Not Recorded		Present	Voluntary
Liberia	Not Recorded		Not Recorded	
Ivory Coast				
Ghana	Sporadic	Compulsory	Sporadic	Compulsory
Togo	Widespread	Voluntary[3]	Widespread	Voluntary[3]
Benin				
Nigeria	Sporadic	Compulsory	Widespread	Compulsory
Cameroon	Sporadic	Voluntary	Regional	Voluntary
Equatorial Guinea			Present	
Gabon	Exceptional[4]	Compulsory	Moderate	Compulsory
Central African Empire				
People's Republic of the Congo				

TABLE 8 (Continued)

Country	Bovine[2]	Treatment	Ovine	Treatment
Eastern and Southern Africa				
Ethiopia	Present	Voluntary	Widespread	Voluntary
Afars, Issas				
Somalia			Possibly Present	Compulsory
Kenya	Sporadic		Sporadic	(Notifiable)
Tanzania	Not Recorded	(Notifiable)	Not Recorded	(Notifiable)
Uganda	Not Recorded		Possibly Present	Notifiable
Rwanda	Moderate	Voluntary	Sporadic	Voluntary
Burundi	Widespread	(Notifiable)	Not Recorded	(Notifiable)
Zaire			No Information	
Zambia	Sporadic	Voluntary[3]	Sporadic	Voluntary[3]
Rhodesia	Not Recorded		Sporadic	Compulsory
Malawi	Sporadic	Voluntary[3]	Possibly Absent	(Notifiable)
Mozambique				
Angola	Moderate	Quarantine	Exceptional[4]	Quarantine
Botswana	Possibly Absent	Voluntary	Regional	Compulsory
South Africa	Sporadic	Compulsory	Present	Compulsory
Lesotho[5]	Possibly Present	Voluntary	Not Recorded	Quarantine
Swaziland	Not Recorded		Sporadic	Compulsory
Madagascar	Sporadic	Voluntary[3]	Regional	Voluntary[3]
Mauritius	Sporadic	Voluntary	Exceptional[4]	Voluntary
South America				
Brazil	Sporadic	Voluntary	Regional	Voluntary[3]
Argentina	Regional[6]	Compulsory	Moderate	Compulsory
Uruguay	Sporadic	Compulsory	Present	Compulsory
Paraguay	Sporadic			
Chile	Not Recorded		Present	Compulsory
Bolivia			Regional	
Peru	No Information	Voluntary	Widespread	Voluntary
Ecuador			Present	Compulsory
Colombia			Not Recorded	
Venezuela				
Guyana			Regional	(Notifiable)
Surinam	Not Recorded		Not Recorded	(Notifiable)

TABLE 8 (Continued)

Country	Bovine[2]	Treatment	Ovine	Treatment
West Indies Trinidad and Tobago				
British Antilles				
Jamaica				
Dominican Republic	Possibly Present		Possibly Present	
Haiti	Not Recorded		Sporadic	
	Not Recorded		Not Recorded	
Central America				
Panama			Not Recorded	
Costa Rica				
Nicaragua	Widespread	Voluntary		
Honduras	No Information	Voluntary		
El Salvador	Sporadic	Voluntary	Present	Voluntary
Guatemala			Present	Voluntary[3]
Belize			Present	
North America				
Mexico	Present	Voluntary	Present	Voluntary
United States	Present	Compulsory	Reduced[7]	Compulsory
Canada	Sporadic	Compulsory	Possibly Absent	Quarantine
Bermuda	Not Recorded		Not Recorded	
Bahamas	Exceptional[4]		Not Recorded	
Western Europe				
Great Britain[8]	Not Recorded		Not Recorded	Compulsory
Northern Ireland	Not Recorded	Quarantine	Sporadic[9]	Compulsory
Ireland	Present	(Notifiable)	Sporadic	Compulsory
Iceland	Not Recorded		Sporadic	Compulsory
Denmark	Present	Voluntary	Not Recorded	Quarantine
Norway	Not Recorded	(Notifiable)	Not Recorded	Slaughter
Sweden	Not Recorded		Not Recorded	Quarantine
Finland			Not Recorded	Slaughter

TABLE 8 (Continued)

Country	Bovine[2]	Treatment	Ovine	Treatment
Netherlands	Sporadic	Voluntary	Moderate	Voluntary[5]
Belgium	Seasonal	Compulsory	Sporadic	Voluntary[5]
Luxembourg			Not Recorded	Quarantine
France[10]	Sporadic	Voluntary[3]	Sporadic	Compulsory
West Germany[10]	Exceptional	Voluntary	Exceptional[4]	Compulsory
Switzerland	Not Recorded		Present	Compulsory
Austria	Sporadic		Sporadic	Compulsory
Italy	Sporadic	Compulsory	Regional	Compulsory
Malta	Not Recorded		Not Recorded	
Spain	Regional	Voluntary	Regional	Voluntary
Portugal	Not Recorded	Quarantine	Regional	Compulsory
Eastern Europe				
Russia[11]				
Poland			Sporadic	Compulsory
East Germany				
Czechoslovakia	Not Recorded	Quarantine	Not Recorded	Quarantine
Hungary	Exceptional[4]	Compulsory	Not Recorded	Compulsory
Romania			Exceptional[4]	Compulsory
Bulgaria	Not Recorded		Sporadic	Compulsory
Yugoslavia	Not Recorded	Compulsory	Regional	Compulsory
Albania			Present	Compulsory
Greece	Sporadic	Voluntary	Sporadic	Voluntary
Middle East				
Turkey	Sporadic	Compulsory	Sporadic	Compulsory
Cyprus	Not Recorded	Quarantine	Not Recorded	Quarantine
Syria	Sporadic	Compulsory	Sporadic	Compulsory
Lebanon	Moderate	Voluntary	Widespread	Voluntary
Israel	Not Recorded	(Notifiable)	Sporadic	Compulsory
Jordan	Sporadic	Voluntary	Moderate	Voluntary
Saudi Arabia			Widespread	Compulsory
Yemen, P.D.R.	Moderate	Voluntary	Moderate	Voluntary
Kuwait			Moderate	Compulsory
Iraq			Widespread	Compulsory
Iran	Sporadic	Voluntary	Sporadic	Voluntary
Afghanistan	Sporadic	Voluntary	Widespread	Voluntary

TABLE 8 (Continued)

Country	Bovine[2]	Treatment	Ovine	Treatment
Southern Asia				
Pakistan	Sporadic	Voluntary	Moderate	
Bangladesh	No Information		Sporadic	Voluntary
Nepal	Possibly Present		Sporadic	
India	Sporadic	Voluntary	Sporadic	Voluntary
Sri Lanka	Possibly Present	Voluntary	Not Recorded	Quarantine
Burma	Sporadic	Voluntary	Not Recorded	
Laos	Possibly Present		Not Recorded	
Viet Nam[12]				
Kampuchea[12]	No Information		Sporadic	
Thailand	Sporadic	Voluntary	Probably Absent	
Malaysia (Western)	Sporadic	Voluntary	Probably Absent	
Singapore				
Malaysia (Sarawak)				
Malaysia (Sabah)	Possibly Present	Voluntary	Not Recorded	
Brunei			Not Recorded	
Philippines	Sporadic	Voluntary	Sporadic	Voluntary
East Asia				
Hong Kong	No Information		Not Recorded	Quarantine
Macao	Not Recorded			
China (Mainland)				
China (Taiwan)	No Information		No Information	
Japan	Not Recorded		Not Recorded	Voluntary[5]
Korea	Not Recorded		Not Recorded	Voluntary
Mongolia			Moderate	
Oceanea				
Australia	Sporadic	Voluntary	Not Recorded	Quarantine
New Zealand	Not Recorded	Quarantine	Not Recorded	Quarantine
Fiji	Not Recorded	Quarantine		
New Hebrides	Present		Possibly Present	
New Caledonia	Widespread		Possibly Absent	

TABLE 8 (Continued)

Country	Bovine[2]	Treatment	Ovine	Treatment
Samoa Papua New Guinea Portugese Timor	Not Recorded	Quarantine	Not Recorded	Quarantine
Indonesia			Sporadic	Voluntary

[1]Blanks as in original FAO-WHO-OIE table.
[2]Includes buffalo, Bubalus bubalis, thus may include Psoroptes natalensis in countries with domestic buffalo.
[3]Oddly, gazetted as a notifiable disease but the treatment is not compulsory.
[4]Exceptional occurrence may indicate found on imported animals in quarantine.
[5]No ovine psoroptic scabies since 1935 in Lesotho; outbreak in 1975.
[6]Moderate in some regions of Argentina.
[7]FAO-WHO-OIE 1971 reported reduced presence of ovine scabies. Eradicated since 1971 in the United States (Graham and Hourrigan 1977).
[8]Beesley (1973), Kirkwood (1977), and Tarry (1974) report ovine and probable presence of bovine psoroptic scabies recurrence in recent years.
[9]No ovine scabies found during 1976 in Ireland.
[10]High incidence of bovine and ovine psoroptic scabies in Germany and France in recent years (Labie et al. 1975; Roger 1975; Liebisch and Petrich 1977; Liebisch et al. 1978a; Liebisch et al. 1978b).
[11]Bovine and ovine Psoroptes ovis present according to extensive Russian literature.
[12]Ovine and bovine Psoroptes ovis present (Segal et al. 1968).
[13]Ovine Psoroptes ovis present and P. natalensis on buffalo (Segal et al. 1968).

damage, whereas Psoroptes and Sarcoptes were unimportant. In the United States, as an example of temperate countries, Fisher (1974) detected demodectic nodules in 88 percent of steer hides examined.

RECOMMENDATIONS

• Although basic research on biology and host interactions of Psoroptes ovis is needed urgently, it should not be given first priority. The current dilemma of an epizootic of scabies despite an extensive eradication campaign requires that priority be given to applied research on treatment and epidemiology.

• Priority should be given to research related to the question of a hidden source of P. ovis, possibly in the southeastern United States. Included should be research on latency of bovine psoroptic scabies, alternate methods for demonstrating P. ovis at extremely low infestation rates, and other diagnostic approaches. Further information should be obtained on climatic conditions in the specific areas within tropical and subtropical countries where bovine psoroptic scabies exists, along with information on clinical effects.

• Priority should be given to practical experiments on transmission of bovine psoroptic scabies via contaminated environments. Extensive research is required in different climates, seasons, and weather to understand the danger posed by reoccupying contaminated holding facilities, grazing grounds, trucks, implements, etc. The data from ovine scabies cannot be relied on without comparison to results with cattle.

• Minor research should be initiated on possible vectors such as birds or flies.

• Several extensive and intensive research programs should be started on the biology of P. ovis on or from cattle. Almost all extant information is based on mites of sheep. Extrapolation is questionable considering the great difference in pelage and skin physiology of these hosts. Included should be life history, bionomics, and host-parasite interaction studies along with measurements of temperature and humidity in the host haircoat. Extensive research is necessary to yield practical information related to haircoat types on different breeds and species of cattle and haircoat changes through the seasons. One goal should be development of life tables useful for population dynamics conclusions related to pest management.

• Biological control agents should be sought. Finding useful predators or parasites of P. ovis appears improbable.

Seeking pathogens may be more profitable. Projects on biological control should be given low priority.

- Pheromones, hormones, and other biologically active natural compounds should be sought. A primer pheromone probably is involved in the failure of unattached pubescent females to molt to the adult stage.

- The question of host specificity of P. ovis should be addressed further, applying modern methods and theory of speciation and varietal differences. Research could involve scanning electron microscopy, internal anatomy, genetics, physiology, biology, ecology, and immunology. Suggestions on cross-host transmission studies are given in detail in the Taxonomy section. Immunosuppressives should be tried to reduce resistance of hosts to alien mites. The possibility of sibling species should be investigated.

- Possible wild host reservoirs should be studied, particularly bighorn sheep. Transmission experiments are needed. Experiments with bison may be profitable.

- Research should be initiated on the practical problems of host condition, nutrition, stress, age, and sex on susceptibility to infestation by P. ovis and the subsequent course of the disease. No research with cattle has been published on this problem.

- A thorough review is needed of all literature on psoroptic scabies. In particular, the fairly extensive Russian and East European literature is not generally available to research workers. Translations are necessary, mainly for Russian, German, French, and Spanish literature. The German and French theses on psoroptic scabies should be made available in English.

- Chorioptic scabies should be removed from the list of notifiable or quarantinable diseases subject to eradication. Time, effort, and resources, even though minor, wasted against chorioptic scabies should be diverted to psoroptic scabies. C. bovis is a common pest of sheep and cattle, usually causing mild symptoms or none at all, so that the majority of infestations are not disclosed by the usual official inspections.

- The Food and Agriculture Organization, World Health Organization, and Office Internationale Epizooties should be encouraged to report the several scabies and manges separately in their Animal Health Yearbook.

CHAPTER 3

REVIEW OF THE CURRENT KNOWLEDGE ABOUT HOST-PARASITE INTERACTIONS

PATHOGENESIS

An extensive and thorough search of the published literature revealed that there have been very few investigations on the pathogenesis and immunity reactions of animals with psoroptic scabies. Most of the available reports on these two subjects are descriptions of the condition in sheep; only a meager few are on the disease in cattle. The scab mites, *P. ovis*, that attack and parasitize both cattle and sheep seem to be of the same species (Sweatman 1958) and have been transmitted between both hosts (Roberts and Meleney 1970, Kemper and Peterson 1956). Because of this and the fact that (a) research involving cattle is more expensive and takes longer to obtain meaningful data than that involving sheep and (b) ovine scabies has been the more important disease until recently, many investigators conduct their experiments on sheep. Presumably, results from sheep, when accurately interpreted, may be of some value in relation to cattle. Final acceptance of sheep data, however, should require proof of applicability by testing on cattle.

The skin lesions of psoroptic cattle scabies are generally classified into two categories: moist and dry. The gross physical features of each category are known sufficiently well that veterinary scientists--parasitologists, regulators, epidemiologists, pathologists, and practitioners--use the appearance of these features and their anatomical distributions as indicators of the cause. They also are indicators of the duration of infestations, of the abatement of infestations during spring and summer, and of the enhancement of infestations during fall and winter.

The histopathology of mite dermatitis, however, is not known. Changes in both epidermis and corium should be investigated through a time scale in order to understand more fully the pathogenesis of lesions. The investigation should measure physiological and hematological parameters and compare them with similar parameters of uninfested and mildly infested cattle. Following death, all organs should be thoroughly examined for gross and microscopic lesions. All of these data--pathological, biochemical, and physiological--may assist in understanding the pathogenesis of the disease and the causes of death.

Bioclimatic chambers--wherein air temperature, humidity, pressure, photoperiod, and contaminants are controlled--should be investigated as a possible research facility for ready induction of latent and active stages of the mite on infested cattle.

In this report, the discussion of published works will be mainly concerned with the disease in cattle, but it will necessarily be supplemented with comparisons to the sheep syndrome.

Gross Lesions

Following transmission of Psoroptes ovis to uninfested hosts, particularly during the cool climatic conditions of winter and after recrudescence on hosts latently infested or infestations acquired during autumn, mite populations increase and may produce visible lesions. Further multiplication and spread of the population causes exacerbation of the dermatitis.

Using their piercing chelicerae, the mites puncture the epidermal layer of the skin and reach the corium. Lymph, as well as serum from extravasated blood, is ingested by the mites. The excess fluid exuding through the puncture mixes with hair, soil, manure, and skin debris, coagulates and forms scabs.

Punctural traumas cause local hyperemia and acute dermatitis. As the affected location becomes unfit for the mites' activities, they move to adjacent areas. Continued movement of these mites to normal skin at the peripheral areas gradually expands the lesions. Coalescence of various neighboring lesions forms large patches, sometimes resulting in generalized infestations (Delafond and Bourguignon 1856, Gerlach 1857). These patches of cutaneous lesions may appear moist or greasy or may be dry, scabby, furrowed, and depilated. In chronic lesions, the skin becomes edematous, thick, and wrinkled. The hair appears to be sparse and erect, giving the area a rough appearance. The affected areas are usually sharply defined by the difference between the denuded or sparse-haired and the normal-haired skin.

Snyder (1942), Kemper and Peterson (1953), and Roberts and Cobbett (1956), all scientists of the USDA, have investigated psoroptic scabies among cattle in the western United States. They observed that the anatomical sites favored by mites for colonization were the densely haired skin over the withers, rump, and back. The initial lesions also were found on the poll or base of the tail. From these areas the parasites spread to the sides and, in some animals, over the entire skin surface. Hutyra et al. (1938) mention initial infestation occurring on the top of the neck also, then spreading down the sides of the neck.

Seasons of the year influenced the size and activity of the mite population, and thus the size and severity of the lesions produced. During winters, numbers were enhanced and the lesions were exacerbated. In summers, the numbers declined and the lesions appeared to be in regression. In most cases, however, some mites survived summer latency and resurged the following winter and produced cutaneous lesions.

During the feeding process, mites may produce and inject irritant substances, possibly saliva, into the skin. These irritating products of the mites presumably provoke severe itching. Such is the opinion of some investigators (Gaafar 1974, Nelson et al. 1975), who speculated that most parasitic mites inoculate salivary products into the tissues of their hosts. Other investigators, using scanning electron microscopy, were not able to verify the presence of salivary glands in P. ovis (Blake et al. 1978). The cutaneous irritation may, therefore, be due to the physical activity of the mites, the chemical effects of their salivary or other secretions, the result of an immunopathological reaction, or a combination of all these factors. Whatever the cause may be, frenetic cattle infested with these acari bite, lick, rub, kick, and scratch their skin until they eventually excoriate the itching area. The resulting injuries often become secondarily infected with a variety of bacterial organisms or invaded by myiasis-producing dipterous larvae. Heavily parasitized young cattle lose body weight and some may die.

The disease in sheep seems to run a parallel, if not identical, course. In early studies, Delafond and Bourguignon (1856) in France and Gerlach (1857) in Germany observed the development of redness and vesicles in sheep skin where mites were feeding. They also induced vesication and pustulation in experimental animals by rubbing ground mites or extracts from ground mites into the animals' skins. They concluded that compounds in mite bodies or in mite secretions were among the causative agents for lesions in naturally infested animals.

Downing (1936) also observed that in parasitized sheep the anatomical sites preferred by mites for colonization were the densely wooled skin over the withers, rump, and back. He found that the parasites fed on near-normal skin by puncturing the epidermis and corium with their sharp chelicerae and ingesting the lymph. The puncture wounds caused local hyperemia and the development of epidermal vesicles that often (1) transformed into pustules exuding lymph and serum, (2) mixed with skin debris and wool, (3) coagulated, and (4) formed scabs. Some lesions were moist and greasy while others were dry, scurfy, rough, and depilated. As the dermatitis became chronic and the tissue thickened, the resident mites moved to the periphery of the lesion where the skin was normal. Continuation of this process expanded the small lesions and many of them coalesced to form large, denuded, scabby areas. These coalesced lesions could cover the whole skin surface in a few weeks. Downing also recorded his observations on the irritating effects of the mites causing the intense pruritíes evidenced by self-biting, scratching, and kicking. He assumed that these clinical signs were produced by inoculation of irritating materials--possibly saliva--by the mites. Hudman (1962) in Texas and Nuallain (1966) in Ireland stated that larval, nymphal, and adult mites punctured the ovine epidermis and penetrated the corium with their chelicerae and fed on the lymph. This activity by the mites resulted in local hyperemia, swelling, serum infiltration, and exudation of tissue fluids onto the skin surface. They also indicated that small vesicles formed around the puncture wounds. These vesicles later coalesced and ruptured, releasing a fluid which mixed with wool and cutaneous debris and coagulated to form greasy, yellow scabs or crusts. Secondary bacterial contamination often complicated the condition and led to loss of weight in moderate infestations and occasionally to death in severe infestations with generalized dermatitis. Following expansion of the lesions and movement of mites to the periphery, the centers of old lesions exhibited signs of excessive keratinization with the presence of excessive amounts of scales, debris, and dandruff--the whole area being covered with dry, pale, and raised crusts. The withers, shoulders, rump, and flanks were the areas where the lesions were more commonly observed.

Environmental factors determining the fecundity of mites and thus the development and severity of the disease in sheep were studied by Downing (1936) and Spence (1949) in Britain and by Roberts, Blachut, and Meleney (1971) in the southwestern United States. During winters, when the average daily minimum temperature was 0°C (32°F) or lower, ovigerous females produced 3 to 6 eggs per day and lived 11 to 15 days. During summers, when the average daily minimum temperature was 4.4°C (40°F) and higher, they laid an average of 1.3 eggs per day and lived up to 42 days. Following transmission of mites to a new host during summer, the parasites were latent and produced eggs slowly. However, when the mites were transmitted during winter and following winter recrudescence from latent infestations, females rapidly accelerated egg production, thereby rapidly enlarged the population, and the lesions became visible.

The population of mites during latent infestations on sheep apparently cause subclinical lesions invisible to the naked eye. Animals which have typical lesions of psoroptic scabies during the winter may show improvement in their general physical condition throughout late spring and summer: the skin lesions may regress, and the wool may grow normally. When the previously infested animals were examined in those seasons, mites were found, in descending order, on general body surfaces, ears, infraorbital fossae, perineum, scrotum, inguinal pouches, tail, vulvar region, and interdigital fossae. The parasites were found on major skin surfaces in 32 percent of the sheep and in hiding places in 7 percent. In fall, when the weather becomes cool and humid, the mites presumably move from these latency sites to the dorsal parts of the skin where they reestablish large populations and induce new lesions (Downing 1936, Spence 1949, Roberts et al. 1971).

Microscopic Lesions

Except for casual descriptions of what many investigators envisage as the probable microscopic appearance of cattle skin infested with P. ovis, there are no published reports on this subject. No concerted effort has been made to describe the histological appearance of the skin during the sequential stages of the disease. Some descriptions of the lesions in sheep, for example the description given by Nuallain (1966), included epidermal keratinization, fibrosis of the corium, and inflammation. Photomicrographs were not presented to substantiate these claims. It is suspected that these were rather gross descriptions and not necessarily based on observations by microscopy. Statements that the loci of infestation are rendered unsuitable for mite feeding appear in some publications without any histological support or indication of cause. Therefore, the appearances of histopathologic changes in dermatitis in both moist and dry lesions in all stages of development should be investigated by means of light and electron microscopy.

IMMUNOLOGY

The earliest statements concerning any facet of immunity of cattle to infestation by P. ovis were made by Imes (1918), who indicated that cattle treated for scabies are not immune to further infestations. Cattle which had clinically recovered from psoroptic scabies became reinfested through contact with other animals exhibiting signs of the disease and harboring mites. Recovered animals also became reinfested by being housed in facilities where infested cattle had been confined recently.

Only two publications, both of which were written by scientists from the USDA, have dealt with the criteria of immunologic reactions in sheep or cattle against P. ovis. Fisher and Wilson (1977) tested sera from infested and uninfested calves for the presence of precipitating antibodies against antigens prepared by extractions from dried, ground homogenates of P. ovis. At the time of testing, the infestations on the animals were 1 to 8 months old. The investigators, using an agar gel diffusion method, demonstrated the presence of precipitating antibodies in 23 of 38 infested animals and in 5 of 54 animals not clinically infested with P. ovis. The authors considered the positive reactions to be specific because they tested the sera against extracts of the cattle grub Hypoderma bovis, the ear tick Otobius megnini, the cattle louse Hematopinus eurysternus, and the follicular mite Demodex bovis. They suggested that some calves infested with P. ovis failed to develop precipitating antibodies because of their young age during the infestation and that some uninfested calves reacted positively because of previous unknown infestations. These authors also indicated that P. ovis shares some common antigenic properties with P. cuniculi. In an earlier publication, Fisher (1972) used sera from infested sheep and antigen extracted from homogenated mite bodies in the agar-gel, double-diffusion method of Ouchterlony and found that sera from 12 of 14 P. ovis infested animals and none of the sera from the 12 uninfested animals possessed precipitating antibodies against P. ovis. In addition, he showed that 12 of 14 sera from the same infested sheep also had precipitating antibodies against antigens extracted from the bodies of P. cuniculi.

It is apparent that there is a considerable deficiency in our knowledge about immunity against P. ovis in cattle. It is possible that such factors as lack of funds or that the disease is highly contagious and reportable are responsible for this neglect. Few institutions other than the USDA laboratories are currently engaged in research related to immunological reactions of this disease.

The presence of salivary secretions emitted by the mites, as well as other likely sources of immunogenicity of the parasites, should be investigated. The role of these secretions in induction of disease should also be studied.

The susceptibility of animals to infestations of mites should be investigated at various locations under strict supervision and quarantine. These studies should compare the immunological competence of young and old animals, various breeds, sexes, genetic lines, and other factors. The effects that weather conditions, such as temperature variations, humidity, and the light cycle, have on the immunological capacity of animals should be studied.

DIAGNOSIS

Procedures for accurate diagnosis of psoroptic scabies in cattle are dependent on (1) observing the clinical signs associated with the cutaneous changes, (2) finding the gross lesions of dermatitis, (3) observing the behavior of the animals, and (4) isolating and properly identifying the mites.

1. The lesions of arthropod parasitic dermatitis in cattle may, at certain stages, be quite similar in appearance. Batte (1972) discussed four groups of agents which may cause these lesions: flies, lice, ticks, and mites. Any chronic dermatitis associated with excessive scurfiness and depilation should be suspected of being caused by arthropod agents. The presence of hard, thick, blood-stained scabs--particularly at the periphery of sharply defined lesions--is an indication that mites are involved. Other lesions such as edema, thickened skin, and pyogenic dermatitis may also be indicative of acaral invasion.

2. The appearance of lesions of dermatitis on animals showing signs of general deterioration in health accompanied by loss of weight may be the hallmark of severe psoroptic scabies. Severely affected animals usually stop feeding. As a result of the severe dermatitis, they may become more susceptible to further cutaneous and other infections. The activity of the mites on the skin and the possible irritation of their secretions or excretions cause the animals to lick, bite, and scratch their hides. They may also stamp their feet and kick.

3. Skin irritation changes the behavior of affected animals. They become nervous, restless, and irritable. During the early phases of the infestation, even before visible lesions appear, the animals are observed to chew nervously and abruptly swish their tails in a manner characteristic of the condition (Meleney 1979). Later these animals may become quarrelsome and aggressive. Eventually, however, when the lesions cover large areas of the body, they tend to be depressed.

4. Positive and specific diagnosis of psoroptic scabies is dependent upon isolating and identifying the mites from scabs or skin scrapings from affected animals. During the early phase of infestation, the mites may be few in number and thus difficult to find. Mites are usually more abundant in the outer edges of the scabby areas. Scraping these areas with the blunt edge of a knife and examining the scrapings in mineral oil under a microscope, breaking up the scabs under a good light source, and using maceration-flotation techniques are some of the methods

available to isolate and identify the mites in the psoroptic scab lesions.

The scraping to isolate the mites should be performed at the edge of the lesions and should be deep enough to cause slight oozing of blood. The scrapings should be transferred onto a glass slide and mixed with a drop of mineral oil. Large pieces of scabs should be broken into small pieces and the preparation covered with a cover glass. Examination under the microscope should be done using the scanning power (25 x) and verified by the low power (100 x) or high power (400 x) if needed.

Hard scabs obtained from animals with lesions suspected of being psoroptic scabies may be examined in the field. When these scabs are broken into small particles over dark paper (e.g., carbon paper) or white paper and under a good source of light, the mites will appear as small grey objects moving about on the paper. They can be better seen with the aid of a hand lens.

In the laboratory, 1 part of scabs may be macerated in 3 parts of 10 percent sodium or potassium hydroxide in a test tube. The preparation is then carefully boiled for 3 to 5 minutes. After cooling, it is centrifuged at 1,500 RPM for 5 minutes. A drop of the sediment is examined under a microscope. Alternatively, the sediment is mixed with saturated sugar solution and after 15 minutes the top miniscus is examined for the presence of mites. A centrifugation-flotation technique could be used to replace the latter step in this method (Omohundro 1970). It should be remembered that applying this technique renders the mites translucent and difficult to recognize in the preparation. This is particularly true when the microscope illuminator is too intense. The maceration flotation method is presented in detail in Appendix E.

Adult mites, eggs, larvae, and nymphs must be properly identified according to the descriptions given in the Parasite section. Differentiation from other mites infesting cattle in the United States may be accomplished by using various published keys, pictures, and descriptions. Literature sources for keys, descriptions, and illustrations useful in differentiating the ectoparasitic mites of cattle include Anonymous (1974), Baker et al. (1956), Kemp and Sloss (1978).

At present, there are no recognized immunological or serological procedures for diagnosis of psoroptic scabies. The anatomical sites where mites hide and survive during latent stages of infestation should be determined so they can be used as a guide to help locate mites.

Research efforts should also be directed towards finding better methods for early diagnosis of infestations. These efforts should include serological studies to develop a diagnostic test. Meleney (personal communication, 1979) noted the research at the USDA Parasite Research Laboratory at Albuquerque, N.M. on a serological test to detect infested animals and continuation of this research at the U.S. Livestock Insects Laboratory, Kerrville, Texas. He stated "progress is being made, but the practical value of the approach remains in doubt." However, such a test might be of great value to the Eradication Program so that intensified effort is warranted. Such a method might be adapted from that used on sera collected for the purpose of testing for brucellosis or leptospirosis at federal and state laboratories. Other methods such as immunofluorescence, guanine fluorescence in the skin, and vacuuming of skin debris should also be investigated.

CHAPTER 4

REVIEW OF THE CURRENT KNOWLEDGE ABOUT THE EPIDEMIOLOGY OF PSOROPTIC SCABIES

The present psoroptic cattle scabies epidemic in the United States started in the early 1970s (Figure 1). This epidemic has been reviewed in recent publications by APHIS (1978a) and Meleney and Christy (1978). There was only one outbreak in Fiscal Year 1970 (1 July 1969 through 30 June 1970). There were 11 outbreaks in Fiscal Year 1971 and 91 in Fiscal Year 1972. The annual total number of outbreaks varied from year to year and reached a maximum of 313 in Fiscal Year 1978 (1 October 1977 through 30 September 1978) (APHIS in press b). The rate at which outbreaks have been reported in Fiscal Year 1979 is only slightly reduced from 1978 (APHIS in press c).

DISTRIBUTION OF PSOROPTIC CATTLE SCABIES IN THE UNITED STATES

Scabies is not uniformly distributed in the cattle population (APHIS in press a,b,c) (see Figures 1, 2, 3). Until recently, outbreaks were largely confined to areas of large feedlots. The feedlot industry can be roughly divided into three major geographic areas: the Corn Belt states of Ohio, Indiana, Illinois, Iowa, Minnesota, and Missouri; the High Plains states of Texas, New Mexico, Colorado, Oklahoma, Kansas, and western Nebraska; and the southern portions of Arizona and California (Figure 5). Within those areas the first outbreak of psoroptic scabies in Fiscal Year 1970 occurred in the Texas Panhandle. Within 2 years outbreaks had spread over the High Plains in a broad band stretching from eastern New Mexico to the Corn Belt in western Iowa. In the next 3 years the epidemic area did not substantially change, despite isolated outbreaks in Indiana, Georgia, Idaho, Arizona, and the Edwards Plateau of Texas. In Fiscal Year 1976 the epidemic area expanded into southern Arizona and California. The expansion has continued since then, moving into northern California and southern Oregon. Isolated outbreaks have been reported in the mountain states of Utah and Idaho. Outbreaks in the Plains have spread to the west and north but have not yet reached Montana and North Dakota. The epidemic in the western Corn Belt has pushed north into Minnesota and east into western Illinois.

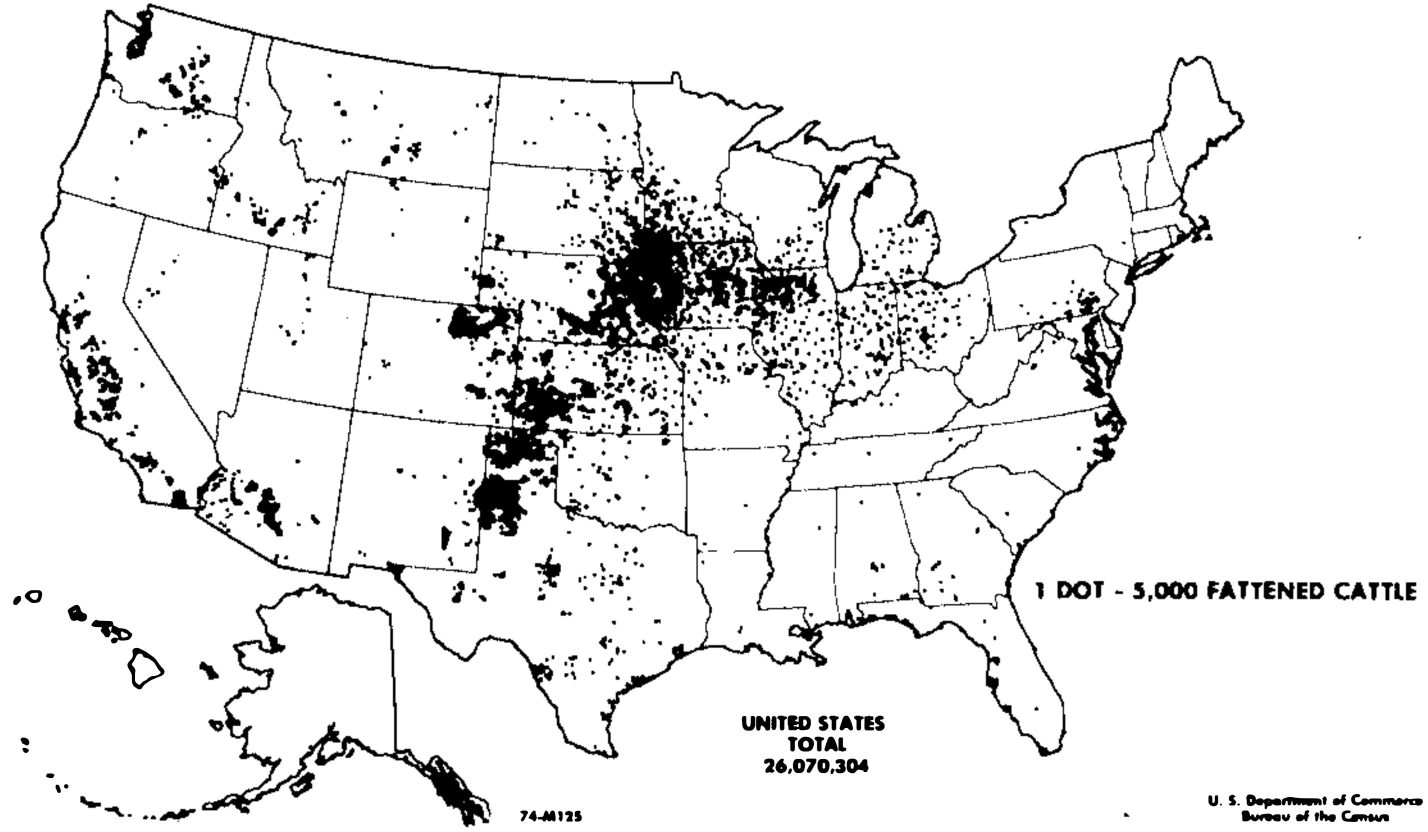


FIGURE 5 Cattle fattened on grain concentrates and sold for slaughter; 1974 (farms with sales of $2,500 and over, county unit basis).

Thus far the disease has not spread into the border states such as Missouri, the southeastern states, or the dairy area of Wisconsin and the northeastern states.

The effects of climate on the spread of psoroptic scabies are not well known. Most outbreaks of scabies are diagnosed in the winter, but a few cases are diagnosed in every month during the summer (APHIS 1978). Experimental infestations in cattle have been maintained throughout the warm season in Albuquerque, N.M., and Amarillo, Texas. However, experimental infestations have been difficult to maintain farther south in Kerrville, Texas (Meleney 1979). Since 1904, psoroptic cattle scabies has occurred in all areas of the country except the northeastern states of New Hampshire and Maine (ADED 1979a). There is no indication from published literature whether the absence of the disease from this northern area is due to climate or, as seems more likely, to low cattle density and low rates of introduction of cattle from areas where cattle are infested with scabies. Prior to the eradication of sheep scabies from the United States, it was found in most states including the warmer states along the Gulf Coast (ADED 1979b).

DISEASE RATES

Available data are inadequate for calculating exact disease rates among cattle at risk or for determining distribution of the disease among the different ages, sexes, and breeds. Older, poorly nourished cattle were said by Imes (1918) to be more susceptible than younger animals, but Meleney and Christy (1978) reported that the disease was more debilitating for cattle under 1 year of age. Prior infestation does not build immunity to the disease (Imes 1918). No sex predisposition is reported. Beef breeds are affected more often than dairy breeds, probably because there are more beef cattle in the feeding industry. Zebu cattle are said to be more resistant than European breeds because of more effective self-grooming (W.P. Meleney, U.S. Livestock Insects Laboratory, Kerrville, Texas, personal communication, 1979). An increased severity of psoroptic scabies in experimental cattle exposed to the disease and stanchioned so they could not groom themselves tends to support this idea (Meleney, personal communication, 1979). Poor nutrition in experimental cattle did not increase susceptibility (Meleney, personal communication, 1979). However, an inferior-quality animal may have greater risk of becoming infested because it tends to be recirculated through market channels, thus increasing the odds that it will come into contact with scabby cattle (Meleney and Christy 1978).

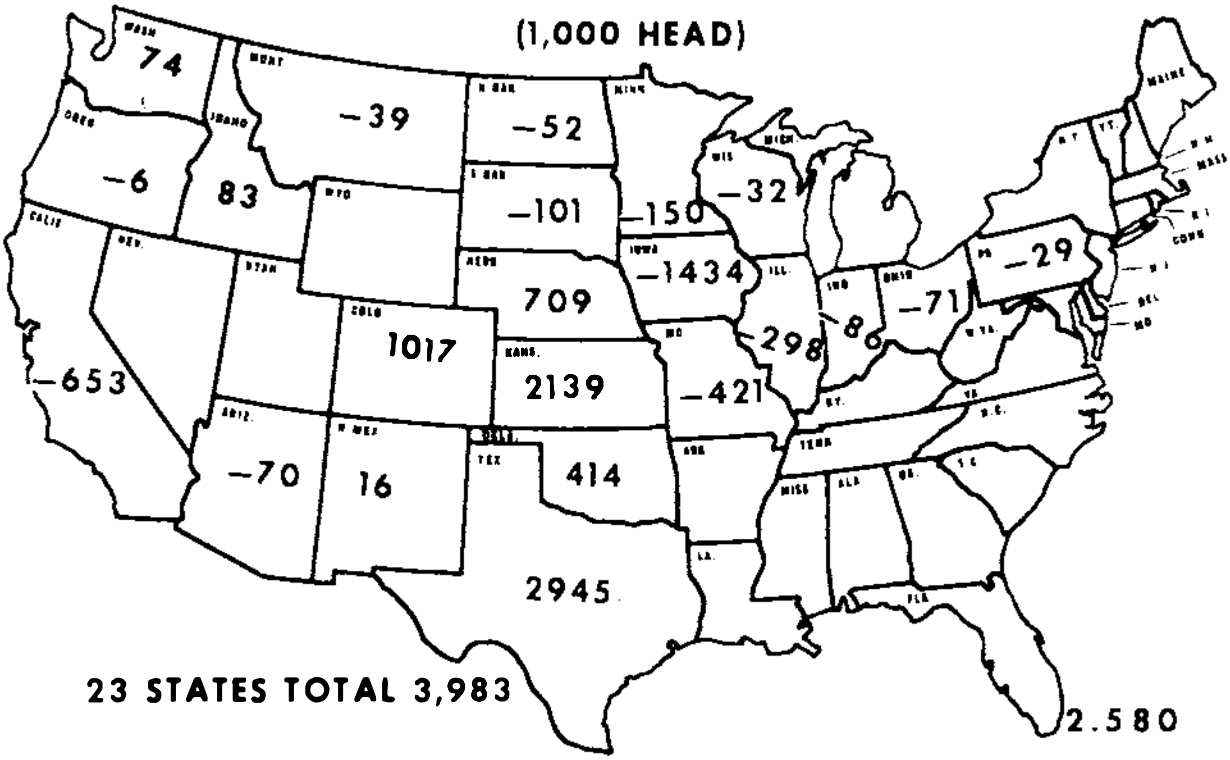
RELATION OF CATTLE CONCENTRATIONS AND MOVEMENTS TO THE SPREAD OF THE DISEASE

The two factors of mixing cattle from multiple sources and crowding large numbers of cattle into small areas such as market pens or feedlots seem to be more important in sustaining the epidemic than climate, age, breed, or sex. During the period from the mid-1960s to mid-1970s, two major production shifts occurred in the cattle industry. First, cow-calf operations shifted from the western states to the southeast and herds decreased in size. Second, the cattle feeding industry shifted from the Corn Belt to the Texas Panhandle and the surrounding High Plains and feedlots increased in size. These shifts have caused a third major change in the industry, an increased shipment and mixing of beef cattle.

Figure 6 shows the change in fed cattle production between 1968 and 1978. During this period, Texas increased the number of cattle fed by 2,573,000 head, while Iowa experienced a 1,219,000 head reduction in fed cattle output. There has been a shift not only in the total number of cattle fed, but--probably more important in relation to the scabies program--also in the types and the size of feeding operations. The average number of cattle marketed per feedlot in Iowa (part of the traditional Corn Belt) was 98 head in 1978 compared to 9,912 head in New Mexico (Figure 7). The number of feedlots having over 1,000 head capacity has rapidly increased since 1962 while the number of feedlots with capacities of less than 1,000 head has decreased (Figure 8).

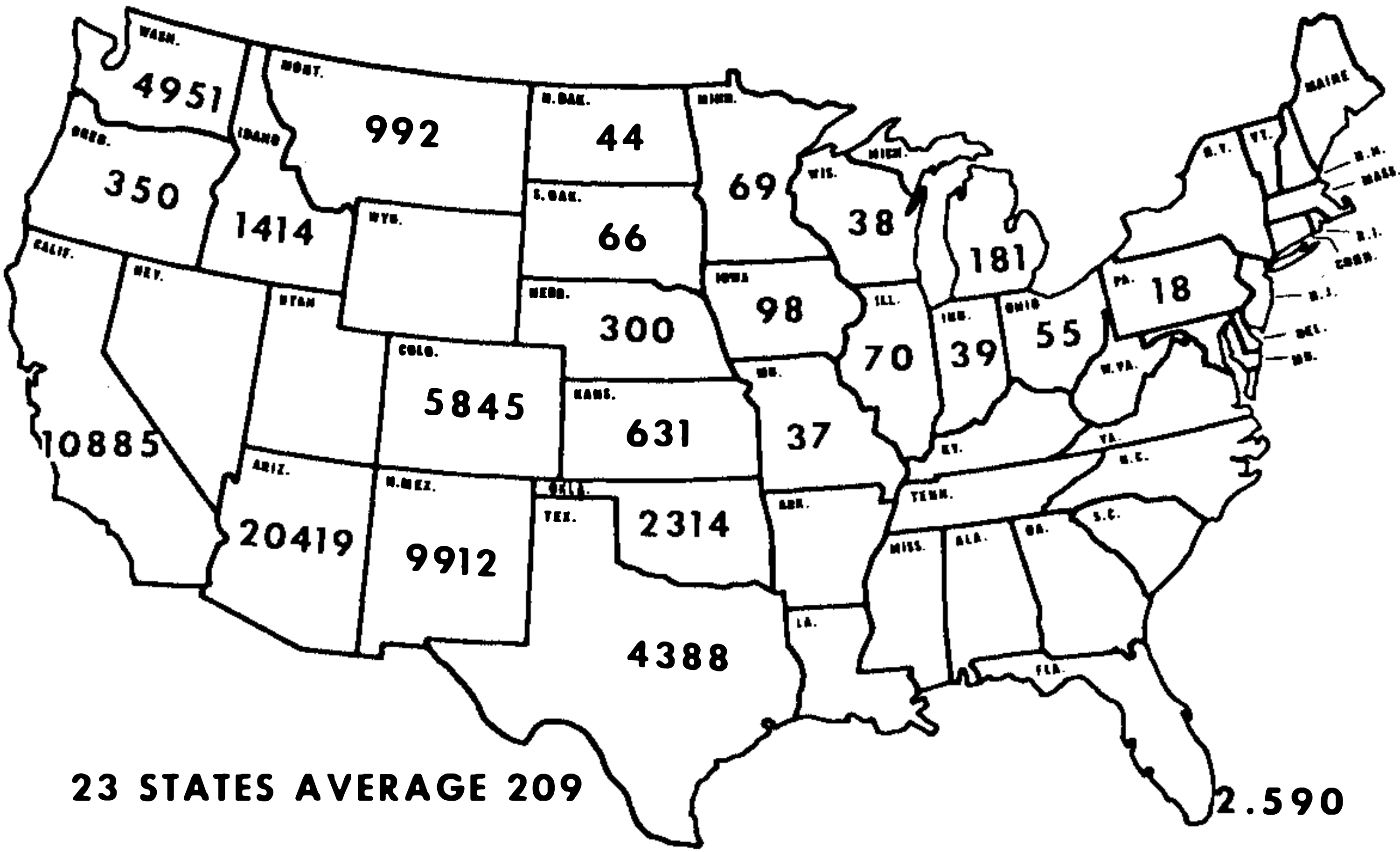
Figure 9 dramatically illustrates the change in the beef-calf crop from 1968 to 1978. As an example, the calf-crop production in Missouri increased by 558,000 head during this time, while New Mexico production decreased by 53,000 head. Along with the shift in the location of cow-calf herds, there has been a decrease in herd size. In 1974, about 9 percent of the beef cows in the western states and about 28 percent of the beef cows in the southwestern states were in herds of less than 50 head (U.S. Bureau of the Census 1978).

For the large feedlots to obtain the numbers of cattle needed, cattle must be concentrated and commingled from many sources. Most of the cattle for the High Plains feedlots originate from small cow-calf farms in the southeastern states. In Georgia, for example, in 1974 the farms selling calves averaged only 22 head of calves sold (U.S. Bureau of the Census 1978). Even if those calves moved directly from farm-of-birth to feedlot, it would require the calves from over 1,000 such farms to stock just one Texas feedlot. However, calves usually are passed through dealers and auctions where mixing and resorting occurs. The calves are



SOURCE: USDA (1979).

FIGURE 6 Change in fed-cattle marketings, 1968 to 1978.



SOURCE: USDA (1979).

FIGURE 7 Average number of cattle marketed per feedlot, 1978.

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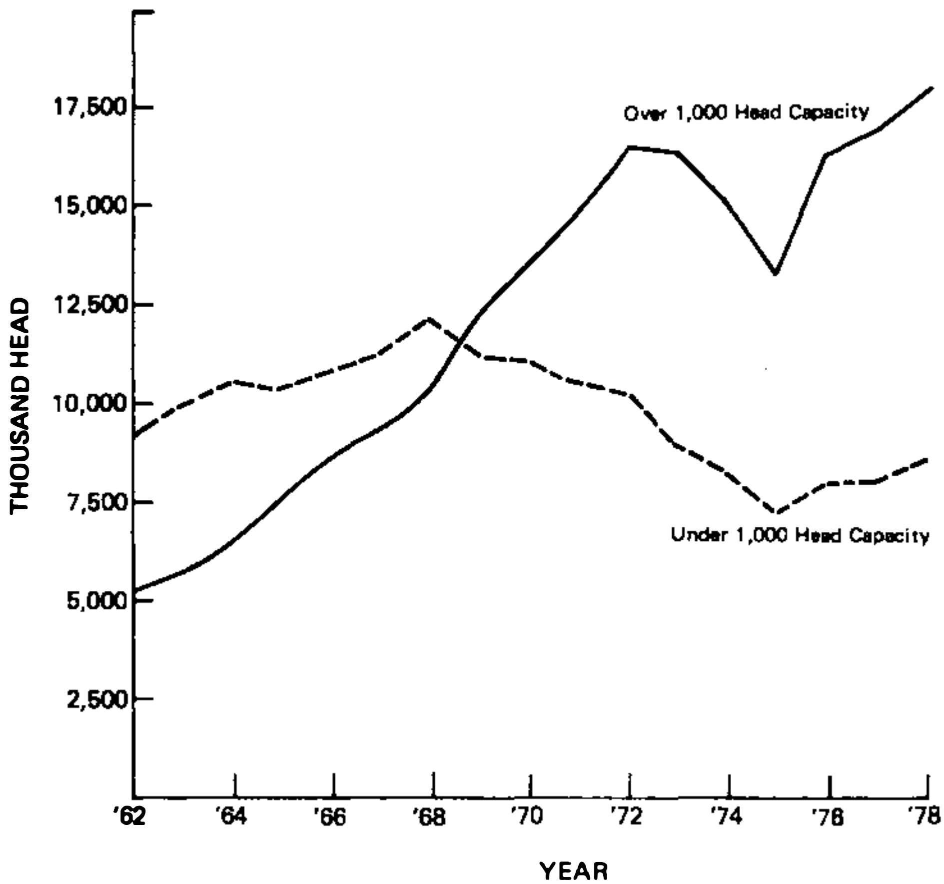
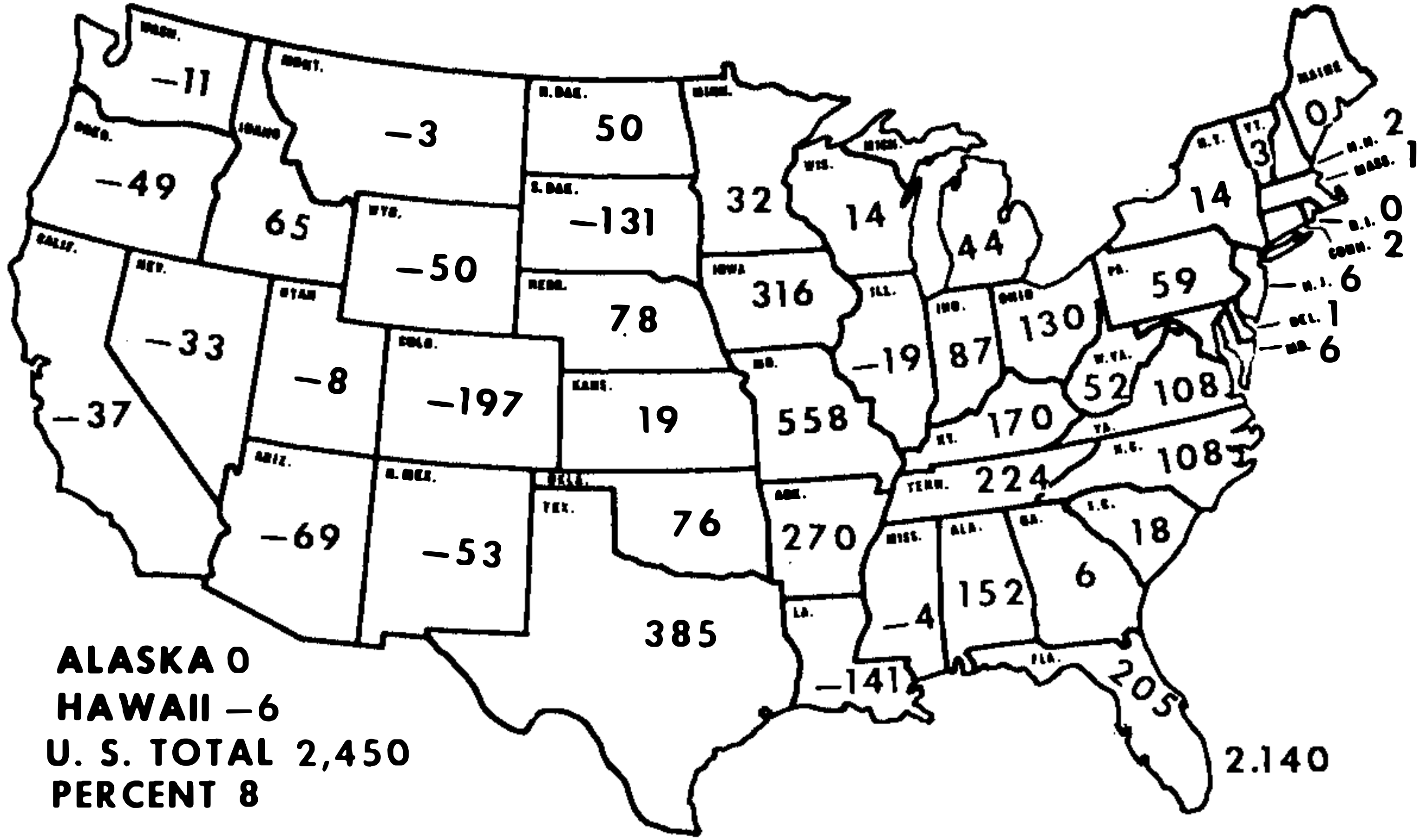


SOURCE: USDA (1979).

FIGURE 8 Fed-cattle marketings by size of feedlot.



SOURCE: USDA (1979).

FIGURE 9 Change in beef calf crop 1968 to 1978 (1,000 head).

then pastured or even passed through a preliminary or preconditioning feeding period prior to the final finishing phase. Thus, the animals in a feedlot may have come from several thousand lots of cattle. It is very difficult to trace cattle movements between states because many states do not keep records showing the origins of inshipments (out-of-state shipments coming across their borders).

The seven major cattle feeding states--Arizona, California, Colorado, Iowa, Kansas, Nebraska, and Texas--receive a large number of cattle from other states (Table 9). According to Dietrich (1971), the major flow of feeder cattle is westward (Figure 10). An example of these data for a specific state, Texas, is presented in Figure 11. Eight southeastern states--Arkansas, Louisiana, Mississippi, Tennessee, Kentucky, Alabama, Georgia, and Florida--accounted for 52 percent of the 1,827,000 head of cattle shipped into Texas during 1977. Similarly, 93 percent of shipments from Texas went to seven High Plains or western states--California, Arizona, New Mexico, Colorado, Nebraska, Kansas, and Oklahoma.

The number of outbreaks of psoroptic scabies has been highest in the feedlot area having the greatest concentration and greatest introduction of new stock, the High Plains. The lowest number of outbreaks, prior to the last 2 years, has been in the feedlot area having the smallest feedlots and least introduction of new stock, the Corn Belt. A close correlation exists between the number of inshipments for a state area and the number of reported scabies outbreaks (Table 9).

The low number of outbreaks among dairy herds, noted previously, appears to be related to herd size and cattle movements. Dairy cows are kept in much smaller units and feedlots than are beef herds. The majority of dairy cows in 1974 were in herds of less than 100 cows; only 6 percent were in herds of over 500 head (U.S. Bureau of the Census 1978). Except for southern California and southern Minnesota, the major dairy and feedlot areas generally do not overlap (Figure 12).

Fewer new animals are introduced into dairy areas. For example, in Wisconsin, the leading dairy state, only 2 percent of the cattle in 1977 had been shipped in from another state, while in Texas, the leading beef state, about 14 percent of the cattle were shipped in (Economics, Statistics, and Cooperatives Service 1978). It is too early to tell whether concentration of dairy cows in large herds near the growing population centers in such Sun Belt states as Florida, Texas, Arizona, and California will allow scabies to gain a foothold in dairy herds.

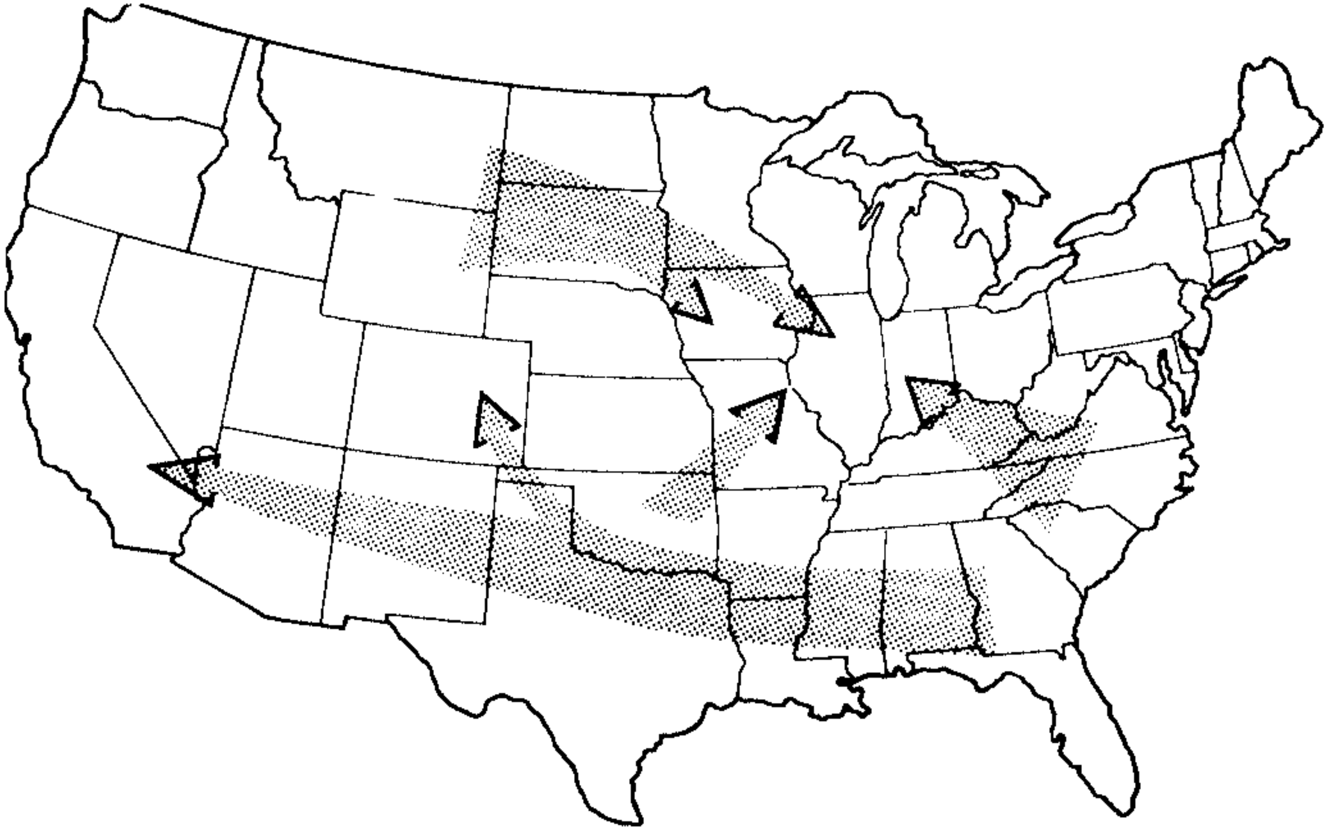
TABLE 9 Inshipments for 1977 and Reported Outbreaks

State	Inshipments[a] (1,000 head)	Cattle Scabies Outbreaks, By Years[b]								
		1971	1972	1973	1974	1975	1976	1977	1978	1979
Ala.	10									
Alaska	0.1									
Ariz.	857								2	1
Ark.	7									
Calif.	1,500						7	4	3	20
Colo.	2,540			5	4	3	4	15	81	30
Conn.	6									
Del.										
Fla.	65									
Ga.	11									
Hawaii	1									
Idaho	249			1						2
Ill.	800								1	2
Ind.	186				1					
Iowa	3,000	7	2	2	1	2	1	1	21	20
Kans.	2,960		9	5	4	8	5	8	32	18
Ky.	140									
La.	10									
Maine	4									
Md.	10									
Mass.	7									
Mich.	89									
Minn.	732									4
Miss.	20									
Mo.	40									
Mont.	115									
Nebr.	2,600	1	5	3	10		12	27	54	27
Nev.	42									
N.H.	5									
N.J.	4									
N.Mex.	1,128		14	19	1	4	34	20	38	16
N.Y.	17									
N.C.	6									
N.Dak.	77									
Ohio	260									
Okla.	1,823		12	1	1	14	7	19	13	8
Oreg.	97								1	2
Pa.	95									
R.I.	0.3									
S.C.	37									
S.Dak.	753								17	23
Tenn.	35									

TABLE 9 (Continued)

State	Inshipments[a] (1,000 head)	Cattle Scabies Outbreaks, By Years[b]								
		1971	1972	1973	1974	1975	1976	1977	1978	1979
Tex.	2,200	3	47	17	11	17	16	40	30	26
Utah	50								1	
Vt.	19									
Va.	7									
Wash.	199									
W.Va.	3									
Wis.	85									
Wyo.	320					1			12	11

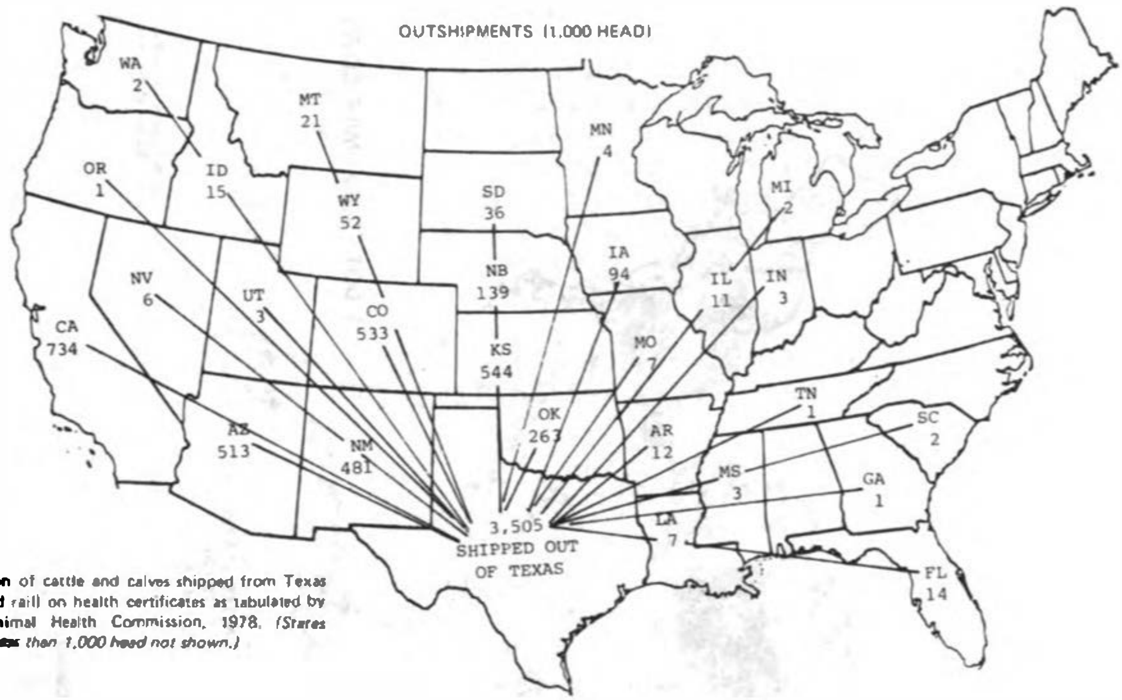
[a]Meat Animals, April 1978, Crop Reporting Board, ESCS, USDA.
[b]APHIS, USDA
[c]October 1978 through April 20, 1979.



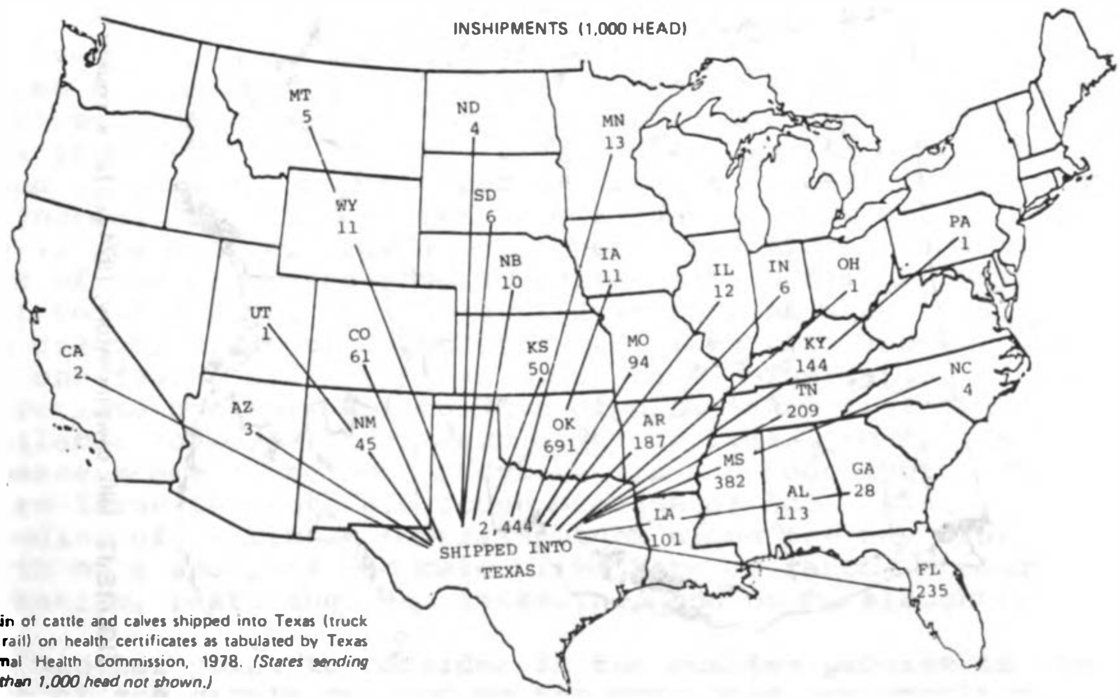
SOURCE: Purdue University (1988).

FIGURE 10 Major directional movements of feeder cattle.

The Texas Animal Health Commission tabulates the health certificates filed monthly with their office. These tabulations include truck and rail movements out of and into Texas. Under Texas law, all livestock must have a health certificate unless consigned to a state or federally inspected slaughtering establishment or specifically approved livestock market. The United States maps below show the states sending and receiving cattle and calves.



Destination of cattle and calves shipped from Texas (truck and rail) on health certificates as tabulated by Texas Animal Health Commission, 1978. *(States receiving less than 1,000 head not shown.)*



Origin of cattle and calves shipped into Texas (truck and rail) on health certificates as tabulated by Texas Animal Health Commission, 1978. *(States sending less than 1,000 head not shown.)*

SOURCE: Texas Department of Agriculture and USDA (1979).

FIGURE 11 Movement of cattle and calves out of and into Texas on Health Certificates, 1978.

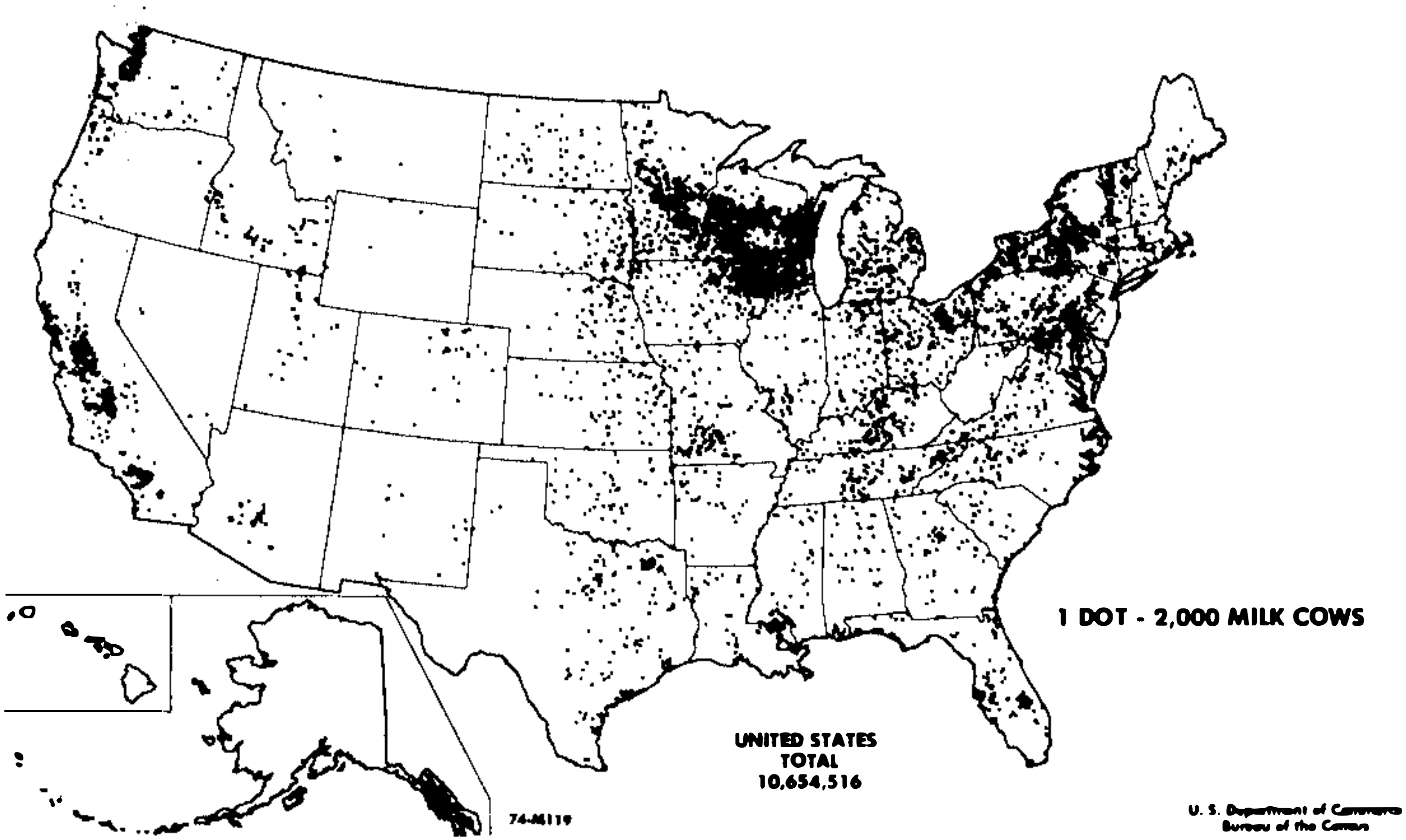


FIGURE 12 Milk cows inventory, 1974 (all farms, county unit basis).

Crowding and introduction of new stock are also associated with outbreaks of psoroptic cattle scabies in Germany, where, as in the United States, the disease is diagnosed in feedlots (Liebisch and Petrich 1977).

It is of interest that 90 percent of the sheep scabies in the western states was attributed to mixing of sheep in "public buck herds," i.e., the practice during the nonbreeding season of forming a herd of rams from several flocks (Babcock and Black 1933). Sheep scabies eradication in the United States coincided with a marked decrease in the sheep population (Meleney and Christy 1978).

PROBLEMS IN DETERMINING DISTRIBUTION AND TRANSMISSION OF *PSOROPTES OVIS*

Data on the distribution and transmission of cattle scabies are limited by difficulties in diagnosis. Even though tens of millions of cattle are inspected annually for scabies, some cases still occur in areas of intense inspection (APHIS 1978). There may be some unidentified geographic areas that are major sources of the mite, but there is no need to resort to such an explanation. The disease is probably capable of maintaining itself in known epidemic areas without periodic reintroduction.

Even though cattle scabies is found in the areas of the United States having large feedlots, only about half of the confirmed outbreaks are found in feedlots. According to data from APHIS (1978), in Fiscal Year 1976 the outbreaks found in feedlots constituted 48 percent of the total number diagnosed, while 40 percent were found on farms and ranches and 12 percent were found in markets or dealers' facilities. Some of the outbreaks were not discovered until the animals went to slaughter. Of the cattle operations where scabies was diagnosed, about two-thirds had fewer than 1,000 head and one fourth had more than 5,000 head. The large operations are more apt to have dipping facilities readily available to keep the disease under control. Thus, the disease seems to be most prevalent in the geographic areas where large feedlots are found because of the mixing and crowding of cattle at several points along the way from birth on a small or moderate sized farm or ranch, through marketing, pasturing, and fattening, and on to slaughter.

Another point to consider in the scabies program is that most of the cattle shipped to the Corn Belt are yearling cattle going directly into farm feedlots to finish growing. In the High Plains feeding area, many of the lightweight southeastern cattle are first grazed on winter-wheat pastures or summer native-grass pastures before going into the commercial feedlots. Also, in the Corn Belt, almost all the cattle are sent to slaughter at the end of the feeding period. If there were any scabies in the lot, very few if any of the cattle would survive to pass it on to the new groups on the pasture or in the feedlot. However, in the Southwest, there is continuous year-round feeding.

PROBLEMS IN APPLYING EPIDEMIOLOGICAL KNOWLEDGE TO THE ERADICATION OF THE DISEASE

Epidemiology is concerned with collecting information about distribution, spread, and etiology of disease in a population. This information is the basis for programs to eradicate psoroptic scabies in cattle by either eliminating or preventing the spread of the mites that cause it. Although there is some possibility that P. ovis can be transmitted by species of animals other than cattle or by inanimate objects such as trucks, it is probable that almost all of the spread is due to body contact with infested cattle. Eradication efforts are aimed at locating infested animals and then treating them to destroy the mites.

Differences among mite strains may account partially for the uncertainty in tracing the transmission of scabies among hosts, the varying effectivenesses of acaricides, the uneven distribution of the disease, the failures in treatment during latency in warm seasons, and--thereby--the failure to eradicate the disease (Roberts and Meleney 1971).

Logistical constraints may prevent field inspection of every lot of cattle from which an infested lot came or to which cattle were shipped prior to diagnosis, but certain lots may have had more suspicious contacts, and efforts should be concentrated on them. Millions of cattle come into contact, but only a few contacts result in scabies transmission.

One of the major techniques for locating diseased cattle is to trace all cattle which have had contact with infested cattle. The capability to trace the movements of cattle within the industry is critical to the success of eradication programs. Hourrigan (APHIS, personal communication, 1979) noted that in Fiscal Year 1978 the source was identified in only 61 percent of the 313 diagnosed outbreaks. There is an average delay of 6 months between the time a herd becomes infested and the time the disease is diagnosed. One factor contributing to the difficulty in tracing contacts is the large amount of cattle movement. Another factor is the incompleteness of cattle shipment records. Individual animals usually are not identified and sometimes even the names of the seller and buyer are not recorded. A third factor is the lack of a centralized system for keeping records of cattle movements and contacts with scabby or suspicious cattle. The state or federal livestock-disease regulatory officials in each state are responsible for notifying their appropriate counterparts in all other states that have received shipments from infested herds.

Research should be undertaken to improve methods of identifying individual cattle and recording their movement through farms, ranches, and markets. This research effort could be coordinated with similar ones in federal and state programs to control brucellosis, tuberculosis, and other diseases in cattle. Some possible approaches are ear tags, back stickers with machine-read barcodes, tattoos, and radioactive machine-read tags or stickers. Because the ideal of being able to identify all cattle may not be achievable, research to develop practical traceback methods that minimally disrupt the cattle industry should be emphasized.

Information and technology from all pertinent fields should be used to enhance the capability of psoroptic scabies eradication programs to trace the movements of cattle. Computer hardware and software, for instance, should be used to test algorithms for cattle-movement data.

A further problem may be suppression of the disease by inadequate treatment. This may result from use of systemic organophosphate compounds developed primarily to kill other pests, incorrect application with an approved pesticide, or single treatment with an approved but not absolutely effective compound (Meleney and Christy 1978).

Scabies researchers should use standard nomenclature, common codes, and standard units of measure such as the Standard Nomenclature of Veterinary Diseases and Operations, Chemical Abstract Registry Numbers, and International Units. The USDA should take the lead in a cooperative, multi-organizational effort to develop standard food codes. Basic statistical, data processing, epidemiological, and informational services should be increased for scabies research personnel as well as for all biological research personnel.

The preparation of this report serves well as an example of how inadequate informational services impede research. The researchers were hampered by the restricted hours of operation of the National Agricultural Library and by the difficulty of obtaining old literature and translations. To help remove those impediments, research and surveillance data should be made machine readable and available for exchange and use by all federal, state, and other researchers and to libraries in general. Scabies research should be coordinated with other types of research in the USDA and in other organizations wherever maximum efficiency will result.

In summary, the major causes of the current United States cattle scabies epidemic are the mixing of cattle from many sources and the crowding of large numbers of cattle into small areas as occurs in the feedlot industry. The eradication program is hampered by inadequate methods of diagnosis, treatment, and animal tracing. Further research should be done on the epidemiology of psoroptic cattle scabies.

CHAPTER 5

REVIEW OF CURRENT METHODS OF TREATMENT AND PREVENTION

PESTICIDES

History

About 1895, sheepmen in several states tried to control the scabies mite, *Psoroptes ovis*, by repeatedly dipping infested sheep and all exposed flocks. Dips commonly used were lime-sulfur, nicotine, nicotine and sulfur, arsenic and sulfur, crude petroleum, cresol, and chloronaphtholeum (Gillette 1897, Anonymous 1903). Ointments containing sulfur mixed in various oils, turpentine, iodine or cresol (Salmon and Stiles 1898) were recommended for hand application. All compounds killed adult and immature mites, but none had long-term residual property on the wool, hair, or skin of treated animals. Only the cresol dips (carbolic acid) were believed to be injurious to the eggs of psoroptic mites (Herms 1915).

Cooperative state and federal programs were intensified in 1905, their goal being to eradicate the scabies mite on both sheep and cattle. Experience in these early years showed that, of all compounds tested, the best ones were lime-sulfur and nicotine sulfate maintained at 95 to 105°F in dipping vats. They were most effective when cattle were given two or more treatments 7 to 10 days apart (Imes 1918). Spraying animals with these compounds was considered ineffective because of the difficulty of thoroughly wetting the wool, hair, and skin of sheep and cattle. Both compounds were recommended by Imes (1927) and tested by Babcock and Black (1933) for use in permanent, heated dipping vats. The number of cases of psoroptic sheep and cattle scabies decreased through the 1930s and 1940s despite all the difficulties with animal management, labor, and operation of hot dips (ADED 1979 a,b).

Of the numerous chlorinated hydrocarbon insecticides registered for pest control following World War II, benzene hexachloride (BHC), lindane (99 percent gamma isomer of BHC), and toxaphene gave excellent control of psoroptic mites. Kemper (1948) found that dips of 0.56 percent, 1 percent and 1.5 percent of 50 percent BHC wettable powder (dip concentrations 0.033 percent, 0.06 percent, 0.09 percent gamma BHC) eradicated *P. ovis* on sheep by a single dipping. The circumstances were those of probable latent scabies. Downing (1947) found that a single dipping in 0.1 percent BHC suspension (0.0125 percent gamma BHC) protected sheep for 8 to 12 weeks against reinfestation. Kemper and Roberts (1950) found that 0.06 percent gamma BHC apparently protected a sheep flock for 3 to 4 months. They found that either 0.03 percent or 0.06 percent lindane eradicated psoroptic scabies in sheep by a single dipping. Roberts and Meleney (1971) determined the period of protection against infestation by *P. ovis* to be: 0.06 percent lindane, at least 121 days unshorn sheep, 72 days shorn sheep; 0.5 percent toxaphene, at least 149 days unshorn sheep, 43 days shorn sheep following a single dipping. Efficacy of 0.5 percent toxaphene and 0.06 percent lindane for eradication of *P. ovis* by a single dipping was proven by Meleney and Roberts (1967). The use of these insecticides nearly eradicated psoroptic scabies. No cases of psoroptic cattle scabies were recorded in the United States during the period 1950-1952, and in the following years this cattle disease was restricted to small areas in the southwestern states (Graham and Hourrigan 1977). During the 1960s, only 49 herds were confirmed as having *P. ovis*. The majority of these were in the Texas and Oklahoma Panhandle region (Christy 1978). Certainly the use of BHC, lindane, and toxaphene dips played an important part in helping to reduce this disease in cattle.

BHC and lindane were removed about 1969 from the list of insecticides permitted to be used against psoroptic mites, but not before the eradication of psoroptic sheep scabies. Only two cases in sheep were discovered in 1967 compared to 872 cases in 1961. Hourrigan (1968) credited the success during these 6 years to the use of chlorinated hydrocarbon acaricides. No psoroptic sheep scabies was found during an intensive 3-year surveillance, 1970 through 1973, and this sheep disease was declared eradicated from the United States (Graham and Hourrigan 1977).

By contrast, the 1970s showed a serious increase in confirmed cases of psoroptic cattle scabies, from 1 outbreak in 1970 to 313 outbreaks in 1978. This cattle disease has increased during these years not only in the United States but also in Germany and France (Liebisch et al. 1978, Roger 1975).

In the mid-1970s, two organophosphorus compounds were permitted to be used as treatments for psoroptic scabies: coumaphos in 1974 and phosmet in 1975. These and other organophosphorus compounds have been extensively used in dips, sprays, and dust applications because of their wide spectrum of control against ticks, mites, lice, and flies. Their systemic activity has been particularly effective against cattle grubs (*Hypoderma lineatum* and *H. bovis*) following dermal application by means of diluted dips or sprays or by highly concentrated formulations poured along the backline of cattle.

The recent increases in the incidence of psoroptic cattle scabies and the recent introduction of organophosphorus compounds for treatment of cattle scabies may have more than a coincidental relationship. Meleney and Christy (1978) relate the increase of scabies in the United States to changes in the cattle feeding industry in the southwestern states, to the increased use of organophosphorus compounds that are "not as effective against scabies mites as are lindane and toxpahene," and to the use of USDA-approved organophosphorus acaricides which do not "eradicate mites on a single dipping." Roger (1975) claimed that the increase of cattle scabies in France was due to the use of organophosphorus compounds, which replaced the organochlorine insecticides, and to the introduction of more beef cattle into smaller grazing areas. Liebisch et al. (1978) related the increase of cattle scabies in Germany to more cattle being managed on less acreage, greater use of indoor housing, inadequate feeding, more rotation of herds, and lower wages paid to farm staffs (resulting in less care of individual animals).

One should not overlook the fact that lindane, by special state exemptions, is still recommended for use against scabies of livestock. For example, Collison (1978) in Pennsylvania recommends the use of 0.05 percent spray applied twice at a 14-day interval to protect sheep and goats from *Chorioptes bovis*. Drazek (1975) in New York recommends the use of 0.06 percent sprays to control psoroptic and sarcoptic scabies on livestock, including beef and non-lactating dairy cattle.

CURRENT ACARICIDES PERMITTED FOR USE IN THE ERADICATION PROGRAM

A summary of the four currently registered compounds for use against psoroptic scabies on livestock is shown in Table 10. Lime-sulfur has been retained because it is the only acaricide permitted for use on lactating dairy cows and goats. It must be used in a heated formulation (90 to 105° F). The other three approved acaricides--coumaphos, phosmet, and toxaphene--are cold formulations, although a specific temperature range of 40 to 80° F is recommended for toxaphene. Guidelines for the use of these compounds are contained in Veterinary Services Memoranda 556.1; Supplements 2,3,6, and 8; APHIS/1972 through 1976, which are presented in abstract form in Appendix F.

TABLE 10 Currently Registered and Approved Chemicals for Treatment of Psoroptic Cattle Scabies

Chemical (registered name)	Formulation	Concentration	Mixing Methods (concentration)	Days from Last Treatment to Slaughter (S) or Lactation (L)	Tolerance (ppm)	Frequency of Treatment
Coumaphos (Co-Ral®)	Wettable powder	25%	10 lb/100 gal water (0.30%)	0 (S) *Do not use on lactating cows or on animals within 14 days of freshening*	1 - meat, fat 0.5 - milk	2 times, 10-14 days apart, all herds[1]
Lime-Sulfur	Powders	Flowers of sulfur	24 lb/100 gal water		Safe chemical	2 times, 10-14 days apart, all herds
		Unslaked lime	12 lb/100 gal water (2.3%)	0 (S) 0 (L)		
	Solution	Lime-Sulfur	1 gal/15 gal water, dip temperature at 95-105°F			
Phosmet (Prolate®)	Emulsifiable solution	11.6%	1 gal/60 gal water (0.21%) plus 10 lb triple super phosphate/ 100 gal water	21 (S) *Do not use on dairy stock*	0.2 - meat, fat	2 times, 7-10 days apart, all herds
Toxaphene	Emulsifiable solution	61%	3 qts/100 gal water (0.55%)	28 (S) *Do not use on dairy stock*	7 - fat	2 times, 10-14 days apart, (once for exposed herds)

[1]All herds include those found with typical symptoms of scabies and positive for mites, and those herds exposed to such positive herds.

Field personnel working in the Eradication Program have suggested useful additions to the published guidelines. For example, their experience has shown that vat dips cover cattle more thoroughly and are less laborious than spray-dip machines. Also, providing a large tub of clean water and soap for emergency washing by persons who accidentally are splashed with the acaricide is an extra safety factor worth consideration.

Although portable kits for testing the dips for the proper concentration of the acaricide are available for coumaphos, phosmet, and toxaphene, federal regulatory staff (APHIS) have not permitted their use because of discrepancies found in critical analysis. Current studies on these kits are proceeding at the National Animal Disease Laboratory at Ames, Iowa. Early results are expected to help place these kits in the hands of commercial operators.

Toxicity of Permitted Acaricides

Data on the toxicity of the four registered acaricides currently used against scabies are presented in Table 11. Buck et al. (1976) tabulated these data from extensive reviews by Radeleff (1970) on the toxicological effects of pesticides on animals.

All chemical compounds classed as acaricides and used against scabies are poisonous to both animals and man. Poisoning in animals is usually the result of accidents, careless use, or improper concentration and mixing. There is little danger to animals or man if these acaricides are handled carefully and correctly (Buck et al. 1976).

Perhaps the safest compounds--certainly the oldest--are the fungicide-insecticides, sulfur and lime-sulfur. An oral dose of about 250 mg/kg body weight of lime-sulfur is required to poison cattle. This minimum toxic dose provides a wide margin of safety for lime-sulfur used at the concentration of 2 percent sulfide sulfur. Clinical signs of toxicity in cattle include erythema, pruritis, colic, purgation, and dark-colored mucous membranes.

Toxaphene, in use for 29 years (1950 to the present), is one of the oldest and most commonly used chlorinated hydrocarbon insecticide against pests and parasites of crops and livestock. The minimum toxic oral dose for cattle is 35 mg/kg. The minimum toxic concentration following a single dermal application is about 0.75 percent for calves and about 4 percent for mature cattle (Radeleff et al. 1955). Clinical signs of neurotoxicity following treatment include excessive salivation and vomiting, hyperexcitability (tremors, shivering), and muscular spasms of the legs and back leading to titanic contraction of all muscles.

TABLE 11 Toxicity of Acaricides to Livestock[1]

Chemical	Species (age)	Oral: Maximum Nontoxic Dose Tested (mg/kg body wt.)[2]	Oral: Minimum Toxic Dose Found (mg/kg body wt.)[3]	Dermal: Maximum Nontoxic Dose Tested	Dermal: Minimum Toxic Dose Found
Coumaphos	Calves (3 mos.)	20		0.25%	0.5%
(Co-Ral®)	Cattle (adult)	20	25	0.50%	1.0%
(Asuntol®)	Sheep (adult)		8	0.25%	0.5%
(Muscatox®)	Goats (adult)			0.25%	0.5%
	Horses (adult)		25 (severe)	0.50%	
	Swine (adult)			0.50%	
Phosmet	Calves (1-2 weeks)		25		
Imidan®	Cattle (adult)	10	25	0.50%	1.0%
Prolate®	Sheep (adult)		50		
(GX-118®)	Goats (adult)				0.5%
Sulfur	Cattle (adult)		250		
Toxaphene	Calves (2 wks.)	1	5		
	Cattle (adult)		35		
	Sheep (adult)		25		

[1]Data adapted primarily from Radeleff (1970)
[2]Maximum single dose that did not produce a toxic effect.
[3]Minimum single dose that caused minimal toxic effects.

Coumaphos and phosmet are classed as organophosphorus insecticides. These insecticides share the common characteristic of inhibiting acetylcholinesterase, an enzyme present at cholinergic nerve endings and in red blood cells. Coumaphos and phosmet have similar minimum toxic dosages for cattle--25 mg/kg for oral dosages and 1 percent for dermal dosages. The minimum dermal toxic dose for 3-month-old calves is 0.5 percent for coumaphos. Similar data are lacking for phosmet. Animals poisoned by either one of these organophosphorus compounds may show similar clinical signs of toxicity: excessive salivation, dyspnea, depression, diarrhea, and ataxia.

Symptoms of acute poisoning in cattle exposed to treatment with any of these four acaricides usually appear within 6 to 12 hours after treatment, but cases are on record in which clinical signs have appeared within a few minutes or not until 30 hours after treatment. Of additional concern may be the appearance of side effects in cattle following treatments with coumaphos or phosmet. These compounds are systemically active and kill the migratory larval stages of cattle grubs (Hypoderma species), which may occur in dense numbers in the esophagus or in the spinal canal during fall, winter, and early spring--the times when cattle are likely to be treated for psoroptic scabies. The death of these grubs causes symptoms similar to those of acaricide poisoning. It is necessary, therefore, to diagnose whether symptoms result from acaricide poisoning or from the death of cattle grubs.

Application Equipment

Instructions for using permitted acaricides in application equipment, chiefly vat dips and spray-dip machines, and for disposing of unused pesticides are fully covered in Veterinary Services Memoranda 556.1 and 556.5 (APHIS 1972 to 1976). Abstracts of these instructions are given in Appendix G.

An average of 600 or more animals per day can be treated in a vat dip 33 feet long if it is well managed and has sufficient personnel to ensure a steady flow of cattle through the chute and vat into the drain pens and holding corrals.

The Hydrasieve machine (Sweeten, personal communication) offers some promise for more economical and effective use of acaricides in dipping vats. It should be investigated further.

Portable dipping vats, not described by APHIS (1972 to 1976), are also available. They usually consist of an all-metal tank of from 2,500 to 3,000 gallon capacity mounted on a 30- to 35-foot long trailer. The vats have metal entry and exit ramps that adjust to the ground level when the trailer is backed into position before a working chute. A small drain area is provided at the exit end of the vat, but it is too small to provide sufficient drain-time. When an average of 800 head per day are pushed through a vat of this type, the cattle in the drain area have to leave to make room for newcomers, even though the dip has not entirely drained off them. Excess splashout of dip often occurs from overfilling the vat (recommended work line is between 1,800 to 2,600 gallon levels) and delays caused by small calves (up to 500 lbs) turning around at the exit end of the vat are also problems faced in operating this equipment.

Several manufacturers have designed stationary, hydraulic-cage dip vats that allow single-animal dipping. The entire machine is hydraulically operated, including the entry and exit gates. The unit consists of a movable metal cage about 7 x 3 x 5 feet high which is lowered into a slightly oversized metal or cement vat about 7 feet deep. The vat capacity ranges from 900 to 1,200 gallons, depending on manufacturer's specifications. The entire unit (cage and vat) is commonly fixed in a position at the end of a working chute (with squeeze) on feedlot operations. Cement-lined drain pens similar to those used for vat-dips are provided in order to recover the dip carried out by the cattle. Hickman (1902) illustrated this device in a simple, manually operated form.

Portable trailer models are also available and usually consist of a tank 10 x 3 x 6 1/2 feet deep and holding 1,200 gallons (18.18 gal/inch of depth). A reserve tank of 500 gallons for recharge is often included. The trailer vat-dip is similar to the portable vat dip except that a slightly longer animal drip-space is available. Modifications made to a unit of this type in California included substitution of a Wisconsin air-cooled engine for the 4-cylinder Ford motor to ensure better performance and the realignment and placement of hydraulic hoses to provide more safety for the operators.

Individual animals are commonly dipped once for a period of 3 seconds and then immediately released. Some operations retain the animal in the cage for a few additional seconds to ensure collection of cleaner "drippings" than those that return from the drain pens. Descriptions and instructions on the use of this equipment are not included in Veterinary Services Memoranda (APHIS 1972 to 1976).

In contrast to dipping vats are the spray-dip machines designed for operation by the cattleman managing a small herd. Portable machines of this type are readily transferred from ranch to ranch and can be adjusted to fit existing cattle working chutes. An average of 250 animals per day can be treated by an experienced crew operating a high-performance spray-dip machine. The number of treated cattle above and below this average usually reflects inadequate treatment or deficiencies in the operation and repair of the machine.

The Brookata Spray Gate or similarly designed equipment is sometimes used for treatment of cattle scabies, but this is not a permitted use for eradication purposes. Originally designed for quick application of material for fly and louse control, this equipment consists of a circular metal tube fitted with numerous spray nozzles along the inside circumference and placed in a vertical position at the end of the chute. A gas or electric engine powers a high-pressure pump that forces the dip solution out of the spray nozzles. Animals, driven down the chute, jump through the spray gate (sometimes called a hoop, ring, or collar), thereby receiving not more than a 1-second exposure. The experiences of responsible field personnel operating this equipment have shown such devices to be ineffective for louse control and rarely effective for fly control. Thus, they are unlikely to be of any value against scabies.

The Mapes Mist Fogger being tested by Clymer (Pest Consultants, Inc., Amarillo, Texas, personal communication, 1979) may offer a more suitable type of spray equipment for small or large operations and could be modified for portable use. Basically, this unit consists of a four-sided metal spray-race 10 x 3 1/2 x 6 feet and equipped with side, top, and bottom nozzles and solid entry and exit gates. Power, pump, and tank accessories are similar to those used on spray-dip machines. In 1978 this unit was pretested by using a dye solution to determine animal coverage. Modifications to, and changes in, some of the equipment are planned in order to further test this unit in 1979.

Perhaps because there are such varied means of treating cattle for psoroptic scabies, or perhaps because of ineffective education about the different methods, there is confusion among cattlemen and veterinarians about which method is best and how to use each method properly. A typical question about vat-dipping is: "Why is it necessary to submerge the head of each animal?" Cattlemen normally see active scabies only on the back, loin, and elsewhere but on the head. They do not know that mites may live on the heads of animals, so they do not understand that complete immersion of the animal is mandatory to ensure total coverage and ultimate control of mites.

Recommendations by APHIS (1972 to 1976) refer to 1-minute treatment for each animal, especially by the spray-dip machine, so, cattlemen ask, how can we achieve total control by vat-dipping in which animals spend less than 10 to 15 seconds, at best, in the dip? This is a grey-line issue and specific answers are difficult to give, considering the differences in the time required by cattle to swim through vats of different lengths. Some of the longest vats, measuring from 50 to 60 feet, are located at inspection stations at the border between the United States and Mexico. Mature, healthy animals can swim the 60 feet in less than 30 seconds and are not exposed for the 1-minute time as recommended. Relatively few vats of this size are constructed on feedlots so the vast majority of cattle treated in this manner receive insufficient treatment. Other than the data reported by Meleney and Roberts (1979a) about the "quick cage-vat dips" with coumaphos, there are no comparative time-tests that show differences in the efficacy of different lengths of time spent in vats.

One of the most frequent problems associated with vat dips, spray-dip machines, and cage-vat dips is the disposal of their contents following a season of use. Each state determines where and how to dispose of this liquid waste. Many states work in cooperation with their local Water Quality Control Boards to approve designated dyked-ground areas (evaporative ponds) or Class I dump sites for receiving this liquid waste. More commonly, however, vat contents are discharged to the ground-surface area (cattle pen, adjacent field) where there is least chance for it to contaminate the underground water supply or to run off into multiuse water channels.

Regarding spray-dip machines, the most frequently asked question is "what is the real efficacy of the spray-dip machine?" Other often-asked questions are: "Is the one-minute stand in the spray-box absolutely necessary and can the time be reduced?" (After all, vat-dip animals get shorter exposure.) "Are new or different spray nozzles available to help avoid clogging?" "What is the correct pressure for machine operation?" "Has anyone worked on a modified machine to include a front-end drain box in which the animal can stand while another is being sprayed?" (To help reduce material loss). Such common questions about the basic aspects of treating cattle for scabies mites indicate that one reason for the current failure of programs to eradicate psoroptic cattle scabies is that cattlemen do not know which method is best or how to use the methods properly.

In summary, many veterinarians and cattlemen do not favor the use of the spray-dip machine but agree that, for the small operator, this equipment is most economical and would be most practical if it could be made effective. Current designs are ineffective. Tobin (personal communication, 1978) mentioned that of 82 cases of cattle scabies treated in Colorado during 1977 and 1978, most were treated in spray-boxes and 9 of those herds broke out with scabies again despite being officially treated twice. Also in Colorado, Coffman (personal communication, 1978) believes that the use of spray-dips is "but a very feeble effort to give absolute and total coverage of the animals which is so necessary." He recommends that spray-dip machines "not be recognized for use on cattle destined for interstate shipment and that intrastate use of them should be sharply discounted." Jones (personal communication, 1979) stated that spray-dip machines are not accepted or approved for use in the State of Texas.

STATUS OF RESEARCH ON OTHER ACARICIDES AND FORMULATIONS

Numerous investigators have studied potential acaricides derived chiefly from the development of organophosphorus and other compounds which have shown a wide spectrum of activity against arthropod pests of livestock and poultry. Some studies have included comparison of the effectiveness of the new acaricides with that of those materials already in use against psoroptic scabies. Unfortunately, however, most studies have been conducted on sheep or on the effectiveness of compounds against *Sarcoptes* and *Chorioptes* mites. The extrapolation of these data may not be valid for reference to psoroptic cattle scabies. Full chemical names of experimental compounds may be found in Appendix H.

Early work in 1960 on crotoxyphos showed that 2 treatments of 0.03 percent at dosages of 2 to 3 gallons per animal were effective for the control of *Chorioptes bovis* on dairy cows (Matthysse and Marshall 1963). In later trials, Matthysse et al. (1967) obtained 100 percent control of *C. bovis* by two mist-spray treatments of crotoxyphos at 8 ounces per cow and by one treatment of 2 percent trichlorfon. Matthysse et al. (1975), by a laboratory test, found crotoxyphos to be much more toxic than 22 other acaricides to the chorioptic scabies mite of cattle. LC_{50} for crotoxyphos was 7×10^{-5}, toxaphene 1×10^{-3}, lindane 7×10^{-3}, and coumaphos 1×10^{-2}. Wright and Riner (1979) reported preliminary laboratory toxicity results with *P. ovis* from sheep and *P. cuniculi* from rabbits. Crotoxyphos and toxaphene were much more effective than 9 other acaricides tested, including coumaphos and phosmet.

Dr. Stendel of Bayer Fabriken (Germany) has been conducting *in vitro* laboratory toxicity tests on *P. ovis*, *P. cuniculi*, and *C. bovis*. Dr. Howell of the Veterinary Institute of South Africa has been using *P. cuniculi*. Mr. Matthewson of Wellcome Research Laboratories has been using *P. ovis*. No results have been reported from any of these *in vitro* experiments (Barnett et al. 1975, Stendel 1975).

Tests against *Psoroptes cuniculi*, the ear mange mite of rabbits, showed that a 0.1-percent emulsion of crotoxyphos or a 0.25-percent solution of stirofos was 100 percent effective. A 1-percent stirofos wettable-powder suspension spray was needed to obtain complete effectiveness (Pandy 1972). In France, the study by Durez and Hargot (1977) showed that 0.125 percent crotoxyphos high-pressure sprays applied twice would control psoroptic cattle scabies. These results were comparable to their single sprays of 0.06 percent lindane.

Meleney and Roberts (1967) reported failure to control P. ovis on sheep with a dip containing 0.1-percent crotoxyphos emulsion. However, in a subsequent experiment Roberts and Meleney (1971) showed that the compounds giving the longest protection against infestation with P. ovis on unshorn sheep were (in descending order): 0.1 percent crotoxyphos, 0.5 percent toxaphene, 0.06 percent diazinon, and 0.06 percent lindane. The results for shorn sheep were: 0.06 percent lindane, 0.3 percent crotoxyphos, 0.06 percent diazinon, and 0.5 percent toxaphene. Crotoxyphos has been recommended by Lyon and Treece (1970) in Ohio and by Collison (1978) in Pennsylvania as a 0.25 percent spray against Chorioptes bovis on dairy and beef cattle.

It is surprising that no further studies have been made on stirofos or, in the United States, on higher concentrations of crotoxyphos. These organophosphorus compounds have broad spectra of activity on ectoparasites and offer minimum residue and animal toxicity hazard. Currently, several formulations are registered for use on nearly all classes of livestock.

Single-dip tests against P. ovis on sheep were conducted by Meleney and Roberts (1967) who used one or more concentrations of organophosphorus compounds for comparison with toxaphene and a cold dip of lime-sulfur. Successful control of psoroptic scabies was obtained with 0.375 percent coumaphos, 0.06 percent diazinon, and 0.5 percent toxaphene. Failures resulted with 0.1 percent crotoxyphos; 0.1 percent, 0.25 percent and 0.4 percent coumaphos; 0.2 percent fenthion; 0.25 percent and 0.5 percent fenchlorfos, and 1.75 percent lime-sulfur. Two explanations for the inconsistencies of coumaphos seem plausible: (1) The compound used in the 1964 and 1965 tests was more toxic to mites than that used in 1963 and 1964 because the toxic properties of some insecticides may increase after storage of a year or more (Meleney and Peterson 1964) (2) The hybrid mites used in 1963 and 1964 may have had more vigor and hardiness than the highly inbred strain used in 1964 and 1965. The latter explanation may be valid since Strickland and Gerrish (1966) reported successful control of P. ovis on sheep dipped once in 0.21 percent and 0.25 percent suspensions of coumaphos. The unexplained failure of 1.75 percent cold lime-sulfur in the above tests stands out, particularly in the light of the success that Keast (1945) had in controlling *Psorergates ovis* and Diamant (1965) had in controlling *P. ovis*, the former using cold lime-sulfur in a 1-percent single dip and the latter using a 2-percent double dip.

Meleney and Roberts (1979a) conducted additional tests in which spray-dip machines and cage-vats containing numerous acaricides, including crufomate, malathion, and SD-14114, were used against *P. ovis* infested cattle from 1973 to 1975. These compounds were ineffective at all concentrations (0.025 percent to 0.6 percent) tested. A fourth compound, cyhexatin, was ineffective when used in the spray-dip method, but proved successful following a single dipping of cattle in a vat containing 0.2-percent concentration. These investigators also reported on susceptibility tests made on three currently registered acaricides: they reported complete success with cattle treated once with 0.5 percent toxaphene in vat or spray-dip treatments; ineffectiveness with cattle treated with three single and four double vat-dip treatments in a 0.25 percent coumaphos; successful mite control from one double dip test in which a polysaccharide wetting agent (Floxine®) was added to the dip; and, as expected, 2 dips were necessary to control mites with 0.25 percent phosmet.

The new liquid formulation of 16 percent coumaphos used in Europe was reported by Liebisch et al. (1978) to be effective against chorioptic and psoroptic mites on cattle, but only after hand respraying of 1-percent emulsions after a 7-day interval. These workers, however, found it necessary to remove the scabs from severe cases before spraying because the emulsion was unable to penetrate the thick crusts.

Strickland et al. (1970) found chlorpyrifos to be effective against *P. ovis* in dip-vat tests on sheep. Their results indicated that a single 0.2-percent dip made from emulsifiable concentrate was preferred over the wettable-powder formulation because of less stripping and loss in concentration. Although intoxication from the solvent occurred in sheep initially exposed to the newly prepared emulsion dip, their dermal toxicity tests indicated a wide margin of safety, up to 3 percent in emulsions sprayed onto sheep and swine and 1.4 percent in emulsions sprayed onto cattle. Loomis et al. (1976) reported no signs of acute toxicity to sheep given less than 100 mg/kg of chlorpyrifos in pour-on formulations for louse control on calves in New Zealand. Chlorpyrifos has been registered in the United States for many years as a mosquito larvicide and as a ground treatment (4 lbs active ingredient/acre) against turkey chiggers. MacLean (1978 personal communication) has reported that seven states have approved the use of chlorpyrifos as a high-concentrate, low-volume, pour-on formulation for control of biting and sucking lice on beef cattle.

Reviews of investigations in Russia on the use of organophosphorus compounds yielded little new information except for the study by Il'yashchenko (1971) in which he found dips of 1 percent dicresyl N-methylcarbamate (3 methylphenyl methylcarbamate) or 3 percent colloidal sulfur to be more effective than 1.5 percent fenchlorfos against P. ovis on cattle. Similarly, an organophosphorus designated as "IPO-62" (a 2-bromate diethyl phosphate compound) and chlorfenvinphos were used in 0.05-percent dips to treat sheep twice within 7 to 10 days, achieving control of Sarcoptes scabiei (Patyk 1974). In a later study, Patyk (1975) reported the effectiveness of 0.05 percent fenchlorfos against S. scabiei, P. ovis, and Chorioptes bovis. This report is of doubtful accuracy considering the extremely low concentration when compared with data from other investigators (Il'yashchenko 1971, Meleney and Roberts 1967) who had poor mite control with fenchlorfos at concentrations of 0.5 to 1.75 percent.

In Germany, several new compounds have been studied for the control of cattle scabies. Gothe (1976) reported on the successful single spraying of "Ektomin" (chloromebuform) for the control of Chorioptes bovis on cattle, but only after each animal had received 10 liters (2 1/2 gallons) of a 0.1 percent emulsion. Stendel (1975) showed that phoxim was effective against P. ovis at one-third the concentration (300 ppm) of that of coumaphos--but only after two dippings of infested sheep and cattle--and that oxythioquinox, quintiofos, and trichorfon were ineffective.

Amitraz, a triazapentadiene compound, was reported by Griffiths (1975) to be effective against Sarcoptes scabiei of swine following a single dipping at 0.1 percent or two dips at 0.05 percent. No other published information could be found for this compound, but Braithwaite (1979 personal communication) reported that 0.05 percent Amitraz is now registered for use against psoroptic sheep and chorioptic cattle scabies in Argentina. He also reported that in Argentina provisional registration is under way on the synthetic pyrethroid, permethrin, at 0.05 percent in a single dip for effective control of P. ovis on sheep. Meleney and Roberts (1979b) have experimental data which show that permethrin at 0.05 percent in a single dip and 0.03 percent in a double dip afforded 100-percent control of psoroptic cattle scabies.

Meerman (1978) tested in vitro 0.07 to 0.1 percent BHC, 0.05 percent coumaphos, 0.025 percent diazinon, 0.05 percent phoxim and 0.025 percent cyhexatin against P. ovis from sheep. Cyhexatin, phoxim, and diazinon were best on moist blotting paper; BHC and cyhexatin were best on subsequently dried paper. BHC and phoxim exhibited best vapor toxicity. Formulations of 0.05 percent and 0.1 percent coumaphos were effective in small-scale *in vivo* tests on sheep. In large-scale tests (over 7,600 sheep), 0.1 percent coumaphos failed to give complete control despite two applications. A formulation of 0.1 percent phoxim did eradicate *P. ovis* by two applications on 384 sheep.

Preliminary experiments with pirimaphos ethyl and "Avermectin" MK932 (Merck, Sharp and Dohme) indicated some effectiveness against *P. ovis* on cattle but results were inconclusive (W.P. Meleney, personal communication, 1979). Meleney also noted toxicity of several candidate secondary and tertiary amines to *P. cuniculi in vivo* and that approximately 100 chemicals have been evaluated in their laboratory by *in vitro* screening with *Psoroptes cuniculi* or *P. ovis*.

Oral administration of the animal systemic insecticides incorporated into salt, feed, or mineral supplements have shown effectiveness against cattle grubs (*Hypoderma* species), born flies (*Haematobia irritans*), and sucking and biting lice. Few investigations, however, have been made in which this route of application was used against *P. ovis*. Beesley (1963) could not control *P. ovis* on sheep given single drenches of fenchlorfos and trichlorfon at 100 mg/kg and 50 mg/kg, respectively. Sheep given trichlorfon at 50 mg/kg showed toxic symptoms, and death occurred at 300 mg/kg. Ronnel given orally to sheep as an anthelmintic by Southcott (1961) resulted in acute toxicity at 100 mg/kg and in death at 220 mg/kg. Roberts and Meleney (1969) found that the organophosphorus animal systemic, famphur, was ineffective against *P. ovis* infestations when fed at the rate of 5 mg/kg to cattle and sheep. Nevertheless, there is promise for development of newer systemic compounds and simple application methods such as intramuscular injection.

The newer formulation techniques, such as use of polymeric extenders, should be studied for prolonging residual activity and vapor toxicity (Cardarelli 1976, Scher 1977).

Miscellaneous Compounds

Various concentrates known as creolins and made from tar oils (wood-tar, coal, peat) were "activated" with BHC by Tsitsin and Cherkaskii (1955) to kill all stages, including the eggs, of *P. ovis* on sheep treated once in a 0.25-percent dip. They considered this to be "the basic remedy for the elimination of mange in sheep." Many other Russian authors, including Zolotarev (1956), reported on experiments and large-scale programs with BHC in creolin. Chotchaev (1974) also mixed lindane in mineral oil as a 0.03-percent dip in which he treated goats twice to provide 100 percent "protection" for 7 months against Sarcoptes and Chorioptes mites. The use of BHC and lindane in Russia, however, has been discontinued because of the residue problems in the milk or meat of animals treated with the above mixtures. Better efficacy and safety in the treatment of psoroptic cattle scabies was reported by Chablin (1974), who used 2 percent colloidal sulfur sprayed twice at 9 to 10 day intervals--no mites or viable eggs were found three days after treatment. Other Russian investigators have reported the large-scale use of colloidal sulfur in control programs against P. ovis, but translations of their work (including English summaries) were not available (Chablin 1974, Nazakov 1963, Nikol'skii et al. 1967, Vodyanov and Chablin 1971).

Several drug preparations and washes have been reported to be effective against scab and mange mites, but their use is chiefly by repeated hand application to infested animals. For example, "tetmosol" (tetraethylthiuram monosulfide) was used by Gordon et al. (1945) in a daily 5-percent soap wash to kill all burrowing mites and eggs of the Notoedres species on rats. "Furaspor," one of several nitrofurans used as antimicrobial agents, was reported by Martin (1959) to be a successful ointment for the treatment of sarcoptic mange in dogs, horses, and cattle. Plant derivatives in the form of emulsions and ointments have been investigated and used against various forms of scabies and mange of domestic animals in India. Both sarcoptic and psoroptic mange in sheep were reported to be fully controlled after daily treatment for six days with 50 percent Juniperus communis extract in linseed oil (Sharma 1968; Srivastava and Sisodia 1969). Srivastava and Chhabra (1971) recommended using double dressing of Taramira oil (Eruca sativa, "rape-seed mustard") mixed with tar oil (oleum picis carbonis) and sulfur for five days to control sarcoptic mange in buffalo. These workers identified the active ingredient of Taramira oil as allyl-isothiocyanate and reported that the combined mixture proved more effective than dressings of tar oil plus sulfur.

Other drugs, indigenous compounds, and home-production mixtures could be cited, but all such materials require repeated application, which has little practicality or economic feasibility for psoroptic cattle scabies eradication in the United States.

RESISTANCE IN PSOROPTES TO CHEMICALS

Considering the millions of cattle and sheep treated worldwide over the past years with chlorinated hydrocarbon and organophosphorus compounds, few documented reports are available on the development of chemical resistance by Chorioptes, Psoroptes, and Sarcoptes mites. An early report by Ault et al. (1962) led investigators to believe that incipient tolerance or possibly true resistance was present in *P. ovis* populations on sheep in Argentina. Comparative tests were made on sheep infested with a still-susceptible (S) strain of *P. ovis* that could be controlled by the normal concentration of 87 ppm gamma BHC dips and on sheep suspected of having the resistant strain (R) of *P. ovis*. The R strain showed only 16-percent control at 87 ppm, whereas 50- and 100-percent control levels were obtained with the R strain on sheep treated at 174 and 348 ppm, respectively. One-hundred-percent control was obtained against the S strain at all three levels of BHC concentration.

Rosa and Lukovich (1970) reexamined these *P. ovis* populations in the same region (Three Rivers Zone) because of reports that organophosphorus resistance had occurred following the long-term use of diazinon. The results of their tests confirmed the earlier discovery of *P. ovis* having resistance to BHC as well as to diazinon.

The chances of *P. ovis* in North America becoming resistant to chemicals become more real as reports of failures to obtain 100-percent control continue to be received. It is imperative, therefore, that present acaricides and methods of application be perfected to the point that ensures absolute control of this parasitic mite on cattle.

RECOMMENDATIONS

In the past 20 years, the sheep and cattle industries have engaged in a cooperative federal and state program to eradicate *Psoroptes ovis*. The sheepmen have been successful in reaching that goal and the cattlemen came close, only to fall far short. The failure to eradicate psoroptic cattle scabies was due neither to technical failures nor to the loss of enthusiastic and conscientious efforts by regulatory and industry personnel, but to the methods used to control the disease not keeping pace with the changing conditions within the cattle industry.

As the sheep industry became more concentrated and the number of sheep decreased, the cow-calf segment of the cattle industry became more diverse and the cattle-feeding business came to involve larger concentrations of animals by fewer operators located in critical marketing and shipment centers. Along with these changes was the development of highly effective formulations of newer pesticides to control a wide spectrum of external parasites of livestock. Dipping vats gradually disappeared on many ranches and even in most feedlots. Spray-dip machines, originally designed to accommodate small ranch operations, became obsolete in view of the arsenal of new pesticides and their variable formulations which provided a choice of alternative methods of application to producers and to feedlot operators. It must be admitted, however, that the efforts to modify old methods and develop new ones to combat psoroptic cattle scabies did not keep pace. The current epidemic of psoroptic cattle scabies warrants immediately considering ways to make eradication efforts more successful than at the present time and then taking action.

- Since spray-dip machines have failed numerous times to protect cattle adequately against mites, a large-scale trial should be conducted with mite-infested cattle to demonstrate conclusively the efficacy of single versus double treatment with the three commonly used acaricides--coumaphos, phosmet, and toxaphene. Treated cattle should be examined for egg kill (ovicidal properties), and hair samples should be analyzed for chemical residues to provide data which to date are lacking.

- Evaluation of portable kits for analyzing the concentrations of coumaphos, phosmet, and toxaphene should be completed as quickly as possible to make available accurate equipment for field use. The current practice of mailing dip samples to diagnostic laboratories is almost totally valueless.

- The single treatment of exposed animals with the organophosphorus acaricides as recommended in some state directives and as practiced by many commercial operations should be discontinued.

- Federal and state recommendations and instructions should include descriptions for the use of these three acaricides and other effective pesticides to treat premises, structures, and cattle trucks which have been exposed to mite-infested cattle.

- Test data should be obtained on the efficacy of coumaphos treatments for lactating dairy animals. This is the only approved acaricide that approaches the effectiveness of the chemical, lime-sulfur, that is safe for use on these animals. Despite the fact that current label use restricts coumaphos treatment on dairy cows, there is an established tolerance of 0.5 ppm in milk and a 14-day withholding period for coumaphos-treated cows. When a dairyman's herd becomes infested with scabies, the dairyman is faced with using either hot dips of lime-sulfur or crotoxyphos sprays, the effectiveness of which is questionable. Colloidal sulfur should be tested as a possible dairy-cow treatment. All mite-infested cattle should be treated in dipping vats if at all possible until the design and operation of currently used spray-dip machines are improved and standardized.

- Similarly, standard specifications should be developed for the design and operation of permanent and portable hydraulic-cage vats and portable vat dips and submitted to manufacturers. The purpose is to reduce the confusion about how to use the many different machines.

- Re-evaluation of old and screening of new candidate acaricides and routes of administration should be a top priority. Several compounds examined in the literature review (for example permethrin, stirofos, crotoxyphos, phoxim, cyhexatin, chlorpyrifos, Amitraz) have shown particular efficacy after single treatments against P. ovis.

- Detailed data on the use of these compounds in foreign countries should be obtained, with emphasis on rapid USDA testing and approval. This is particularly important if Rebuttable Presumption Against Registration (RPAR) action eliminates the use of toxaphene for treatment of cattle scabies. Combinations of acaricides may prove useful, for example making use of specific activities of ingredients to incorporate ovicidal, vapor, and/or residual toxicity with rapid toxic action to the mite.

- BHC and lindane should be reconsidered for approval as permitted dip and spray-dip treatments in the Scabies Eradication Program. Testing of the most promising commercial formulations produced by the United States and foreign manufacturers should be done to validate label recommendations for maintaining gamma BHC concentration during treatments. Lindane, in particular, warrants this attention because (1) it is equal to or more efficient than toxaphene, (2) it is still used in some states for scabies and mange control on non-lactating cattle and on sheep and goats, and (3) formulation problems have been remedied by foreign investigators so that lindane and BHC sprays and dips are in large volume use in many parts of the world. The main efficacy problem with lindane has been "stripping," or selective removal of its components from dip vats by the haircoat of cattle. This formulation problem is of much less significance in spray-dips.

- Specific attention should be given to screening tests of potential acaricides for ovicidal activity--the eighteen research projects outlined by the U.S. Livestock Insects Laboratory, USDA, Kerrville, Texas, do not refer to this, although there are plans for mite-colony investigations of P. ovis and P. cuniculi.

- Rapid expansion of laboratory screening is urged so that a large number of new chemicals can be tested quickly and efficiently, followed by in vivo testing on cattle those shown promising by the preliminary screen. Testing all new compounds on cattle is too slow, laborious, expensive and imprecise.

- Because resistance remains an all too likely consequence of large scale pesticide use, data should be developed on in vitro laboratory LD_{50} or LC_{50} values for the current susceptible strain of *P. ovis*. The in vitro method used should be capable of producing statistically significant dosage-mortality regression lines.

- Despite the wealth of information available in the form of federal and state bulletins, memoranda, pamphlets, and reports, there is no concise, easily read, fully illustrated material for cattlemen. The few published Extension pamphlets on this subject are open to the same criticism. Federal agencies and educational institutions should be charged with the responsibility of producing illustrated texts as well as visual slide sets for educational use at meetings of cattlemen and others in the livestock industry.

CHAPTER 6

REVIEW OF CURRENT RESEARCH PROJECTS

In the United States, three agencies conduct formal research on psoroptic cattle scabies. Each supports an active project. Even though they are based in Texas or New Mexico, their results have regional and national significance. Their combined interests and activities cover the entire subject, and the specific projects are beneficially associated with other research activities in the broader field of arthropod parasitisms. In addition, pesticide manufacturing companies in Europe are screening new compounds against scabies mites, developing formulations and conducting field tests. The projects are summarized below.

FEDERAL

Agency: Scabies and Mange Research Unit, U.S. Livestock Insects Laboratory, Agricultural Research, Science and Education Administration, U.S. Department of Agriculture, Kerrville, Texas 78028.

Number: 7305 20480 007

Principal Investigator: Dr. W.P. Meleney SY's: 4

Budget: $383,254 for Fiscal Year 1979.

Title: Biology and Control of Parasitic Mites of Animals

Objectives:

a. Maintain suitable infested cattle and sheep in isolation at Kerrville to satisfy needs of the Scabies and Mange Research Unit.

b. Discover new and improve known methods and materials for controlling scabies of cattle.

c. Establish discrete colonies of mites on restrained calves for evaluation of candidate acaricides against scabies mites *in situ* and for isolation of possibly resistant strains of mites.

d. Discover changes which may occur in hematological values of cattle before, during, and after infestations with scabies mites.

e. Purify *Psoroptes ovis* and *P. cuniculi* antigens to remove nonspecific antigens that contribute to the nonspecificity of serological tests.

f. Determine when antibodies appear in the sera of cattle after infestation or reinfestation and how soon they disappear after treatment with a suitable acaricide.

g. Detect *P. ovis* antibodies in cattle using tests other than agar-gel.

h. Determine effects of mites on blood parameters of hosts.

i. Control *P. cuniculi* on rabbits with nonsteroidal secondary and tertiary amines and other compounds.

j. Determine if poorly nourished calves are more susceptible to scabies than well-nourished calves are.

k. Determine if calves prevented from self-grooming will develop scabies more rapidly and/or more severely than unrestrained calves.

l. Develop a screening method to determine the effectiveness of candidate acaricides against *P. ovis*.

m. Develop an artificial diet for *in vitro* rearing of *P. ovis*.

n. Relate the amino acid composition of *P. ovis* to that of the serum of the host animal.

o. Rear *P. ovis* on laboratory animals.

p. Determine the enzyme and isozyme patterns of *P. ovis* and *P. cuniculi*.

q. Determine how parasitic mites feed and what they feed upon.

r. Determine allergic reactions in animals infested with *P. ovis*.

Laboratory personnel consist of veterinarians, entomologists, serologists, chemists, and technicians who specialize in acarology. These scientists pursue nearly all project objectives, but not at uniform rates. Objectives with high priorities receive more investment than do objectives with lower priorities, and objectives promising high yields of information receive more attention than do those having lower expectations. Facilities include land, normal and infested cattle and sheep, acaricide treatment equipment, colonies of small animals, and modern research laboratories. Resident scientists collaborate with investigators of other agencies on common problems.

STATE

Agency: New Mexico State University, Las Cruces, New Mexico.

Number:

Principal Investigator: Dr. Grant Kinzer SY's: 1

Budget: $22,500--Funding Fiscal Year 1979

Title: Livestock Pesticide Impact Assessment for the ARPAR Process--The Economic Impact of Toxaphene for Control of Scabies Losses on Cattle

Program: Western Pesticide Impact Assessment--USDA

No results yet.

COMMERCIAL

Agency: Pest Consultants, Inc., Box 7513, Amarillo, Texas 79109.

Principal Investigator: Dr. B.C. Clymer SY's: 1

Title: Practical Control of Cattle Psoroptic Scabies

Objectives:

1. Evaluate efficacies of available and candidate acaricides for treating infested cattle.

2. Evaluate efficacies of available and candidate equipment for applying acaricides to infested cattle.

3. Develop and improve equipment for applying acaricides to infested cattle.

4. Improve methods for detecting mites, P. ovis, on cattle.

5. Determine survival periods for mites on and off host cattle.

6. Determine the pathogenesis of dry and moist lesions on infested cattle.

7. Measure the economic importance of psoroptic cattle scabies.

The Corporation pursues all seven objectives but emphasizes numbers one, two, and three. Its facilities include land, pens, machinery, infested and normal cattle, and acarology laboratories. It contracts with producers and merchandisers of extant and new acaricides and formulations to test efficacies of the products and the associated management practices. It also contracts with manufacturers of spraying, dipping, and other applicators to check efficacies and to improve efficiencies of the equipment. Even though much of the data produced are privileged information, final development will provide economic benefits to the cattle industry. The investigators frequently collaborate with scientists of other agencies in conducting research on related problems.

Agency: Pesticide Companies

Wellcome Research Laboratories in England and Bayer Fabriken in Germany are screening new compounds for activity against scabies mites, including _P. ovis_ and _P. cuniculi_. Some formulation and _in vivo_ testing also are under way by these and other companies. I.C.I. (England and Americas) is field testing new pyrethroids against scabies mites. Currently Ectiban formulation containing permethrin as a commercial product is undergoing field trials on psoroptic sheep scabies in Argentina for provisional government registration. The Government of Argentina and sheepmen are interested currently in new acaricides because organophosphorus and chlorinated hydrocarbon resistance has become a problem in psoroptic scabies control.

FOREIGN PUBLIC INSTITUTIONS

The Veterinary Research Institute in South Africa is screening for toxicity of pesticides to _Psoroptes_ mites.

We have not surveyed research currently in progress in foreign government or university laboratories. Greater interchange of information is needed between U.S. and foreign scientists, particularly since bovine psoroptic scabies incidence has increased in several countries, stimulating research.

SUMMARY

Nearly all of the nation's research on psoroptic scabies of livestock has been performed by scientists working on projects at the Scabies and Mange Research Unit of the U.S. Livestock Insects Laboratory at Kerrville, Texas, and especially at the preceding laboratory at Albuquerque, New Mexico.

The federal project has 18 objectives and 4 SY's, or an average of 4.5 objectives per SY. The private project has 7 objectives per SY, and the state project has 1 objective per SY. Even though the past performances of these laboratories have been commendable and probably will continue to be so, the number of scientists engaged in the studies seems grossly incommensurate with the magnitude of the scabies problem that had spread through 15 states by the end of Fiscal Year 1978. All states maintain agricultural experiment stations and many of them employ parasitologists, epidemiologists, biochemists, pathologists, and physiologists who doubtless have interests and capabilities for research on this important problem. Such scientists should be encouraged to enter the field. Their participation would add more SY's to the subject and probably would stimulate greater interest and thus accelerate enlargement of the needed data base. Research scientists from private industry should also be encouraged to join such a movement, especially for developing applied research projects.

From the above review of previous and current research activities on psoroptic scabies of cattle, it is evident that the USDA should set aside a certain amount of funds for research on psoroptic scabies in various state agricultural experiment stations and not only at the U.S. Livestock Insects Laboratory at Kerrville, Texas and New Mexico State University, as the situation is now.

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APPENDIXES

The following documents are appended here word for word as they were originally written without substantive editorial change by NRC staff.

APPENDIX A

PRESENT NATIONAL SCABIES ERADICATION REGULATIONS
February 6, 1976

Section	
73.1	Interstate movement prohibited
73.1a	Notice of quarantine
73.1b	Quarantine policy
73.2	Interstate shipment for immediate slaughter
73.3	Shipment for purposes other than slaughter; conditions under which permitted
73.4	Interstate shipment of cattle exposed but not visibly diseased; conditions under which permitted on one dipping
73.5	Interstate shipment of undiseased cattle from quarantined area; when permitted
73.6	Placarding cars and marking billing of shipments of dipped scabby cattle or cattle exposed to scabies
73.7	Movement from quarantined to free area and shipment therefrom; restrictions under which permitted
73.8	Cattle infected or exposed during transit
73.9	Owners assume responsibility for treatment, waiving all claims against the United States
73.10	Permitted dips; substances allowed
73.11	Treatment of cars, vehicles, and premises having contained scabby cattle

SOURCE: APHIS, USDA, Code of Federal Regulations, Part 73 - Scabies in Cattle, 1979.

ANIMAL AND PLANT HEALTH INSPECTION SERVICE
PART 73--SCABIES IN CATTLE

73.1 Interstate movement prohibited.

(a) Cattle affected with scabies. No cattle affected with scabies shall be shipped, trailed, driven, or otherwise moved interstate for any purpose "except as provided in this part."

(b) Cattle affected with or exposed to scabies. No cattle which, just prior to movement, were affected with or exposed to scabies shall be shipped, trailed, driven, or otherwise moved interstate for any purpose except as provided in this part.

(c) Cattle from area quarantined for scabies. No cattle shall be shipped, trailed, driven, or otherwise moved interstate from the area quarantined for the disease of scabies in cattle except as provided in this part.

73.1b Quarantine policy.

The Act of March 3, 1905, as amended (21 U.S.C. 123), authorizes the Secretary of Agriculture to quarantine any State, or any portion of any State, when he determines the fact that any animals in such jurisdiction are affected with any contagious, infectious, or communicable disease of livestock or that the contagion of any such disease exists, or that vectors which may disseminate any such disease exist in such jurisdiction. Pursuant to this authority, the Department has quarantined various areas because of cattle scabies and has issued the regulations in this Part governing the interstate movement of cattle from such areas.

It is the policy of the Department to quarantine those portions of any State that are clearly identifiable, and in which exist animals affected with cattle scabies, or mites which are the contagion of said disease and not to quarantine an entire State for cattle scabies if the State adopts and enforces requirements for the interstate movement of cattle that are at least as stringent as the requirements in the regulations in this Part for interstate movements of cattle. Further, it is the policy of the Department to remove the quarantine from any quarantined area when it is determined that scabies-affected animals and the mites which are the contagion of scabies no longer exist in such areas.

73.1c Definitions.

For purposes of this Part the following terms shall have the meaning set forth in this section.

(a) Veterinary Services Inspector. A veterinarian or livestock inspector employed by Veterinary Services, Animal and Plant Health Inspection Service, U.S. Department of Agriculture, in animal health activities, who is authorized to perform the function involved.

(b) State Inspector. A veterinarian or livestock inspector regularly employed in animal health activities by a State or a political subdivision thereof, authorized by such State or political subdivision to perform the function involved under a cooperative agreement with the U.S. Department of Agriculture.

73.2 Interstate shipment for immediate slaughter from quarantined or nonquarantined areas; conditions under which permitted.

(a) Conditions under which permitted after one dipping. Cattle which, just prior to shipment, were affected with scabies but have been dipped once in a permitted dip (other than a toxaphene dip), under the supervision of a Veterinary Services inspector or State inspector within 10 days prior to the date of shipment may be shipped or transported interstate for immediate slaughter to a recognized slaughtering center, upon compliance with the following conditions:

(1) They shall not be diverted en route.

(2) The means of conveyance shall be placarded and the billing shall be marked "Dipped Scabby Cattle," in accordance with Sec. 73.6.

(b) After one dipping; to be slaughtered within 14 days or redipped by owner. Cattle shipped interstate subject to the provisions of paragraph (a) of this section shall be slaughtered within 14 days from the date of the dipping or shall be again dipped by the owner.

(c) When part of diseased herd not visibly affected. Cattle of the free area not visibly diseased with scabies, but which may be part of a diseased herd, may be shipped or transported interstate for immediate slaughter to any recognized slaughtering center where separate pens are provided for yarding exposed cattle: Provided, That the following conditions are strictly observed and complied with.

(1) Provided, That means of conveyance in which the cattle are transported shall be placarded and the billing accompanying the shipment shall be marked "Cattle Exposed to Scabies," in accordance with Sec. 73.6.

(d) Undiseased herds in quarantined area: conditions under which permitted. Cattle of herds of the quarantined area which are not diseased with scabies may be shipped, transported, or otherwise moved interstate for immediate slaughter, upon inspection by a Veterinary Services or State inspector "within 10 days prior to the date of shipment" and when accompanied by a certificate from such inspector showing the cattle to be free from disease.

73.3 Shipment for purposes other than slaughter: conditions under which permitted.

Cattle affected with scabies may be shipped interstate for any purpose if dipped twice in a permitted dip, 10 to 14 days apart, under the supervision of a Veterinary Services inspector "or State inspector," and so certified by such inspector, or such cattle may be so shipped if dipped once in a permitted dip under Veterinary Services supervision "or State supervision" at the point of origin, provided arrangements have been made for the second dipping, under Veterinary Services supervision en route or at destination within 10 to 14 days after the first dipping. If shipped in the latter manner the "means of conveyance" containing the cattle shall be placarded and the billing shall be marked "Dipped Scabby Cattle," in accordance with Sec. 73.6.

73.4 Interstate shipment of exposed but not visibly diseased cattle from a quarantined or nonquarantined area: conditions under which permitted.

Cattle not visibly diseased with scabies, but which are known to be part of a diseased herd or to have come in contact with diseased cattle or infectious cars or premises, may be shipped interstate for any purpose if dipped at the point of origin, under the supervision of a Veterinary Services inspector, "or State inspector" in a permitted dip, or the cattle may be dipped en route by special permission first had and obtained from the Deputy Administrator, Veterinary Services; but in such event the "means of conveyance" shall be placarded and the billing shall be marked "Cattle Exposed to Scabies," in accordance with Sec.

73.6, and the cattle shall not be permitted to mingle with other cattle until disposed of in accordance with the regulations in this part.

73.5 Interstate shipment of undiseased cattle from quarantined areas when permitted.

Cattle of any herd in any quarantined area, which herd is not diseased with scabies, may be shipped, transported, or otherwise moved interstate for any purpose upon inspection by a Veterinary Services or State inspector "within 10 days prior to the date of shipment and" when accompanied by a certificate from such inspector showing the cattle to be free from such disease or exposure thereto. When it is determined by the Deputy Administrator, Veterinary Services that all cattle of all herds in any quarantined area have been inspected for scabies by a Veterinary Services or State inspector, that all the infected or exposed herds have been identified, and that all the infected herds have been dipped twice, and all the exposed herds have been dipped in a permitted dip as prescribed in Sec. 73.10, under supervision of a Veterinary Services or Veterinary Services-approved inspector, cattle of herds in such area which are not diseased with or exposed to scabies may be moved interstate in accordance with this section, without further Veterinary Services inspection or certification, directly to a slaughtering plant where Federal Meat Inspection is maintained. Information may be obtained from a Veterinary Services inspector whether a determination as required by this section is currently applicable to authorize such movement. Cattle moved interstate under this section shall not be diverted en route and must be accompanied by a waybill or similar document, or a statement signed by the owner or shipper of the cattle, stating: (a) That the cattle are not known to be infected with scabies or exposed thereto; (b) [Reserved]; (c) the purpose for which the cattle are to be moved; (d) the number of the cattle; (e) the point from which the cattle are to be moved interstate; (f) that the cattle shall not be diverted en route; and (g) the name and address of the owner or shipper of the cattle.

73.6 Placarding means of conveyance and marking billing of shipments of dipped scabby cattle or cattle exposed to scabies.

When cattle are shipped as "Dipped Scabby Cattle," or "Cattle Exposed to Scabies," the transportation companies shall securely affix to and maintain upon both sides of each means of conveyance carrying such cattle a durable, conspicuous placard, not less than 5 1/2 by 8 inches in size, on which shall be printed with permanent black ink in boldfaced letters, not less than 1 1/2 inches in height, the words, "Dipped Scabby Cattle," or "Cattle Exposed to Scabies," as the case may be. These placards shall also show the name of the place from which the shipment was made, the date of the shipment (which must correspond to the date of the waybills and other papers), the name of the transportation company, and the name of the place of destination. The carrier issuing the waybills, conductors' manifests, memoranda, and bills of lading pertaining to such shipments shall plainly write or stamp upon the face of each such paper the words, "Dipped Scabby Cattle," or "Cattle Exposed to Scabies," as the case may be. If for any reason the placards required by this part have not been affixed to the means of conveyance as aforesaid, or the placards have been removed, destroyed, or rendered illegible, or the cattle are rebilled or are transferred to other means of conveyance the placards shall be immediately affixed or replaced by the carrier, and the new waybills shall be marked as aforesaid by the carrier issuing them, the intention being that the billing accompanying the shipment shall be marked and the means of conveyance containing the cattle shall be placarded "Dipped Scabby Cattle," or "Cattle Exposed to Scabies," as the case may be, from the time of shipment until the cattle arrive at destination or point of dipping and the disposition of the means of conveyance is indicated by a Veterinary Services inspector or state inspector.

73.7 Movement from quarantined to free area and shipment therefrom; restrictions under which permitted.

No person, firm, or corporation shall deliver for transportation, transport, drive on foot, or otherwise move interstate from the free area of any State, Territory, or the District of Columbia any cattle which have been moved from the quarantined area of the same State, Territory, or the District of Columbia into such free area: Provided, however, That such cattle may be delivered for transportation, transported, driven on foot, or otherwise moved interstate for the purposes for which the shipment, transportation, or other movement interstate of cattle of the quarantined area is permitted by this part, Provided, That in such shipment and transportation or other movement the requirements of this part governing the shipment and transportation or other movement of cattle of the quarantined area are strictly complied with: And provided further, That this section shall not apply to cattle of the quarantined area which, before being moved into the free area, are certified by a Veterinary Services inspector or State inspector as free from disease and are accompanied by such certificate in their shipment by transportation or other movement interstate.

73.8 Cattle infected or exposed during transit.

(a) Healthy cattle from unquarantined State exposed en route. Should healthy cattle in transit from a State not quarantined by the Secretary of Agriculture for scabies in cattle be unloaded en route and placed in infectious premises, they shall be treated as exposed cattle, and their further movement shall be subject to the provisions of this part with respect to the movement of exposed cattle.

(b) Interstate shipments of cattle under Veterinary Services "or State" certificate found affected or exposed en route. Cattle shipped interstate under a certificate from a Veterinary Services inspector, "or State inspector" or other cattle which are found en route to be affected with scabies or to have been exposed thereto, shall thereafter be handled in the same manner as diseased or exposed cattle are required by this part to be handled, and the "means of conveyance" and the chutes, alleys, and pens which have been occupied by diseased animals shall be cleaned and disinfected as provided in Sec. 71.4-71.11 of this subchapter.

73.9 Owners assume responsibility; must execute agreement prior to dipping or treatment waiving all claims against United States.

When the cattle are to be dipped under Veterinary Services supervision or control the owner of the cattle, offered for shipment, or his agent duly authorized thereto, shall first execute and deliver to a Veterinary Services inspector an application for inspection and supervised dipping wherein he shall agree to waive all claims against the United States for any loss or damage to said cattle occasioned by or resulting from dipping or other treatment under this part, or resulting from any subsequent treatment prior to their interstate shipment, or resulting from the fact that they are later found to be still scabies infected, and also for all subsequent loss or damage to any other cattle in the possession or control of such owner which may come into contact with the cattle so dipped or treated.

73.10 Permitted dips; substances allowed.

(a) The dips at present permitted by the Department for the treatment, as required in this part, of cattle affected with or exposed to scabies, are as follows:

(1) Lime-sulphur dip, other than proprietary brands thereof, made in the proportion of 12 pounds of unslaked lime (or 16 pounds of commercial hydrated lime, not airslaked lime) and 24 pounds of flowers of sulphur or

sulphur flour to 100 gallons of water; or a specifically permitted proprietary brand of lime-sulphur dip.

(2) Dips made from specifically permitted proprietary brand emulsions of toxaphene and maintained throughout the dipping operation at a concentration between 0.50 and 0.60 percent toxaphene. Animals treated by such dips should not be slaughtered for food purposes until the expiration of such period as may be required under the Federal Meat Inspection Act (21 U.S.C., Supp. III, 601 et seq.). The length of this required period shall be specified on each certificate issued by the Veterinary Services inspector "or State inspector" who supervises the dipping with such dips.

(3) Approved proprietary brands of coumaphos (Co-Ral®), 25 percent wettable powder used at a concentration of 0.30 percent.

(b) The dipping bath for lime-sulphur dip must be used at a temperature of 95° to 105°F., and must be maintained through the dipping operation at a concentration of not less than 2 percent of "sulphide sulphur", as indicated by the field test for lime-sulphur dipping baths approved by the Veterinary Services.

(4) Approved proprietary brands of organophosphorous insecticides (Prolate®) used at concentration of 0.20 percent to 0.25 percent.

73.11 Treatment of means of conveyance and premises having contained scabby cattle.

"Means of conveyance" yards, pens, sheds, chutes, or other premises or facilities which have contained cattle of a consignment in which scabies is found shall be treated within 72 hours of use and prior to further use in the required concentration with a permitted dip listed in Sec. 73.10 under supervision of a State or Federal inspector or an accredited veterinarian.

APPENDIX B

RECOMMENDED PROCEDURES--CATTLE SCABIES ERADICATION

United States Animal Health Association
Parasitic Diseases and Parasiticides Committee
November 4, 1975

I. Definitions

For the purpose of these recommended procedures, the following definitions apply:

Scabies - Scabies is a disease caused by mites of the genus *Psoroptes* or the genus *Sarcoptes* and does not include infestations caused by *Chorioptes*, *Psorergates*, or *Demodex* mites.

Infected animal - An animal from which mites have been collected prior to official treatment or a member of an infected herd or lot.

Infected lot - Any lot of cattle in which one or more cattle have been disclosed to have scabies mites prior to official treatment.

Lot - Any group of cattle which are gathered together in any manner whether it be in a pasture, on a range, or a farm, in a market, or concentration point.

Herd - A group of cattle maintained for any purpose on common grounds, or two or more groups of animals under common ownership or supervision, geographically separated, but which have an interchange or movement. Herd decision must be based on sound epidemiological evidence.

Feedlot - Any location in which animals are gathered together for purposes of fattening for sale and where the feed is carried to them.

Range - Grassland on which cattle may forage for their food.

Ranch - Any operation where cattle are maintained and from which animals, both breeders and/or feeders, are sold.

Farm - A premises which carries out more than livestock operations. This may be either a dairy farm in which cattle are cared for and in which milk is sold, or it may be a farm in which grain is raised and fed to livestock which were purchased or raised on that farm.

Farm feedlot - A farm which, as part of its operation, takes animals raised on that farm or purchased and places them in a drylot on the farm. This is compared to a feedlot operation where the feedlot is the sole or primary operation.

Dairy - This may be where milking cows are kept for the production of milk or where a dairy herd raises its own replacements. All cattle involved are primarily of the dairy breed and maintained for the production of milk.

Exposed - An animal which is known to have had an opportunity to be contact with animals which may have been infected or to have been in contact with trucks, pens, chutes, and alleys through which infected animals have moved within the preceding 10 days.

Official treatment - That treatment which makes use of a pesticide listed as a permitted pesticide by Veterinary Services, APHIS, USDA, and which is used in a manner prescribed by Veterinary Services and where such treatment is carried out under the direct supervision of an employee of the USDA or State livestock health agency.

Free area - That area in which scabies is not known to exist and which is not under State or Federal quarantine because of scabies.

Permitted pesticide - A pesticide which is listed in Part 73 or 74, Title 9, Code of Federal Regulations.

Change of animals' status - Infected animals and exposed animals shall be considered free of scabies when official treatment, as listed above, is completed on all animals on the infected or exposed premises. The treatment shall be two times for infected animals and either one or two times for exposed animals, according to the permitted pesticide used.

II. Guideline for Handling Cattle Scabies

A. Psoroptic Cattle Scabies: Handling of Infected and Exposed Cattle and Premises

Infected and exposed cattle should be placed under State quarantine until properly treated under supervision. Only permitted dips should be used.

Every animal in an infected herd, both beef and dairy, should be treated twice. This includes both those with lesions and those not showing visible signs. Herds in which no mites can be demonstrated but from which cattle have moved that are found to be infected within 30 days should be treated twice as infected herds. Herds through which these animals have passed should be treated as exposed. Every animal in an exposed beef or dairy herd should be treated according to the directions for the pesticide used.

Cattle previously moved from infected herds during the period they logically could be considered exposed to scabies, i.e., up to 120 days, should be treated as exposed and the entire herd into which the animals have gone or through which they have passed should be treated as exposed herds.

Herds not showing any evidence of scabies but which are adjacent to infected herds should be treated as exposed herds. This includes all adjacent herds separated from the infected animals by a fence only.

Following treatment of infected or exposed cattle, the premises on which they are located should be treated with the acaricide used to treat the cattle.

2. Handling Adjacent Herds

Adjacent herds separated from the infected cattle by a road with a fence on both sides or other appropriate barriers, should be placed under surveillance and inspected regularly but do not need to be treated unless otherwise indicated.

3. Handling Scabies in Feedlot Cattle

When scabies is found in a feedlot, all cattle in the feedlot should be treated as infected. An exception may be made if the feedyard operation is so divided that there is no mixing or exposure between sections, and a separate sick pen is used for each section.

Pesticide residues in cattle treated for scabies and moving to slaughter present a problem and owners should be advised concerning the possibility of residues in treated animals. It is desirable to work out arrangements to permit infected cattle to move to immediate slaughter without dipping. The following is recommended:

When feedlot cattle are found to be infected, they may move intrastate upon State concurrence, for immediate slaughter. Cattle should leave the feedlot for slaughter within 21 days of the time the mite was identified in order to take advantage of this provision. Those not to be slaughtered during this period require official treatments.

Previous arrangements, approved by State and Federal officials, must be made with the slaughtering establishment. The animals must move in placarded trucks. They should go directly to slaughter pens and should not pass through other public facilities. The vehicles used must be treated with a permitted acaricide before being used to haul cattle from other premises.

Cattle from infected premises may be moved interstate for immediate slaughter after one treatment, provided they move in placarded trucks. They should go directly to slaughter pens and should not pass through other public facilities. The vehicles should be treated with a permitted acaricide before being used to haul cattle from other premises.

4. State Quarantines

Infected and exposed herds and lots should be immediately placed under State quarantine and remain in this status until they receive proper treatments and post-treatment inspections. Cattle in such herds should be identified.

When State quarantines are necessary, they should be promptly placed and properly enforced. Quarantines must be practical and operate against the infected and exposed herds while protecting neighboring herds and herds in other areas and States. Quarantines should not be released until all animals have been treated or slaughtered.

5. Federal Quarantines

Preliminary geographical survey of the areas recommended for quarantine to be received by Regional Director in 7 calendar days from the finding of the outbreak. The Federal quarantine will be applied on confirmation of mite at first point with trained identifiers.

Quarantine will be released when the infection has been eliminated from the quarantined area.

6. Methods of Treatment of Infected or Exposed Cattle

The dipping vat is the superior and certainly the preferred method of treatment. However, it is recognized that a dipping vat is not always available nor is it possible in every case for owners of small herds to construct one. The spray-dip machine can be used in such instances. It is an effective method if treatment is closely supervised by qualified inspectors. Close supervision must be given to the use of the dipping vat also. Infected or exposed animals must be held in the spray-dip machine or dip vat for a minimum period to assure wetting the animal to the skin. The pesticide selected will determine whether one or two treatments of exposed animals are required.

7. Assembled Cattle on Pasture

Assembled cattle on pasture, wheat field, etc. handle as herd.

B. Sarcoptic Cattle Scabies

Treat the same as psoroptic, including epidemiological investigation.

C. Other Mite Infestations

1. Chorioptic - Cattle in infected herds may not be shipped interstate until treated under procedures outlined for psoroptic cattle scabies. Epidemiological investigation may be omitted.

2. Psorergatic - Cattle in infected herds may not be shipped interstate until treated in heated lime-sulfur. Two treatments, with a 21-day interval between treatments, are required to eliminate the infection. Epidemiological investigations may be omitted.

3. Demodectic - Inform owner of diagnosis and no satisfactory treatment. Epidemiological investigations may be omitted.

III. Tracing Movements from Infected or Exposed Herds

Every effort should be made to locate any infected cattle and trace animals moved to and from infected herds in order to locate all foci of the disease.

Officials should immediately notify other States of any movements from infected or exposed herds that involve them. This should be done by wire or telephone (followed by a letter giving further details) if this will aid in locating the animals more properly and thus prevent exposure of additional herds and spread scabies.

All pertinent information available should be furnished. This includes description of animals, vehicles (breed, age, sex, color, weight, brands, eartag numbers, car numbers, waybill numbers, truck and trailer license plate numbers, truckers, owners, shippers, and commission company names, etc.) date shipped, and other information that will aid in locating the cattle and/or herds concerned. Veterinary Services should also be notified.

APPENDIX C

COLORADO SCABIES REGULATIONS

March 1, 1978

Basic Scabies Regulations Adopted by the Colorado Agricultural Commission are as follows:

1. All cattle leaving public livestock markets, or purchased, sold or handled by any livestock dealer or any cattle sold or traded in private transactions will be officially treated with an approved scabicide.

2. All cattle moving from Colorado Counties east of the Continental Divide to Counties West of the Divide, and from Counties West of the Continental Divide to Counties East of the Divide shall have been officially treated within ten days prior to such movement.

Exceptions:

a. Cattle--positively identified--which have been officially treated in Colorado within the previous ten days.

b. Cattle--positively identified--which are being moved directly to a premises which has an officially approved treatment facility--to be treated upon arrival (within 24 hours) and before being placed with or adjacent to any other cattle.

c. Cattle positively identified and consigned directly to federally inspected slaughter establishment for immediate slaughter, SHALL require only a movement permit.

d. Lactating dairy cows and dairy calves (under two weeks) originating from dairy farms may be sold without being treated for scabies.

e. Breeding cattle and their progeny may be sold or traded in county transactions without treatment for scabies in counties which have not had cattle scabies diagnosed since July 1, 1977, provided they do not cross county lines and it is agreeable with both buyer and seller.

SOURCE: Colorado Agricultural Commission, March 1, 1978.

APPENDIX D

ARIZONA SCABIES REGULATIONS FOR FEEDYARDS
Effective January 1, 1979

The following refers only to "certified feed yards" as outlined below, and all other incoming shipments will adhere to present regulation.

1. Livestock Sanitary Board will determine which feedlots meet the criteria for certification, and upon application from the feed yard will either grant or deny certification.

2. Definition of a "certified feed yard":

A. Must have a dipping vat approved by the Livestock Sanitary Board.

B. Ninety-five percent (95%) of all cattle shipped out of feed yard on an annualized basis must go to slaughter.

C. All cattle leaving the feed yard, other than those going to slaughter, must be dipped prior to shipment, and be inspected by the brand inspector.

3. Cattle will be allowed to be shipped, without unloading anywhere else in Arizona, from any area within the United States to a certified feed yard without point-of-origin dipping.

4. Livestock Sanitary Board will continue to issue permits to out-of-state shippers. Cattle not destined to a certified feed yard will continue the practice of point-of-origin dipping. Cattle destined to a certified feed yard will carry a permit stating that the cattle must be dipped upon arrival. The order buyer either by phone or wire will inform the Livestock Sanitary Board of shipment, number of head, approximate time of arrival, etc., so that area livestock inspector can be alerted to the shipment. Such shipments must not be diverted in transit. Health certificates must be mailed within twenty-four (24) hours of shipment.

5. Cattle, upon arrival at a certified feed yard, will be maintained separately in quarantined pens, from other cattle until dipped. Dipping must be done within twenty-four hours.

6. Dipping vat solutions must be approved by and be subject to, inspection at any time by the Livestock Sanitary Board.

7. Livestock inspectors must ascertain that all cattle moving out of the feed yard, other than to slaughter, have been dipped prior to shipment.

8. Feed yards other than certified feed yards, and all other cattle handling facilities, shall continue to have cattle dipped at point-of-origin if the cattle come from Scabies infected areas as identified by the Livestock Sanitary Board.

9. Failure to comply with any of the aforementioned regulations will cause immediate revocation of the certification granted by the Livestock Sanitary Board.

APPENDIX E

MACERATION-FLOTATION PROCEDURE FOR DEMONSTRATING PARASITIC MITES OF LIVESTOCK AND SUBMISSION OF MITE SPECIMENS TO BELTSVILLE

USDA/ARS
Animal Health Division
June 24, 1970

I PURPOSE

The purpose of this memorandum is to provide information and instructions for the recommended techniques for demonstrating parasitic mites of livestock and for the submission of mite specimens. ANH Division Memorandum No. 556.3, dated December 21, 1965, ANH Division Memorandum No. 556.3, Supplement No. 1, dated April 1, 1970, and ANH Division Memorandum No. 587.7, dated October 11, 1963, are hereby cancelled.

II GENERAL

The maceration-flotation procedure is recommended if skin scrapings from scabies-suspicious animals have been carefully examined and no mites isolated. It may be difficult to demonstrate mites due to previous but inadequate treatment of the animal, the time of the year when mites are less active, etc. Mites can be demonstrated by the maceration-flotation procedure and a diagnosis of scabies confirmed when all other means have failed. During recent years, many outbreaks have been confirmed using this procedure. These outbreaks would have been otherwise missed. Also the maceration-flotation procedure is the only practical procedure for isolating *Psorergates* mites from cattle or sheep.

The maceration-flotation procedure may be performed with or without the use of a centrifuge.

III MACERATION-FLOTATION PROCEDURE

1. Trim away excess hair or wool from the scab portion of the scraping and place the remainder in a pyrex glass beaker. Add a sufficient amount of 10 percent sodium hydroxide[1] or 10 percent potassium hydroxide[2] to cover the material. Boil approximately 3-5 minutes while stirring with a glass rod. This will dissolve much of the extraneous material such as wool, hair, or scabs, releasing mites.

2. Carefully fill two conical centrifuge tubes almost full (within one-half inch of top) and centrifuge at 1,000-1,500 r.p.m. for at least 5 minutes; OR, IF CENTRIFUGE IS NOT AVAILABLE,

Carefully fill two 10 cc. test tubes with boiled material and allow to stand for 8 hours or longer to permit further dissolving and complete settling.

3. Pour off supernatant fluid (upper 85-90 percent of fluid). Fill the tubes half full with flotation solution[3] and vigorously stir solution with a clean stick or rod. Finish filling tube with flotation solution. Place a cover glass over the mouth of each tube making certain that the cover glass is in contact with the liquid. Let stand for one hour or longer to allow mites to rise to the cover glass.

4. Carefully remove the cover glass and mount on clean glass slide. Examine each slide carefully under a compound microscope for the presence of mites and/or fragments of mites. Mites are not always readily found on the first preparation. It might be necessary to prepare several slides from each tube before mites are found.

IV REMOUNTING OF MITES

If only one mite or a fragment of a mite is isolated, it is wise not to attempt to transfer the material from the Karo mount to a permanent Hoyer's mount to avoid loss. A well-dried Karo mount is adequate for confirmation. All slide mounts should be adequately dried before shipment. The microslide mount may be dried by placing it 12 inches from an incandescent light bulb (100° to 110° F.) for 12 hours or longer or drying overnight in an incubator at 100° F.

V SUBMITTING MITE SPECIMENS TO BELTSVILLE

Mites from all suspected outbreaks of psoroptic, sarcoptic, chorioptic, and psorergatic sheep or cattle scabies must be submitted for confirmation and cataloguing.

The field veterinarian is not relieved of his responsibility of making a tentative identification by the submission of specimens to appropriate laboratories within the State and to Beltsville. He is still expected to attempt to make his own identification. In most cases, it would not be practical for the veterinary inspector to wait for a laboratory identification of all specimens before taking appropriate action. However, if the veterinary inspector requires assistance on the initial diagnosis, he should not hesitate to seek such assistance.

VI PURPOSE OF THE PARASITE REFERENCE CENTER

The Parasite Reference Center was established to assist field stations and to serve as a national center for the cataloguing and filing of parasites encountered in the Division's field programs. Invaluable information can be obtained by having accurate records of the incidence and distribution of the various external parasites of livestock.

VII HOW TO SHIP SPECIMENS

A rubber band should be placed around each end of the slide to cushion it in the mailer and prevent it from sticking to the mailer if the mounting medium has not fully hardened. Each collection is to be accompanied by an ANH Form 5-38 properly filled out. The slides are to be identified with a label.

Mail all slides with mites, fragments of mites, other ectoparasites, or eggs to:

ANH Parasite Reference Center
Building 320
Agricultural Research Center
Beltsville, Maryland 20705

VIII WHEN THE MACERATION-FLOTATION PROCEDURE IS NOT USED

If it is not possible to prepare mounts, isolate several mites and place them in a small vial of 70 percent alcohol and forward as directed above.

If the condition is highly suspicious and mites are still not isolated by the maceration-flotation procedure and it is impossible to secure additional scrapings, place some of the material in a tight container (add 70 percent alcohol to prevent bacterial action) and forward as directed above. Scrapings should be sent to Beltsville only as a last resort.

IX REPORTING MACERATION-FLOTATION PROCEDURES PERFORMED

A monthly report of the number of maceration-flotation procedures performed at a station is to be provided by entering on the "remarks" section of the monthly ANH Form 5-10 the number of scrapings taken and the number of maceration-flotation procedures performed for each species.

R. E. Omohundro

Acting Director

NOTES

1 Prepared by dissolving 10 grams sodium hydroxide in 100 ml water.

2 If sodium or potassium hydroxide is not available, household lye, which is approximately 97 percent sodium hydroxide, may be used.

3 The recommended flotation solution is made of one part white Karo syrup and one part water.

APPENDIX F

TREATMENT METHODS OF CATTLE AND SHEEP PERMITTED BY THE ANIMAL AND PLANT HEALTH INSPECTION SERVICE, USDA

Abstracts of instructions to be followed in the treatment of cattle and sheep scabies by APHIS, Veterinary Services Memorandum 556.1, Supplements 2, 3, 6, 8 (1972-76).

Concentration

Lime-sulfur for treating cattle is 2 percent "sulfide sulfur" as determined with a vatside test. A test kit and instructions for use can be secured from the Veterinary Services Diagnostic Laboratory, Agricultural Research Center, Beltsville, Maryland.

The concentration of phosmet must be 0.15 to 0.25 percent and requires the addition of 10 pounds of triple superphosphate per 100 gallons of water to maintain the dip solution at a level of pH 5.5. Coumaphos dips should be maintained at 0.30 percent, and toxaphene dip solutions are used from 0.5 to 0.6 percent.

Method of Treatment

Vat dipping is the preferred method when treating cattle as it is usually faster and more economical than using a spray-dip machine. Spraying with a hand-held nozzle, whether with a power or hand-operated sprayer, is not acceptable.

Dipping Interval

Infested and exposed herds should be treated twice within a 10 to 14 day interval between treatments using lime-sulfur, coumaphos, or phosmet. For toxaphene, infested herds are dipped twice at the 10 to 14 day interval while exposed herds are treated only once.

Recharge

The vat or spray-dip tank must not be allowed to fall below the 7/8 level. Amounts per 100 gallons of water for replenishment of these materials are rigid: 4 quarts of 61% toxaphene concentrate; 8 lbs. of 25% wettable powder coumaphos; 2 gallons of 11.6% prolate concentrate plus 10 lbs. of triple superphosphate for the optimum pH of 5.5 (range 4.5 to 6.5); and 6 1/2 gallons of lime sulfur solution.

Vat and spray-tank machines should be emptied, cleaned and recharged when the solution becomes too visibly foul (manure, dirt, hair) for use, the sediment in the vat or tank equals 10% of the volume of the vat or tank, when the number of animals treated is equal to twice the total gallonage of the initial vat or tank volume, or when the vat or tank has not been serviced within 120 days for all acaricides except phosmet which requires a 60 day service period.

Additives

Various types of detergents, wetting agents, and water softeners are available for use in these vats or spray-dip machines to help wet the animal hair and skin. APHIS/USDA Memoranda instructions state that none should be used except on specific authority from State and/or Federal Veterinary Regional Directors.

Precautions of Use

Lime-sulfur is the only acaricide which may be used on lactating dairy cattle and goats. Animals treated with lime-sulfur or coumaphos may go to slaughter without a withholding period. The intervals between treatment and slaughter for phosmet- and toxaphene-treated cattle are 21 and 28 days, respectively.

Legal tolerances in parts per million (ppm) in animals treated with these acaracides are: coumaphos-1 ppm meat and fat and 0.5 ppm milk, lime-sulfur-safe chemical, phosmet-0.2 ppm meat and fat, and toxaphene-7 ppm fat.

Calves under 3 months of age should not be sprayed while those under 6 months of age should not be dipped with toxaphene. Likewise, calves under 3 months of age should not be treated with phosmet. No animal age limitations are suggested for dips and spray-dips using coumaphos or lime-sulfur.

Contraindications

Coumaphos should not be used in conjunction with internal medication, with phenothiozine, natural or synthetic pyrethroids or their synergists, or in dips of a strong alkaline nature. All acaricide dips or spray-dips should not be used to treat sick, convalescent, or stressed cattle. All animals scheduled for treatment should be rested and allowed to drink their fill of water (minimum of 2 to 4 hours prior to dipping).

Permitted Proprietary Acaracides

The following brands of pesticides have been permitted by APHIS (1977) for official use against scabies, are registered with the appropriate Federal agency, and have undergone further evaluation to assure their efficacy when used in cooperative programs.

1. Toxaphene emulsion. "Coopertox Livestock," (Burroughs-Wellcome Company, North Carolina); "Lintox-X Livestock spray and dip" (Zoecon Industries, Texas); "Toxaphene-61 Livestock spray and dip" (Helena Chemical Company, Tennessee).

2. Coumaphos (Co-Ral ®) wettable powder. "Co-Ral 25% W.P." (Bayvet Corporation, Missouri).

3. Phosmet (Prolate ®) emulsion. "Starbar GX-118" (Zoecon Industries, Texas).

4. Lime-Sulfur solution. "Acme Lime-Sulfur Spray" (Acme Inc., Michigan); "Laccq Liquid Lime-Sulfur" (Los Angeles Chemical Company, California); "Ortho Lime-Sulfur Solution" (California Chemical Company, California); Sterling Brand Liquid Lime-Sulfur" (Smith Chemical Company, Colorado); "Valley Spray Rex Lime-Sulfur Solutions" (Yakima Spray Company, Washington).

Human Safety

Ranch and regulatory employees who manage and participate in cattle scabies treatment programs are exposed to pesticides which, in concentrate and dilute formulations, may be toxic to man.

Persons mixing concentrate formulations and those involved with application of dilute solutions should wear special equipment such as gloves, goggles and/or respirators, and protective clothing and shoes. Workers using dip forks to manage animals in vat dips should be fully protected (rain gear is advised) as they are subject to being splashed and are at a high risk of exposure.

Permanent employees should have blood cholinesterase levels determined before and at intermittent periods while working with pesticides--particularly when using the organophosphorus compounds such as coumaphos and phosmet.

APPENDIX G

APPLICATION EQUIPMENT: VAT-DIPPING AND SPRAY-DIPPING

Abstract of Dipping Vat Management and Treatment Procedures and Guidelines for Use of Spray-dip Machine for Treating Cattle, by APHIS, Veterinary Services Memoranda, 556.1 (1972) and 556.5 (1975).

Dips

Permanent dipping vats are recommended to be at least 33 feet long by 3 1/2 feet wide at the top and bottom, or in case of a V-shaped vat, not less than 20 inches wide at the bottom; the minimum bath depth should be 6 feet at the 7/8 full level.

The running chute should be at least 30 feet long with a gate or bar located near the vat entrance to hold animals back in order to prevent pile up and drowning. Some cattlemen make the final 10-12 feet of the running chute in a semi-circular form to prevent balking of the cattle before they jump into the vat. A highly polished cement slide or stainless steel covered board of about 3 1/2 feet long is often used for easy entry of animals into the vat.

The first 10 feet of the vat extending from the start of the slide is usually built with 5 to 6 feet high solid wood sides (splash guard) to prevent loss of dip material and to help prevent contamination of workers standing by the vat dip for the purpose of managing animals during their swim through the dip. These workers are instructed to use dipping forks to help dunk heads of cattle not wet from the jump-in; ropes are also provided to assist young cattle or those in distressed condition.

The vat exit ramp is usually 16 feet long, fitted with cleats or grooves set 12 inches apart, and provided with 12 feet long by 5 or 6 feet high side walls. The exit leads to a pair of equal size drain pens (16' wide by 30' long) fitted with a cutting gate and concrete floors with sufficient slope to permit return of the dip material to the vat.

Special features included in the construction of some vat dips include a 12 feet long by 1 foot deep concrete foot bath placed in the working chute to help reduce vat contamination by mud and manure. Also, some operations provide a collection basin to receive drainage from the dip pens with an alternate exit to the outside to prevent rain water from entering the vat. A much-used and properly constructed vat usually has a slant-roof structure over the body of the vat to prevent rain from entering and causing dilution of the dip.

Extra equipment is advisable when using Co-Ral wettable powder dips since this material must be thoroughly mixed at frequent intervals to avoid rapid settling out of the active ingredients. A hand-stirrer in the form of a metal rake or a long-handled 18 inch square, perforated board is used for mechanical agitation. A more expensive method is the use of a portable, gas-driven compressor equipped with a long hose fitted to a T-shape pipe to permit air agitation of the vat contents.

Spray Dip Machines

Portable and stationary machines, also called "spray- or dip-boxes" are available from numerous commercial sources. Most popular are the portable type which can be towed from ranch to ranch where they can be positioned flush with the end of a chute or squeeze. The all-metal spray chamber is about 9 feet long by 4 1/2 feet wide with sliding front and rear doors. There are adjustable screw jacks on each corner to place the machine on a level with the entrance chute. The machine is usually powered by an 18 hp air-cooled, gas engine fitted with an adjustable high pressure centrifugal pump to deliver 250 gpm and can be operated at 50 to 200 psi measured at nozzle discharge. Speed of treating cattle is controlled by one operator located on a side platform overlooking animals entering and leaving the machine. Stationary models are similar in design without axle and wheels or jack equipment. A 7 1/2 hp electric motor may be substituted for the gas engine.

With the portable model, the machine should be positioned so that the rear doors do not interfere with the end gate of the chute or squeeze. In some cases metal or wood baffle plates must be constructed to prevent animals from turning aside and possibly escaping through an opening between the machine and the chute. Also, a small ramp must be used in some machine-chute arrangements because of uneven ground surfaces. Two chains are commonly used to anchor the machine to the end of the chute to prevent movement of the machine after continued impact by active cattle. The chute should have a sliding gate or a pole about 8 feet from the point where cattle leave the chute and enter the machine.

For this reason a chute having a squeeze on the end is ideal for operating spray-dip machines.

Animals should remain in the spray dip machine for 1 minute, receiving three 20-second bursts of spray with a few seconds pause between bursts to allow the animal to breathe. Calves under 2 months of age should be given two 10-second sprayings with one pause between.

Recharging the tank is on the basis of 25 gallons to bring the sump up to full mark. This is critical because of the usual 1 1/2 gallon carry-out per treated animal which exits immediately after the 1-minute treatment.

Like any power-driven equipment, the spray-dip machine including all parts, must be maintained in good repair. Engine maintenance is critical, and the pump must be constantly inspected to guard against air leaks. Holes in the hydraulic agitator must be kept clean, and all 28 nozzles must be open and clear of debris to insure adequate pressure and complete wetting of animals. The injector and strainer must be operated between 50-75 rpm.

Disposal of Unused Pesticides

Brief instructions from the Federal Memorandum are included on what to do with the volume of acaracide remaining in the vat or spray-dip machine following completion of animal treatment.

No instructions are given for disposal of lime-sulfur (Vet. Serv. Memo 556.1 Suppl. 8). A broad warning is given to dispose of solutions in areas where animals or persons will not come in contact, in an area where seepage cannot reach animal feeds or underground water supplies, or where drainage cannot reach streams where fish or animals can be poisoned.

Recommendations for disposal of coumaphos and toxaphene solutions are described beyond the general warning given above for phosmet (Vet. Serv. Memo 556.1 Suppl. 6 and 3 respectively). Suggestions are made to empty solutions into a fenced sump or pit located on heavy soils. Also, the sump or "evaporative pond" should be bordered by a berm of adequate height to prevent surface water to enter and cause an overflow. Instructions also advise consultation with staff of the Soil Conservation Service, USDA. In many states cooperation is required from staff of the Water Quality Control Board where specialists may be asked to evaluate individual disposal sites. In some states Class I dump sites are available to receive unused pesticide solutions (and empty containers). Vats and dip tanks can be pumped empty into a motorized tanker or a tank trailer and taken directly to these sites or to sewage treatment plants.

Some of the unused solutions from portable vat and dip machines are used to wash down common structures used by cattle during the treatment procedure--corral fencing of holding pens, entry chute and squeeze. No instructions are given in this respect nor are there any warnings made for pesticide treatment of trucks used to haul scabby cattle.

APPENDIX H

NAMES OF ACARICIDES

Common Name (Registered® and Trademark™ Name)	Chemical Name
Amitraz	1,5-di-(2,4-dimethyl)-3-methyl-1,3,5-triazapenta-1, 4-diene
Chlorfenvinphos (Birlane ™)	2-chloro-1-(2,4-dichlorophenyl)vinyl diethyl phosphate
Chloromebuform (Ektomin ®)	chloromethylphenyl butylformamidine
Chlorpyrifos (Dursban ®)	0,0-diethyl 0-(3,5,6-trichloro-2-pyridyl) phosphorothioate
Crotoxyphos (Ciodrin ®)	alpha-methylbenzyl 3-hydroxycistonate dimethyl phosphate
Crufomate (Ruelene ®)	0-4-tert-butyl-2-chlorophenyl 0-methyl methyl phosphoramidate
Cyhexatin (Plictran ®)	tricyclohexylhydroxystannane
Diazinon	0,0-diethyl 0-(2-isopropyl-6-methyl-4-pyrimidinyl phosphorothioate
Famphur (Warbex ®)	0-p-(dimethylsulfamoyl)-phenyl 0,0-dimethyl phosphorothioate
Fenthion (Tiguvon ®)	0,0-dimethyl 0-(3-methyl-4-methylmercapto-phenyl) phosphorothioate
Malathion (Cythion ®)	diethyl mercaptosuccinate, S-ester with 0,0-dimethyl phosphorothioate
Oxythioquinox (Morestan ™)	6-methyl-2,3-quinoxaline dithiol cyclic S,S-dithio-carbonate
Permethrin	(3-phenoxyphenyl) methyl (±) cis-trans-3-(2,2-di-chloroethylenyl)-2, 2-dimethylcycloproprane-carboxylate

APPENDIX H (Continued)

Common Name (Registered® and Trademark™ Name)	Chemical Name
Phoxim (Valaxon ™)	a-[[(diethoxyphosphinothioyl)oxy]imino] benzene-acetonitrile
Quintiofos	0-ethyl 0-quinolyl-8 benzenephosphono-thioate
Ronnel (Korlan®)	0,0-dimethyl 0-2,4,5-trichlorophenyl phosphoro-thioate
SD-14114 (Vendex®)	hexakis (2-methyl-2-phenylpropyl) distannoxane
Stirofos (Rabon®)	2-chloro-1-(2,4,5 trichlorophenyl) vinyl dimethyl phosphate
Trichlorfon (Neguvon®)	2,3 dimethyl (2,2,2-trichloro-1-hydroxyethyl) phosphonate