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## OPENING REMARKS—TWELFTH VERTEBRATE PEST CONFERENCE

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## **OPENING REMARKS—TWELFTH VERTEBRATE PEST CONFERENCE**

**TERRELL P. SALMON**, Wildlife Specialist, Cooperative Extension, University of California, Davis, California 95616.

On behalf of the Vertebrate Pest Council, welcome to the 12th Vertebrate Pest Conference.

Every other year since 1962, the Vertebrate Pest Council has sponsored the conference with the primary objective of bringing individuals interested in vertebrate pest control together to discuss problems and solutions of mutual concern. The main objectives of the conference are:

1. To exchange information on vertebrate pest management and related matters.
2. To advance environmentally safe vertebrate pest management methodologies.
3. To build cooperation with public and private agencies in solving vertebrate pest problems.
4. To consider and promote discussion and interaction among agencies and others about problems of mutual concern in the field of vertebrate pest management.
5. To foster educational work in vertebrate pest management.
6. To encourage research by both public and private agencies on vertebrate pest problems and their solutions.
7. To promote uniformity and coordination of activities among agencies and individuals concerned with the regulatory aspects of vertebrate pest management.

As you can see from our program, we are accomplishing these objectives. During the next 3 days, we anticipate well over 400 attendees from around the world. At the meeting and through private discussions, we encourage you to share your experiences and learn about those of others.

The Conference has changed over the last 24 years, but the objectives still remain the same. After the 11th Conference, we mailed a survey to those who attended, asking them for their thoughts about the Conference and the kinds of things they would like to see at the 12th. This year's program reflects many of the ideas transmitted to the Council through this survey. The major change is adding concurrent sessions. We recognize the conflicts these present but feel that the expanded scope of the Conference allows you greater opportunities for exchanging vertebrate pest control information. For those who miss papers, we will be publishing the Conference proceedings within 6 months, allowing you access to all the information presented at the Conference.

We hope you enjoy the Conference. We welcome you to San Diego and encourage you to communicate your ideas and thoughts about the Conference to members of the Vertebrate Pest Council.

With that I begin the 12th Vertebrate Pest Conference.

## KEYNOTE ADDRESS—CHANGING TIMES FOR ANIMAL DAMAGE CONTROL

**JAMES O. LEE, Jr.**, Deputy Administrator, Animal and Plant Health Inspection Service, U.S. Department of Agriculture, Washington, D.C.

Times do change! USDA's Animal and Plant Health Service, or APHIS, is now in the process of taking over the animal damage control program from the U.S. Fish and Wildlife Service. The transfer will be completed by April 1.

This is the opposite of what was happening back in 1939. At that time, a government reorganization plan resulted in the transfer of the Bureau of Biological Survey--forerunner of Fish and Wildlife Service--from Agriculture to Interior; and with it went the ADC program.

We're pleased to have the ADC program back at Agriculture. We never lost interest in it. While the program was at Interior, the Agricultural Research Service contributed to ADC projects such as those on guarding dogs and improved coyote attractants. The Extension Service provided ADC training and instructions to farmers and ranchers. USDA's Economic Research Service conducted studies on agricultural losses caused by depreddating animals.

### YESTERDAY

But let's look back for a moment to the early days. We're inclined to think of the ADC program as beginning in 1931 when the Animal Damage Control Act was passed. But USDA was involved with animal damage control long before then. More than a hundred years ago, in 1885, records show that USDA officials sent a questionnaire to farmers inquiring about bird damage to crops. Two years later, a letter was mailed to farmers informing them of ways to reduce losses to ground squirrels.

From 1888 to 1914, the Department carried out several studies in animal control. In 1911, for example, a bulletin on fences to exclude predators was published. In 1916, USDA's Bureau of Biological Survey began building a field force to control predatory animals in principal western livestock-producing states. From then until 1931, USDA cooperated extensively with states and other organizations to control animal damage.

The Act of March 2, 1931, authorized the Secretary of Agriculture to carry out a cooperative program to reduce losses caused by predatory animals, birds, and rodents. In those days, the program not only protected livestock and crops, but desirable species of wildlife as well. Predators were considered a liability to the wildlife resource, and predator control was an inherent part of the wildlife manager's job.

In 1939, ADC became a responsibility of the Secretary of Interior. In the view of many people, however, that responsibility began to conflict with Interior's role in wildlife conservation. To quote one pundit, it appeared that "putting ADC in a fish and wildlife organization made as much sense as putting weed control under supervision of the national arboretum."

But in all fairness, many people believe there's little or no evidence that killing coyotes reduces livestock losses. They suggest that control programs kill nontarget species and are otherwise environmentally unacceptable. Some believe the use of toxicants incurs too high a risk to the environment and to nontarget species. The use of toxicants is indeed controversial.

Because of its economic and environmental advantages, the Department of Agriculture supports and promotes the concept of integrated pest management in all attempts to reduce economic losses caused by vertebrate animals. The goal of the Department is to reduce damage where animal damage reduction is determined to be necessary for economic reasons and, if at all possible, without environmental harm.

According to a study by USDA's Economic Research Service, one of every nine lambs born in 15 western states during a recent year was killed by predators--primarily coyotes. Annual losses to agriculture from various depreddating animals--such as blackbirds, rodents, and coyotes--were estimated at more than 300 million dollars. That was reason enough for USDA to maintain its interest in ADC.

The 1922 Yearbook of Agriculture contains this interesting statement, and I quote: "Similar to the warfare against Plant and animal diseases and insect pests is the struggle to control predatory animals and rodent pests." We at APHIS would have to agree with that assessment. Our basic mission is "Protecting American agriculture," and ADC fits in with that mission very well indeed.

### TODAY

USDA always has been quick to defend the need for an ADC program. But with backing by the livestock industry, Secretary Block began actively exploring a return of the program to Agriculture in 1981. He took up the matter--first with Interior Secretary Watt, then with Secretary Clark, and finally with Secretary Hodel.

With a nod from the President's Office of Management and Budget, and Secretary Hodel's agreement not to object, Congressional proponents of a transfer pursued the necessary legislation by two routes--the farm bill and the Agriculture funding measure. It was actually the latter--the Continuing Resolution--passed by Congress and signed by the President on December 19, 1985, that achieved the transfer.

Strictly speaking, the transfer occurred October 1, with Interior continuing to manage the program until the transition is completed.

The transfer included all personnel, property, records, and funding for the ADC program. On the other hand, responsibility for administering laws protecting bald and golden eagles and other endangered species remains at Fish and Wildlife Service; and this is as it should be.

In transferring the ADC program to Agriculture, Congress set current funding at about \$20 million. I want to tell you, however, that this was before reductions brought about by the Gramm-Rudman-Hollings Act. All APHIS programs may have to take a cut of about 4.3% during this fiscal year. More drastic cuts may come later.

Funding provisions specifically include \$500,000 for ongoing research on ways to minimize losses caused by blackbirds. Some \$45,000 is for the guard dog program at Hampshire College. Provisions also include funding for research now underway on nonlethal predator control in California, Nevada, and Arizona. I understand that this project actually deals with taste aversion using lithium chloride in sheep-meat baits.

Altogether, about \$4.3 million is committed for research. This includes \$1.3 million for in-house research on bird damage and \$1 million for predators.

As noted, transfer of the ADC program from Interior to Agriculture is targeted for completion by April 1. Our immediate goal is a smooth and orderly transfer. Both APHIS and Fish and Wildlife Service have assigned transition teams, and they're working diligently to complete the transfer in good order. Let me say that Fish and Wildlife Service's cooperation has been excellent!

TOMORROW

Now don't expect to see dramatic changes come April 1. But we do have some positive thoughts on how to run ADC, and I'd like to share them with you. Keep in mind that we'll have three major areas of emphasis: cooperative operational control, research, and informational and educational efforts. The program will be managed from offices in Washington, D.C. We'll have a technical staff located nearby at Hyattsville, Maryland.

For the first time, the program will have a Secretary's advisory committee on ADC. This committee will advise the Secretary on policies and program issues necessary to control depredating animals that reduce agricultural production and nuisance animals at airports and urban areas. Having this committee will help improve coordination with producer groups and conservation organizations. People from all major groups with a stake in the program will sit together to discuss and recommend policy.

Other USDA agencies besides APHIS already have a role in this program. For that reason, we'll also have an intradepartmental policy committee on ADC chaired by APHIS. Other agencies represented will include Forest Service, Extension Service, Economic Research Service, Agricultural Research Service, and Cooperative State Research Service.

For those of you who are familiar with APHIS's present structure, ADC will be managed as a third major program area, separate and apart from our Veterinary Services and Plant Protection and Quarantine programs.

Currently, ADC field operations are carried out under several regional offices of Fish and Wildlife Service. APHIS will manage field operations from two regional offices only.

A line dividing eastern and western regions will coincide with the North Dakota-Minnesota border and extend southward. Everything is already in place for the western region to be headquartered in Denver. The eastern regional headquarters will be near Columbus, Ohio, as soon as we can get set up for it.

Some things won't change under APHIS. Cooperative and participatory features of this program will be preserved. APHIS has no desire to take over jobs already being well handled at the state, county, and community levels. Program structures within individual states will remain pretty much intact.

And to those of you who represent commercial pest control firms, let me assure you that APHIS has no plans to assume your roles either. We'll continue to count on a lot of people who've been making contributions to animal damage control over the years.

RESEARCH

Research will continue to play a vital part in the ADC program under APHIS, with the Denver Wildlife Research Center serving as the hub of ADC research. We'll be researching new control methods as well as more efficient and safe uses of present methods. We'll be looking into toxicants, repellents and attractants, biological controls such as reproductive inhibitors, and physical approaches such as fencing.

We support the concept of using chemical toxicants (including 1080) if not prohibited by other laws or regulations, and if they can be used safely without a significant threat to nontarget species and humans.

As most of you know, the livestock protection collar was recently registered by EPA. These collars will become available as soon as state pesticide regulatory agencies get state registrations and are ready to handle certification of applicators, together with training, distribution, and monitoring of collar use. They'll be suitable for some sheep and goat raisers in some areas of the country.

Owners of graineries, feedmills, feedlots, orchards, and grain crops are not the only ones concerned about the bird and rodent threat. Urban communities have problems, too. Through research, we'll be looking for ways to update and improve the methods of controlling rodent and bird problems in urban areas.

The topic of urban problems with winter roosts of blackbirds and starlings was covered in a recent article in the Wall Street Journal. As the Journal article said: "For people in the South, bye-bye blackbird is a wish, not a song."

Airplane pilots, on the other hand, don't wish--they pray! Birds ingested by airplane engines cause \$25 to 40 million worth of damage a year, depending on value of engines affected. FAA records about 1,500 bird strikes annually.

Bird strikes don't often cause crashes; but when they do, it can be calamitous. Most strikes are by gulls, but migratory waterfowl--blackbirds and starlings--also figure in the problem. We'll be working closely with FAA on finding solutions.

APHIS cares about people. Bird strikes are just one example of ADC involving human health and safety. There are others, such as the need to control rabid animals.

APHIS also cares about animals. We favor painless, life-sparing approaches to control animal damage wherever and whenever possible. Through research, we'll be looking for nonlethal control devices and techniques that are both affordable and effective. Projects that achieve goals by attaining a favorable ecological balance through natural means will be looked on with special favor.

As this audience knows well, there are many areas of ADC research that need to be considered. Our objective will be to maintain a safe and effective ADC program that is biologically sound, environmentally acceptable, and economically feasible.

#### INFORMATION AND EDUCATION

Now a few words about information and education. Remember Johnny Mercer's lyrics that say "You've got to accentuate the positive"? Well, the ADC program offers very positive benefits to agriculture and the public, and we want to tell about it!

We have nothing to hide. This program will operate in the full light of day, open to public scrutiny. Not all of it will be pretty, we know. But we'll want the public to see the methods we employ and what happens if we do nothing.

Educational materials will be targeted for the people who really need to know--the farmer, the rancher, the feedmill operator, the airport manager. And we'll be counting on the Extension Service to provide the kind of services they're noted for.

The Extension Service has wildlife specialists with special expertise in animal damage control. These individuals develop educational materials and programs on ADC for private landowners and managers in every state. In so doing, they evaluate all methods of controlling problems caused by a particular species. The educational materials and programs they develop incorporate the most practical, effective, species-selective, safe, and humane methods and procedures available.

Programs vary from state to state, depending on the magnitude of predation of livestock, crops, and wildlife, and the significance of these industries and resources to the local economy. They're implemented primarily through the educational system of county agents who provide group demonstrations and group training for persons with damage problems.

#### CONCLUSION

Those are just some of the plans we have for animal damage control in the months and years ahead. Before concluding, let me just briefly review my main points.

-- The program, designed to attain results, must be biologically sound, environmentally acceptable, and economically feasible.

-- All interest groups with a legitimate stake in the program will have a voice in policy decisions.

-- APHIS will not attempt to usurp the role of the states or the private sector.

-- The three main ingredients of the program will be cooperative operational control, research, and informational and educational efforts.

After a period of losing ground to wildlife damage in some areas, that trend is about to be reversed. We at APHIS know we can't do it alone, however. So let's all work together by latching onto the affirmative and accentuating the positive.

# THE STATUS OF BROMADIOLONE IN THE UNITED STATES

RICHARD M. POCHÉ, Chempar Products, Lipha Chemicals, Inc., New York, New York.

ABSTRACT: The anticoagulant rodenticide bromadiolone is used throughout the U.S. under a number of trade names. An expanded research program is underway within Chempar to examine the use of bromadiolone in commensal and field rodent control. Data are presented herein on the toxicology, metabolism, secondary hazards, efficacy, and formulation developments with bromadiolone. A new Maki 0.001% liquid bait is being tested and excellent control results obtained against Norway rats (*Rattus norvegicus*), roof rats (*R. rattus*), and house mice (*Mus musculus*). New Maki paraffin blocks containing 50 ppm bromadiolone have been developed and are soon to be on the market. Bromadiolone biogradability in the field and in animal tissues offers promise for expanded label claims for use in urban and field situations.

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## INTRODUCTION

The second-generation anticoagulant rodenticide bromadiolone was first introduced into the U.S. market in 1980 under the trade name MAKI. Details on its chemical structure and aspects of early development research are presented by Grand (1976) and Meehan (1978).

Summaries of early bromadiolone field testing in the U.S. were presented by Marsh (1977), Marsh et al. (1980), and Lechevin (1985). Since then, numerous research studies have been completed, most of which have not been published.

In the U.S. bromadiolone was first marketed under the trade name MAKI. Since then, through several licensing arrangements and subregistrations, many end-use baits containing the compound are now available in the PCO and consumer markets. Table 1 lists those trade names currently marketed and containing 0.005% of the compound.

Table 1. Products marketed in the U.S. containing bromadiolone.

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### Commercial Bromadiolone Products

- Maki Rat and Mouse Meal Bait
- Maki Paraffinized Pellets
- Maki Rat and Mouse Bait Packs (Pellets)
- Maki Paraffin Blocks
- Rat Arrest
- Mouse Arrest
- Contrac Rat and Mouse Bait
- Blitz One Feeding
- Rat Flip One Feed
- Mousebuster
- Ratfree
- Chacon One Shot Rat and Mouse Killer
- Just One Bite Rat and Mouse Bait
- Pied Piper Rat & Mouse Bait Packs (Pellets)
- Last-Stop Rat and Mouse Bait Packs (Pellets)
- NCH Paraffinized Pellets
- Rat-Tat-Tat II Rat and Mouse Bait Packs (Pellets)
- Starbar Trax-One

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As a second-generation anticoagulant, bromadiolone is more active than products such as warfarin and chlorophacinone. Bromadiolone, however, is less toxic than brodifacoum and difenacoum. A summary of toxicity information on rodents and key domestic and wildlife species is presented in Table 2. The compound is not very soluble in water (19 ppm) (Lipha, undated). Data on bromadiolone toxicity to fish are given in Table 3.

Table 2. Toxicity of bromadiolone to various rodents, domestic animals and wildlife (Anon.)

Species	LD-50	LC-50
House mouse	1.750 mg/kg	--
Norway rat	1.125	--
Pine vole	3.900	--
Dogs(1)	15.000	--
Cats	25.000	--
Rabbit (oral)	1.000	--
Bobwhite quail	138.000	62.0 ppm
Mallard	--	110.0

(1) Maximum tolerated dose of 10 mg/kg. LD-50 is an estimate.

Table 3. Toxicity of bromadiolone to aquatic organisms.

Species	LC-50 (mg/L)		
	24 hrs.	48 hrs.	96 hrs.
Daphnia	8.8	0.24	--
Rainbow trout	3.9	2.4	1.4
Bluegill sunfish	4.4	4.1	3.0

## FIELD TRIALS

Numerous field trials have been conducted through the U.S. to control commensal rodents with MAKI. Table 4 (Marsh et al. 1980) outlines major studies completed in the U.S. to support bromadiolone registration by the Environmental Protection Agency. As the efficacy data illustrate, the compound is very effective in reducing rodent numbers in various regions of the country.

Table 4. The results of field trials conducted for several rodent species with Bromadiolone (MAKI) in the U.S. (Marsh et al. 1980).

Species	Site	State	Efficacy (% mortality)
Norway rat	Horsebarn	New York	> 75%
	Grain elevator	Texas	70-80%
	Chicago Inner City	Illinois	86%
	Commercial buildings	California	99%
	Hog farm	Ohio	85%
	Farm home	Wisconsin	Near 100%
	Store	New Jersey	100%
	Feed lot	Nebraska	95%
	River bank	Minnesota	Near 100%
	Poultry farm	N. Carolina	89%
Norway rats & House Mice	Vacant lot	Massachusetts	> 90%
	Apartment bldg.	Massachusetts	> 90%
Norway rats & House Mice	Farm home	Wisconsin	68-85%
	Grain mill	Wisconsin	Near 100%
Roof rat	Residential block	Florida	100%
	Hospital	Texas	100%
	Residential block	California	100%
	Feed lot	California	85%
House mouse	Store room	New Jersey	100%
	Apartments	Massachusetts	Near 100%
	Home	Wisconsin	100%
	Grain mill	California	Near 100%
	Barn	Florida	> 75%
	Old field	Florida	> 90%
	Univ. campus bldg.	Kansas	Near 100%
	Office bldg.	Texas	Near 100%
Warehouse bldg.	Texas	Near 100%	



A more recent study by Salmon et al. (1984) resulted in a 96% rodent population reduction on a dairy farm. Table 5 outlines research completed on field rodent species throughout the U.S. The compound is very good at controlling virtually any pest species. Meehan (1985) reported on the good palatability of bromadiolone making it readily accepted by rodents.

Table 5. The results of field trials using Bromadiolone to control key field rodent species.

Species	Concentration	Site	State	Researcher	Efficacy(%)	Notes
Columbian Ground Squirrel	500	pasture	Montana	D. Sullivan	90.3	Handbait
	50	pasture	Montana	D. Sullivan	95	Bait Station
	50	pasture	Washington	L. Askham (1985)	70-80	Mid-Season
					100	Late-Season
California Ground Squirrel	200	pasture	California	R. Baker	78-91	Handbait
	50	pasture	California	R. Baker	79-80	Handbait
Pocket Gophers	300	pasture	California	R. Baker	62	Handbait
	400	pasture	California	R. Baker	62	Handbait
	500	pasture	California	R. Baker	85	Handbait
	175	clearcut	California	Tunberg et al(1984)	100	Handbait
Wood Rat	50	indoor	California	R. Baker	100	Buildings
	50	outdoor	California	R. Baker	100	
Meadow Voles	50	orchard	Washington	R. Hunter	100	
	50	orchard	Virginia	R. Byers	71	
	50	orchard	New York	Richmond and Miller (1980)	100	

Ground squirrel control ranged from 70 to 100% and varied according to time of application and species controlled (Table 5). Pocket gopher control results were more variable. Results using bromadiolone in a study by Tunberg et al. (1984) demonstrated that the rapid reinvasion of pocket gophers may hamper control efforts if made on a localized basis.

Vole control using MAKI ranged from 71 to 100% (Table 5). Research by Byers (1978, 1979, 1981), Byers et al. (1982), and Steblein et al. (1983) demonstrated the compound to be relatively consistent in reducing orchard mice problems. A major factor affecting efficacy is that of bait acceptance which varies in various parts of the U.S. No one formulation can meet all the needs within pest control.

#### FORMULATIONS

Currently MAKI is marketed as pellets, meal bait, and paraffin blocks. Several grain formulations are currently being tested. Submission of the registration support data is scheduled for late 1986. Two products which show promise are MAKI SOL and the new MAKI PARAFFIN BLOCK.

#### Liquid Bait

A 10 ppm end-use MAKI liquid bait is near test completion. When registered, the product will be sold under the name MAKI SOL and will be available in a liquid concentrate of 0.011% bromadiolone. Table 6 presents the result of laboratory testing of MAKI SOL against Norway rats and house mice. In rats, 100% mortality was achieved with a 5-ppm liquid bait; however, 10 ppm was required to attain the same level of control in mice. Dye-free baits increased acceptance significantly.

Table 6. Liquid MAKI bait laboratory evaluations using various concentrations (tap water as controls) and following EPA test protocol.

	Test no.	Days exposed	Color	Concentration (ppm)	Mortality (deaths/total)
<b>Norway rats</b>					
	84006	14	Red	50	25/25
	85004	12	Red	50	10/10
	85006	13	Red	10	8/10
	85006-B	9	Clear	10	20/20
	85009	8	Clear	5	10/10
<b>House mice</b>					
	85008-B	6	Clear	10	10/10
	85008-A	7	Clear	5	7/10
	85010-A	8	Clear	10	20/20
	85010-B	7	Clear	10	20/20

Field testing of MAKI SOL was completed in California (R. Baker, unpubl.). Table 7 summarizes the results with over 95% efficacy after 6 days and up to 99% after 12 days when used against roof rats (*Rattus rattus*). Additional test results are given in Table 8, again demonstrating the excellent control against three commensal species.

Table 7. Results of a field trial using MAKI SOL (50 ppm bromadiolone) liquid bait to control roof rats in a hay shed near Fullerton, California (R. Baker, unpubl.).

Census type	Efficacy (percent reduction)	
	Days after bait provided	
	6	12
Untreated water	95.7	99.7
Dry census bait (mash)	95.9	90.9
Electric counter	96.0	98.0

Table 8. Test data using 10 ppm MAKI SOL (liquid bait) to control three rodent species in a barn-type enclosure (R. Baker, unpubl.). Water consumption, census ration and electric counters were used to estimate efficacy.

Species	Number of test animals	Efficacy (% mortality)
House mice	40	100%
Norway rats	20	80%(1)
Roof rats	20	100%

(1) Test still in progress.

#### Paraffin Blocks

During 1985 a new paraffin block containing 50-ppm bromadiolone was developed. Test results are presented in Table 9. In Norway rats and house mice, acceptance was near 50% for both species, while acceptance of the incubated bait averaged in the range of 39%. Mortality in the test animals was 100%. Regional field testing is currently being organized for the three commensal species. It is anticipated that this new formulation will be available by early summer.

Table 9. Laboratory test results with a new 0.005% bromadiolone paraffin bait formulation used against Norway rats and house mice in standard EPA choice tests.

	House mice		Norway rats	
	1	2	1	2
<b>Unincubated bait</b>				
Test no.				
Acceptance(1)	52.6%	48.3%	48.6%	49.4%
Mortality(2)	20/20	20/20	20/20	20/20
<b>Incubated bait (100°F, 100% humidity x 15 days)</b>				
Acceptance	35.7%	38.2%	42.7%	37.7%
Mortality	20/20	20/20	20/20	20/20

(1) Test bait consumption / Test and placebo consumption

(2) No. rodents died / No. rodents in test

#### Pelleted and Meal Baits

In laboratory tests recently completed, MAKI was compared to other rodenticide products on the market. In these tests, a new MAKI pellet formulation attained an acceptance of 71.3% in males and 68.1% in female Norway rats and 100% mortality. Tests using the MAKI MEAL BAIT had an average acceptance of 50.8% (44.8-58.6) with 100% mortality when used against house mice. A study by Frantz (1982) showed MAKI baits to be highly palatable to Norway rats with acceptance results of 56.6% and 67% in two pelleted formulations. A summary of these results is presented in Table 10.

Table 10. Test results from 1985/86 using MAKI formulations against Norway rats and house mice.

	% Acceptance (1)			Mortality (2) (deaths/total)
	M	F	C	
<b>Norway rats</b>				
MAKI Pellets	71.3	64.0	68.4	20/20
MAKI Meal	61.2	48.4	54.6	20/20
<b>House mice</b>				
MAKI Pellets	26.7	57.2	43.6	20/20
MAKI Meal			50.8	40/40

(1) M=male, F=female, C=combined sexes

(2) No. rodents died / No. rodents in test

#### RESISTANCE TESTING

Historically, secondary-generation anticoagulants have been marketed as a tool to control warfarin- or cross-resistant rats and mice. As with resistance in most pest species, a compound that is too toxic may result in other environmental problems, while a product with less potency may control rats adequately but might be less susceptible to mice (Marsh 1977).

Early resistance testing results in the U.S. are presented in Table 11 and show Norway rats to be very susceptible to bromadiolone. Additional research on resistance was completed by Frantz (1982). Summary data (Table 12) from a study completed in Chicago demonstrated that a resistant Norway rat population could be reduced by 85.5% by using MAKI (Ashton and Jackson 1979).

Table 11. Laboratory tests using 0.005% bromadiolone bait fed to anticoagulant resistant Norway rats.

Test type	Resistance Type <sup>1</sup>	Sex	Number test animals	Consumption (g) Challenge	Test	Mortality (deaths/total)	Source
No-choice (6-day)	W	M	7	--	91.6	7/7	BGSU <sup>2</sup> , unpubl.
	W	F	10	--	80.4	10/10	
Choice (15-day)	C	M	10	146.9	15.9	7/10	BGSU, unpubl.
	C	F	10	123.9	21.9	10/10	
No-choice (6-day)	C	M	5	31.0	73.0	5/5	BGSU, unpubl.
		F	5	70.5	30.2	5/5	
		F	5	29.1	61.6	5/5	

<sup>1</sup>W=Warfarin resistant; C=Cross-resistant

<sup>2</sup>Bowling Green State University, W. B. Jackson

Table 12. Results of a field trial using 0.005% MAKI in an area of Chicago to control anticoagulant resistant rats. Approximately 71% of the rodent test population was considered resistant (Ashton and Jackson 1979).

	Number premises surveyed	Percent premises infested	Number of applications	Efficacy (% mortality)
Test 1 (Talon)	137	65	3	77.7%
Test 2 (Maki Pellets)	108	59	1	41.7%
Test 3 (Maki Meal)	128	59	3	85.5%
Control	168	64	-	-2.5%*

\*% change

House mice are more difficult to control with anticoagulants. In France, laboratory tests using resistant mice revealed bromadiolone to be effective, as outlined in Table 13 (Lorgue, unpubl.). Tests recently completed in the U.S. (Table 14) resulted in 85% mortality in the resistant mice.

Table 13. Laboratory tests using 0.005% bromadiolone bait against house mice (Mus musculus) from France (Lorgue unpubl.).

Test type	No. test mice died / Total test mice	
	Males	Females
Nonresistant	Tank	
	27/27	15/15
	22/22	17/17
Individual Cages	11/11	6/6
	6/6	6/6
Totals	66/66	44/44
Warfarin-resistant	Tank	
	20/20	20/20
	17/17	17/17
Cages	3/3	11/12
	7/8	3/4
Totals	47/48	57/59

Table 14. Laboratory tests from February 1986 using MAKI (50 ppm) bait to control warfarin-resistant house mice (Ashton, unpubl.).

	Acceptance (percent)	Mortality (deaths/total)
Males	31.7	10/10
Females	37.0	7/10
Combined	34.35	17/20

Reports by Lund (1984) and Siddiqi and Blaine (1982) indicate the potential for house mice to develop resistance to bromadiolone after extended use.

#### NONTARGET HAZARD POTENTIAL

Of concern in the use of rodenticides is not only the activity, or toxicity, of a compound to various target species, but also its potential effect on domestic animals and wildlife (Poché and Sharp 1986). Toxicosis to rodenticides may occur by animals feeding directly on the bait or by consuming toxic-laden target species. Since anticoagulants have a delayed mode of action when compared with acute products, the tendency is increased for a rodent to accumulate a toxic load greater than the required lethal dose. Therefore, factors such as dose level (ppm) in the baits, methods of application, timing and rate of application of the bait, carriers and bait type, metabolism of the compound in biological systems, and fate of the product in the environment contribute to the potential impact of its use. A combination of factors interact in determining the fate of a compound in a target species. Data on residue levels, degradation, half-life, and metabolism of rodenticides are but a few important considerations in determining the relative safety of a product.

With bromadiolone, within 4 days after ingestion by rats, over 89% of the compound is eliminated through the feces via the bile duct (Table 15). Of the amount excreted, about 90% of the bromadiolone degrades into metabolites.

Table 15. Elimination of 14-C bromadiolone from rats in percentages of the dose administered. Test rats were gavaged with 5 mg/kg body weight bromadiolone (Lipha, unpubl.).

	Day				Total
	1	2	3	4	
Feces	58.90	20.25	8.65	1.30	89.10
Urine	0.42	0.19	0.06	0.07	0.74
Total	59.32	20.44	8.71	1.37	89.84(1)

(1) Only 10% was bromadiolone. Remainder was degraded metabolites.

Once a rodent ingests a rodenticide, the chemical is assimilated into the system and residue levels may appear in various tissues. Carbon-14 labeled bromadiolone studies in rats, demonstrated that within 48 hours after intubation, residue levels degraded within various body tissues an average of 61% (Table 16). The breakdown was most rapid in the carcass (81%) and slowest in fat tissues (27%) 46 hours later (HRC 1977).

Table 16. Concentrations of 14-C labeled bromadiolone (BDN) in rat tissues at 2 and 48 hours after intubation with 5 mg/kg of the compound (HRC 1977).

Organ	Concentrations of BDN in micrograms per gram of organ (ppm)	
	2 Hrs. (n=2)	48 Hrs. (n=4)
Liver	43.50	20.54
Kidneys	3.53	1.36
Lungs	1.60	0.49
Heart	1.25	0.25
Muscle	0.37	0.15
Fat	3.04	2.22
Carcass	5.95	1.11

Studies on bromadiolone tissue concentrations in Japanese quail (*Coturnix japonica*) over time were completed in the United Kingdom (Table 17). Adult birds, averaging about 235 g in weight, were gavaged with 1000 mg per kg body weight. At time intervals of 1, 2, 4, 7, 14 and 56 days after intubation four birds were sacrificed. The legs were removed at the hock joint and discarded, the birds plucked, and the whole carcass examined by HPLC for levels of bromadiolone. The average residue level was 286.5 ppm after 1 day. By day 4, the figure dropped to 0.19 ppm and after 7 days the birds contained an average of 0.065 ppm bromadiolone in the tissues. Extrapolation of these revealed the half-life of bromadiolone in quail tissues is about 4.5 days.

Table 17. Determination of tissue concentration of bromadiolone (BDN) in Japanese quail after a single oral dose of 1000 mg/kg (HRC 1980).

Sampling time (days)	Amount of BDN in tissue (ppm)
1	286.500
2	2.250
4	.190
7	.065
14	.092
56	.050(1)

(1) Limit of detection

A study with owls by Mendenhall and Pank (1980) demonstrated the hazard potential of using anticoagulants in field situations. Although laboratory studies do not always indicate a true picture of what one might expect in the field, such data are necessary to determine the "potential" hazard to nontarget animals.

As part of their study, Mendenhall and Pank (1980) fed bromadiolone-killed rats to barn owls (*Tyto alba*) (Table 18). The birds were fed only treated rats for periods of 1 to 10 days. Mortality was observed in one of the six owls which consumed bromadiolone-killed rats for 10 consecutive days during which it consumed 463 grams of rat tissues. Although one might interpret these data as being evident that bromadiolone is a potential hazard to raptors, one has to examine carefully the probability of a wide-ranging avian species to consume only bromadiolone-killed rodents for 10 consecutive days.

Table 18. Secondary toxicity of bromadiolone to barn owls (Mendenhall and Pank 1980).

Days Dosed	OWLS		RATS OFFERED		RATS EATEN			INTOX.
	Wt(g)	Sex	Total wt	Dose (mg)	Total wt(g)	Livers	Intestines	
1	460	M	118	2.65	52	1	0.8	-
3	450	M	358	6.60	281	3	3	-
3	425	M	228	3.96	146	3	2.8	-
6	490	M	625	11.11	295	5	4	-
10	540	F	1106	14.59	576	7.8	4.5	-
10	635	F	710	9.63	463	8.5	5.2	D(11)

The potential hazard bromadiolone poses to avian species is low (Grolleau and Lorgue 1984). As listed in Table 2, for example, the acute LD-50 of bromadiolone in bobwhite quail is 138 mg per kg. For a 50-ppm bait this translates to about 2.76 kg of MAKI. The propensity for bromadiolone to accumulate in avian tissues is not evident, as demonstrated in the rapid metabolism of the compound in Japanese quail.

A laboratory secondary hazard evaluation of bromadiolone was conducted in adult coyotes (Canis latrans) (Marsh, unpubl.). Fifty-ppm bromadiolone oat bait was fed to California ground squirrels (Spermophilus beecheyi) for 3 days in a choice test. As the test squirrels died, each was frozen and later fed to coyotes conditioned to feed on the sciurids. Each of four adult coyotes was fed one bromadiolone-killed squirrel daily for 5 consecutive days (Table 19). The protocol followed EPA recommendations for a worse-case situation in which in the canids consumed only rodenticide-killed squirrels. The coyotes were observed for 30 days posttreatment during which time none of the test animals died. Two, however, exhibited a reduction in food consumption, which returned to normal after 8 and 16 days into the observation period.

Table 19. Results of feeding bromadiolone-killed ground squirrels to adult coyotes (Canus latrans) for 5 consecutive days with no other food provided (UCD(1), unpubl.).

Animal Number	Sex	Weight (kg)	Wt. (g) of squirrels consumed	Toxicant (mg) consumed by squirrels	Toxicant (mg) consumed by coyotes	Results
B-1	M	13.6	3,199	22.5	18.0	Survived; no symptoms
B-2	F	7.9	2,165	22.5	15.75	Survived; feeding reduced 16 days
B-3	F	10.4	3,445	22.5	22.5	Survived; feeding reduced 8 days
B-4	M	7.5	3,133	22.5	22.5	Survived; no symptoms

(1) University of California, Davis; Rex Marsh, principal investigator

As with avian species, the potential secondary hazard of bromadiolone to coyotes is extremely low. In this study, which simulated exclusive feeding on bromadiolone-killed squirrels, no mortality was observed in adult coyotes.

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#### LITERATURE CITED

- ANONYMOUS. (Undated). MAKI, Bromadiolone rodenticide technical bulletin. Chempar, Division of Lipha Chemicals, Inc. 9 pp.
- ASHTON, A. D., and W. B. JACKSON. 1979. Field testing of rodenticides in a resistant-rat area of Chicago. *Pest Control*:8:14-16.
- ASKHAM, L. R. 1985. Effectiveness of two anticoagulant rodenticides (Chlorophacinone and Bromadiolone) for Columbian ground squirrel (Spermophilus columbianus) control in eastern Washington. *Crop Protection* 4:365-371.
- BYERS, R. E. 1978. Performance of rodenticides for the control of pine voles in orchards. *J. Amer. Soc. Hort. Sci.* 103:65-69.
- BYERS, R. E. 1979. Results of pine vole control studies in 1978. *Proc. 3rd Pine and Meadow Vole Symposium*:64-76.
- BYERS, R. E. 1981. Pine vole control with anticoagulant baits in apple orchards. *J. Amer. Soc. Hort. Sci.* 106:101-105.
- BYERS, R. E., M. H. MERSON, and S. D. PALMATEER. 1982. Control of orchard voles with broadcast baits. *J. Amer. Soc. Hort. Sci.* 107:613-619.
- FRANTZ, S. 1982. Paired preference efficacy evaluation of Maki peiletized baits. NY State Dept. of Health Report. 27pp.
- GRAND, M. 1976. Experimental results on a new anticoagulant rodenticide-bromadiolone. *Phytiatric-Phytopharmacie* 25:69-88.
- GROLLEAU, G., and G. LORGUE. 1984. Secondary toxicity of an anticoagulant rodenticide-bromadiolone - for the common buzzard (Buteo buteo) - Experimental study. *In: The International Symposium of Ectotoxicology. Les Arcs, Savoy. 12-14 Dec. 1984.*
- HUNTER, K. 1983a. Determination of coumarin anticoagulant rodenticide residues in animal tissue by High-Performance Liquid Chromatography. I. Fluorescence detection using post-column techniques. *J. of Chromatography* 270:267-276.
- HUNTER, K. 1983b. Determination of coumarin anticoagulant rodenticide residues in animal tissue by High-Performance Liquid Chromatography. II. Fluorescence detection using ion-pair chromatography. *J. of Chromatography* 270:277-283.

- HUNTINGTON RESEARCH CENTRE. 1980. Determination of tissue concentrations of bromadiolone in Japanese quail after a single oral dose (1000 mg/kg). HRC, unpublished report. 36 pp.
- HUNTINGTON RESEARCH CENTRE. 1981. The metabolism of 14C-LM-637 (Bromadiolone) in the rat (Interim Summary Report). Unpublished Huntington Research Centre Report. 8 pp.
- LECHEVIN, J. C. 1985. Bromadiolone. Lipha, unpublished report. 42 pp.
- LIPHA. (Undated). Bromadiolone. Technical bulletin. 18 pp.
- LIPHA. 1977. Fate of bromadiolone (LM-637) in the rat urinary and fecal elimination. Lipha, unpublished report. 11 pp.
- LOGUE, G. 1981. Bromadiolone rodenticide on semolina. National Veterinarian School of Lyon, unpublished report. 15 pp.
- MARSH, R. E. 1977. Bromadiolone, a new anticoagulant rodenticide. EPO Bull. 7:495-502.
- MARSH, R. E., W. E. HOWARD, and W. B. JACKSON. 1980. Bromadiolone: a new toxicant for rodent control. Pest Control 8:22-26.
- MEEHAN, A. P. 1978. Rodenticidal activity of Bromadiolone - a new anticoagulant. Proc. 8th Vertebrate Pest Conference. pp. 122-126.
- MENDENHALL, V. M., and L. F. PANK. 1980. Secondary poisoning of owls by anticoagulant rodenticides. The Wildlife Society Bulletin 8:311-315.
- POCHÉ, R. M., and R. SHARP. 1986. Vole control in the eastern United States. Proc. 2nd Eastern Wildlife Damage Conference, September 22-25, 1985. Raleigh, N.C. pp. 52-59.
- RICHMOND, M. E., and P. N. MILLER. 1980. Field evaluation of candidate rodenticides. Proc. 4th Eastern Pine and Meadow Vole Symposium: 78-87.
- SALMON, T., W. P. GORENZEL, R. E. MARSH, and G. HUTTON. 1984. Rodent control down on the farm. Pest Control Technology 12(1):52,54.
- SIDDIQI, Z., and W. D. BLAINE. 1982. Anticoagulant resistance in house mice in Toronto, Canada. Pest Management:10-14.
- STEBLEIN, P. F., P. N. MILLER, and M. E. RICHMOND. 1983. Efficacy of spring broadcast rodenticides in the Hudson Valley, N.Y. Proc. 7th Pine and Meadow Vole Symposium:19-24.
- TUNBERG, A. D., W. E. HOWARD, and R. E. MARSH. 1984. A new concept in pocket gopher control. Proc. 11th Vertebrate Pest Conference. pp. 7-16.



# A REVIEW OF BRODIFACOUM EFFICACY IN THE U.S. AND WORLDWIDE

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## INTRODUCTION

It was just over 10 years ago with the paper by Hadler and Shadbolt (1975) that a series of novel anticoagulants, which included brodifacoum, was announced. Today, after a decade of brodifacoum study and experience, the value of this compound in vertebrate pest management, particularly in rodent control, can scarcely be questioned. In order to most effectively build upon this experience, a thorough review of the literature for the period of 1975 to 1985 was undertaken to also include much unpublished information available to the authors.

Undoubtedly to a greater extent than any other new vertebrate pesticide, brodifacoum has been the subject of extensive testing and development around the world. This research has included much original work by scientists within ICI since 1975 with the acquisition of rights to brodifacoum and related compounds, in the areas of efficacy, toxicity, hazard determinations, formulation development, and new application techniques. Supporting open, responsible research and publication in the scientific literature, ICI has provided brodifacoum samples to, and maintained close liaison with, various government, university, and other research groups in the United States, England, and elsewhere. These efforts and resulting publications in recognized journals and proceedings have served to stimulate, coordinate, and add to the rapidly growing body of scientific knowledge about this compound. Laboratory characterizations led to field trials, and the confidence and results derived from such testing allowed in due course for registrations of brodifacoum as a vertebrate toxicant in many countries. Then other but equally valuable data sets could emerge for documentation. These are concerned with the practical experience with a chemical tool in actual large-scale use.

A number of conferences or symposia have also been convened or sponsored by ICI to supplement the few regular symposia on the subject, and to provide an open forum on vertebrate pest management, including discussions of brodifacoum research findings. Examples are an International Public Health Seminar, in Surrey, England, in 1979; a symposium entitled "The Organization and Practice of Vertebrate Pest Control," held in Hampshire, United Kingdom, in 1982 (Buckle 1983); and a conference, Rodent Control in the Tropics, held in London in 1983 (McDonald 1983). Proper concern and attention have been given by ICI and other researchers to determining environmental and nontarget animal impact of brodifacoum use (Kaukeinen, 1982, 1984b; Hegdal et al. 1984; Godfrey 1985). As with all available vertebrate pest toxicants, brodifacoum can be toxic to other organisms if misused or accidentally ingested. Formulation developments and new application techniques, to be later discussed, can reduce hazard and improve selectivity by taking advantage of brodifacoum's unique properties.

The discovery of brodifacoum in England as first published in 1975 (Hadler and Shadbolt) was quickly followed by reports concerning its characterization and promise in the area of rodent control. While initial reports concerning a "new development in rodent control" were concerned with difenacoum, a related compound in the Hadler series, published work on brodifacoum in England by Hadler and the staff of the UK Ministry of Agriculture, Fisheries and Food soon followed (Redfern et al. 1976, Rowe and Bradfield 1976, Anon. 1978). These studies characterized the properties of brodifacoum against those most predominant of rodent pests, the commensal species Rattus norvegicus, Rattus rattus, and Mus musculus. Research began soon after in the United States and elsewhere on these and other species. Such work, including further commensal studies from MAFF, such as Rowe et al. (1978), was the subject of an extensive review by Dubock and Kaukeinen (1978). That first major review of brodifacoum encompassed 25 species, involved work in 14 countries, and contained 38 references.

Additional reviews or general articles that summarized brodifacoum's characteristics or that touched upon further findings soon followed (e.g., Hadler 1979, Dubock 1980, Anon. 1981b, Hone and Mulligan 1982, Renapurkar and Kamath 1982, Meehan 1984, Lund 1985); however, these were not comprehensive, prompting the current review. Prior reviews did indicate the basic properties of the compound, which are now generally familiar, and provided a framework for an update.

## PROPERTIES OF BRODIFACOUM RODENTICIDE

1. Same mode of action and antidote as other anticoagulants.
2. Highly active against a broad spectrum of pest species.
3. Efficacious with limited feedings, including against rodents resistant to other anticoagulant rodenticides.

4. Palatable, active, stable and otherwise amenable to conventional incorporation in baits.

This review is organized in a fashion similar to the above listing, first covering brodifacoum activity, formulation development, and palatability in the laboratory, followed by efficacy in both the laboratory and field worldwide within specific pest problem areas for both commensal and agricultural species. A concluding section includes areas for further developments of brodifacoum formulations.

The present review encompasses some 62 pest species, 37 countries, and over 200 published references on brodifacoum efficacy. Published papers reviewed were as determined from review of the existing pest rodent bibliographies (described in Kaukeinen 1986), from a search of ICI-PPD's HARVEST database in the United Kingdom, utilization of the United States' on-line DIALOG system for access to various literature databases, and from searches of personal reprint files and those of associates. Copies of all referenced papers were obtained. This review has also provided an opportunity to include reference to considerable new data and information produced by ICI, or that from elsewhere as kindly provided to the authors, which have not yet been published. The United States has been the scene of principal technical developments of brodifacoum formulations and early registrations for brodifacoum. Also, the States have seen considerable experimental work on their considerable and often unique agricultural problems with noncommensal pest rodent species. Therefore, and in deference to the principal audience of these proceedings, a review of brodifacoum efficacy information for the United States will constitute a separate section.

#### REGISTRATION HISTORY

Beginning in 1978, and following regulatory authority review of both published and unpublished findings, brodifacoum began to receive registrations around the world for rodent control. Initially registered in Indonesia and then the United Kingdom that same year, registration in the United States followed in 1979. Brodifacoum is currently registered in over 40 countries in the form of over 100 separate registrations covering different formulations or product forms. ICI has applied for registrations in a further 50 countries, based on in-house, cooperator, and independent research data.

#### GEOGRAPHIC DISTRIBUTION OF BRODIFACOUM RESEARCH AND EXPERIENCE

Table 1 arranges published references from this review by origin where this criteria is of importance, as in reference to local species and problems, according to a standard convention which comprises 11 world divisions. Appendix 1 gives further information on countries and research areas represented. Brodifacoum efficacy research within the European, South Asian and North American regions has predominated. Although brodifacoum is currently undergoing development and registration as well in regions less represented, the lack of publications for some areas generally follows that noted in a similar analysis of some 20,000 citations relative to general pest rodent biology and control, as published over a 25-year period (Kaukeinen 1986). Exceptions to this distribution for brodifacoum efficacy references from this review are a relatively greater contribution from South Asia and a relatively reduced contribution from Europe than would otherwise be expected (perhaps due in part to the unfortunate recent curtailment of pest rodent research at the United Kingdom Ministry of Agriculture). For the most part, information given in this review and the details in the appendices indicate that some information on the use of brodifacoum as a rodenticide exists in reported form for most world areas, species, and problem situations.

Table 1. Published brodifacoum references from this review arranged by geographic region.

Region	Number	Percent
Europe	30	17
Middle East	3	2
Africa	9	5
South Asia	42	24
Far East	15	8
S. E. Asia	17	9
Oceania	7	4
North America	49	27
Central America	2	1
Caribbean	0	0
South America	6	3
Totals	180*	100

\* Some papers counted in more than one category.

#### COMPARABLE MODE OF ACTION AND ANTIDOTE TO OTHER ANTICOAGULANTS

Considerable pharmacological and other research has documented that brodifacoum has a mechanism of action which is comparable to warfarin and other anticoagulants. This subject is beyond the scope of an efficacy review, but recent examples of brodifacoum pharmacology research are Bachman and Sullivan (1983)

and Breckenridge et al. (1985). Vitamin K<sub>1</sub>, as with other anticoagulants, is an effective antidote. Also, as with other anticoagulants and in spite of brodifacoum's potency to target species, there is a delay to death of normally 4 to 10 days or more. A test with albino Norway rats (ICI, unpubl.) involved intubation of a group of 14 rats with 27 mg/kg, or 100 times an LD50. This resulted in 100% kill with an average day of death of 5.5 (range 3 to 7 days), which is comparable to the time to death seen with lab administration of low doses. The delay to death with some pest species, such as up to 20 to 30 days with Mus (e.g., Lund 1981), can result in misleading study results if brodifacoum test protocols do not ensure an adequate observation period after toxicant exposure.

#### HIGHLY ACTIVE/REDUCED RODENTICIDE REQUIREMENTS

The activity of brodifacoum has been investigated in the laboratory by many researchers, and is summarized in Appendices 2 to 6. These appendices include reference to species strain or source as such differences can be important. For example, Hoque (1983a) noted that R. r. mindanensis from the Philippines showed 1.7 times greater tolerance to warfarin than the same subspecies from Indonesia. Also, where appropriate, these appendices cite the bait formulation tested. Variations in mortality to brodifacoum as observed in these and other studies may result in part from differences in vitamin K content of baits offered, or from other physiological or pharmacological effects after anticoagulant intake as produced by different diets themselves (Colvin and Wang 1974). Also, rodents that may have been recently exposed to sublethal doses of other toxicants, such as zinc phosphide, may subsequently respond differently to anticoagulants such as brodifacoum (Bhardwaj and Prakash 1984).

Appendix 2 lists available acute LD50 figures, Appendix 3 reports subacute LC50 information, Appendix 4 gives lethal feeding periods, and Appendix 5 notes restricted feeding trial results. The LD50 values reported in Appendix 2 encompass 12 genera of rodents, generally of worldwide pest status, and show LD50 values of less than 1 mg/kg against these pests in all cases. For the two lagomorph species as given, LD50s are less than 0.5 mg/kg; the marsupial species represented has an LD50 of 0.2 mg/kg. The variations seen in LD50 values for the same or similar species with brodifacoum (or as noted in the literature for nearly all rodenticides) may be attributable to animal source or strain differences, or result from different experimental approaches and preparations (e.g., see Ashton et al. 1986).

One means to assess the potency of an anticoagulant is to compare LD50 and LC50 values as derived for the same species. For example, warfarin has a high LD50 but a low LC50 value, and is generally considered the least potent of the anticoagulants. Brodifacoum is at the opposite end of the range in the comparability of its LD50 and LC50 values. Thus, it can be noted from Appendix 3, which lists subacute LC50 values, that repeating brodifacoum exposure on successive days until death does not normally decrease the total dose of brodifacoum required to kill in an acute LD50 test. For example, with Bandicota bengalensis and R. norvegicus, the cumulative 4- or 5-day divided dose for an LC50 closely approximates the LD50 as given in Appendix 2.

Only 2 species in Appendix 3 show a lower total for divided daily doses from LC50 derivations as compared to their LD50: Cricetulus and Mus. Fortunately, Cricetulus is a pest in only limited and localized areas. The greater tolerance to all anticoagulants, including brodifacoum, as seen with Mus, can be partially explained by the fact that all available anticoagulants and the new second-generation anticoagulant materials, were developed from basic screening on the Norway rat and therefore are particularly suited to field use against this species. Generally poor efficacy with first-generation anticoagulants against house mice is well known to the extent of precluding their use for this species in some areas. As Appendices 2 to 5 indicate, brodifacoum retains good efficacy against M. musculus, particularly at 50-ppm active concentration in baits.

Regarding lethal feeding period (LFP) data, Appendix 4 suggests that most pest rodent species can be killed with limited exposure to brodifacoum. Six rodent species have LFP98 values reported of less than 4 days, and 2 species have values of less than 11 days. Only Acomys, of species reported, has a high LFP corresponding to its tolerance of anticoagulants in general.

Appendix 5 gives restricted, no-choice feeding exposures of generally 1 to 4 days, further illustrating the reduced need for rodenticidal exposure with brodifacoum. With 50-ppm bait (0.005%) and a 1-day exposure, test groups of 28 species show 100% mortality. Most of the remaining 18 species or subspecies as represented showed either control of 80% or better in a 1-day exposure to 50-ppm brodifacoum, or (particularly with some gerbil and hamster species) 80 to 100% kill after 2 to 3 days of exposure. Appendix 6 gives further verification of broad spectrum pest efficacy and limited bait requirements with the results of just 6- or 12-hr exposures to 7 nonfasted rodent species giving high levels of control.

#### EFFICACY ON RODENTS RESISTANT TO OTHER ANTICOAGULANTS

Resistance in rodents to warfarin and other first-generation anticoagulants during the past 20 years has been ably reviewed by others (e.g., Greaves 1985). Brodifacoum retains efficacy against resistant Norway rats as reflected in Hadler's "resistance factor" comparisons as given in Table 2 (from Hadler and Shadbolt 1975, Dubock and Kaukeinen 1978).

Table 2. *Rattus norvegicus* resistance factors of anticoagulants.

Anticoagulant	Prothrombin ED50 Wistar (mg/kg)	Prothrombin ED50 Homozygous (mg/kg)	Resistance factor (ratio)
brodifacoum	0.08	0.10	1.3
difenacoum	0.17	0.32	1.9
coumatetralyl	0.31	4.4	14.2
chlorophaconone	0.22	>20.0	>90.9
diphacinone	0.22	>50.0	>227.3
warfarin (S-)	0.30	>50.0	>166.7

Lab test data against warfarin-resistant strains of the three common commensal species are included in Appendices 2, 3 and 5. Appendix 5 shows that a 1-day feed on 5-ppm brodifacoum was insufficient against resistant house mice, but that 50-ppm bait gave 90% in a 1-day no-choice feed and 100% after a 3-day feed. Only some Canadian resistant mouse strains (Siddiqi and Blaine 1982a) showed lowered efficacy, at 75% kill with a limited 3-day exposure to 50-ppm bait. For warfarin-resistant Norway rats, a 1-day exposure to only 10-ppm brodifacoum bait gave 100% kill. With warfarin-resistant roof rats, 20-ppm bait gave 80% control in 2 days, whereas 50 ppm gave 100% mortality. Further verification of brodifacoum efficacy on warfarin-resistant strains is given in Rowe and Bradfield (1976), Rennison and Dubock (1978), and Myllymaki (1986). Field trials of brodifacoum against difenacoum-resistant Norway rats in England (Greaves et al. 1982) reported less efficacy against this population than expected for warfarin-susceptible rats. However, these trials were conducted with 20-ppm brodifacoum, whereas 50 ppm is the recommended active concentration for control of commensal species (as well as for most agricultural rodent pests). In some countries, such as Denmark and England, regular anticoagulant susceptibility surveys utilizing laboratory techniques from field captures have continued from prior baseline years through the advent of new anticoagulants, such as difenacoum, bromadiolone, and brodifacoum. Findings suggest a limited resistance to difenacoum, and resistance of a more practical significance to bromadiolone, but there have not been reports of rodent survival with 50-ppm brodifacoum (e.g., Lund 1984b, Lund and Lodal 1986) when challenged in standard laboratory resistance screening tests such as recommended by the World Health Organization (Anon. 1982c).

#### BRODIFACOUM PALATABILITY AND FORMULATION DEVELOPMENT

The rodenticidal properties of a material such as brodifacoum would be of limited value if the active at normal bait strength caused significant taste rejection in baits such that lethal doses would not be ingested. The innate taste of anticoagulants rodenticides is certainly of less importance than with fast-acting acute materials, because of generally lower active concentrations in anticoagulant baits, and due to the delay to death which does not normally result in bait discrimination (or general changes in dietary habits due to poisoning symptoms) for at least 2 or 3 days.

It may be an oversimplification to attribute the normally excellent acceptability of anticoagulant baits to a conclusion that levels of active ingredient in the normal range of 10 to 250 ppm are completely undetectable by rodents. Bentley and Larthe (1959) showed clear differences in the acceptability of several first-generation anticoagulants at normal use concentrations. For example, it was noted that diphacinone showed less acceptance at the same active concentration than warfarin with *R. norvegicus*, whereas the reverse preference was found for *R. rattus*. With brodifacoum, work exemplified by Redfern et al. (1976) with the three commensal species comparing poisoned versus unpoisoned bait consumption found brodifacoum baits somewhat less acceptable than the plain bait base with house mice at 20 and 50 ppm, although both concentrations gave complete kills.

While relative acceptability of brodifacoum-treated versus untreated diets in the literature is generally about equal, variations exist and may possibly be due not only to possible "taste" of the active ingredient, but also to noncomparable test diets in experimental studies. An example would be a blank bait not treated with the same solvents or diluents as the treated bait. In much of the published literature, it is unclear how diets were prepared. In addition, some bait bases may be more effective at "masking" toxicant taste qualities.

Major factors in determining the palatability of a rodenticidal bait are the nature and quality of the ingredients. In much of the world in areas where efficacious rodenticides are needed, expertise in bait development and formulation procedures may be insufficient to safely produce an optimum material with consistently high quality. Brodifacoum in technical and concentrate form requires handling precautions that precludes the "mixing in a pan" approach familiar to users of some other rodenticide concentrate products which may have been available.

It has therefore been necessary to improve the consistency of performance of brodifacoum against pest rodents and to control safety aspects in formulating brodifacoum baits. In some cases, because of special local needs, specific brodifacoum formulations have been developed with ICI assistance for local production. However, ICI has concentrated much internal research effort in developing optimum formulations with novel characteristics that can be commercially produced within the confines of approved contractors for widespread distribution. Formulations developed include the 50-ppm TALON, KLERAT or HAVOC pellet, the 50-ppm TALON or KLERAT wax block, the 30-ppm MATIKUS wax block, and the 10-ppm VOLID pellet. These formulations form the core of the product range in a variety of shapes, colors and sizes according to local preferences, and are exported by ICI to many countries. The ICI formulations have characteristics providing considerable shelf stability (2 years or more), moisture-resistance in the field, and are subject to rigorous quality control assuring consistency from batch to batch. As these registered trade names refer to specific, proprietary ICI formulations, they should not be used to refer to brodifacoum baits made locally by non-ICI personnel (e.g., for research purposes), as the only similarity to ICI baits may be in strength of active.

Appendix 7 gives results of standard acceptability studies of principal ICI formulations with 14 species. Percent acceptance levels of 30 to 80% with generally 90 to 100% kill of test groups were achieved after 3- or 4-day choice exposure versus an attractive blank bait. The ICI pellets are highly acceptable even to agricultural pest species (e.g., lab studies in the USSR showed good palatability of TALON pellets with the great gerbil, Rhombomys opimus, versus corn (Anon. 1980 rept. to ICI). For increased moisture and mold resistance, or to provide a larger "unit feed" appropriate to some baiting strategies (for example, in agriculture), the ICI wax block formulation is useful and highly attractive, even to Mus and microtines not normally expected to accept paraffinized baits (Appendix 7, also Myllymäki 1986, Lund and Lodal 1986). In special circumstances, the wax block formulation may be at advantage in being more difficult for poultry or wild birds to accidentally consume.

#### NEW BAITING STRATEGIES

Brodifacoum baits can be utilized in the field as for conventional first-generation anticoagulants in sustained baiting approaches. The greater cost that toxicants represent in relation to labor for many control situations, and the great potency of brodifacoum itself, have led to the development of "pulsed baiting". This has been ably described by Dubock (1982, 1984b) and also verified in the field as reported by Richards (1983) and others, including the authors of many of the examples used in the following section and several citations from Appendices 8 and 9. Briefly, the application method involves the placement of many small bait placements throughout the infested area. Baits are allowed to be entirely consumed and rodents which fed allowed to die before rebaiting (pulse) is conducted. When such baiting, limited in total quantity but increased in distribution, is conducted at intervals of 1 to 4 weeks, successive "waves" of rodents are poisoned and the total bait requirements are reduced. Trials comparing the older, "sustained" baiting approaches with pulsed baiting have supported these advantages of the latter technique (e.g., Mo and Liang 1984, Hoque and Olivida 1986).

Although pulsed bait methodologies are still undergoing study and refinement (e.g., Richards and Husin 1985), the pulsed baiting method as presently verified has great merit at present, being particularly useful in agricultural or village-wide rodent control campaigns. The method does require coordinated planning and organization to be successful, and must incorporate efforts for more extended monitoring and allowance for rebaiting. The method is especially suited to a compound such as brodifacoum which, although toxic in a single feeding, does not produce poison shyness and so can remain effective after repeated applications. In reducing the total amounts of rodenticide applied, pulsed baiting also reduces potential hazard to those nontarget animals which might directly consume the bait. And as Dubock (1984b) reports, pulsed baiting also reduces the toxic residues in target rodents over that produced from sustained baiting, and so may offer less hazard to potential secondary feeders, such as birds of prey.

#### VERTEBRATE PEST PROBLEM AREAS

Problems with commensal vertebrate pests in villages and cities are essentially universal, as are agricultural pest attacks to stored crops and commodities, damage to structures, and losses in crops and in domestic animal production. No fewer than 25 separate rodent problem areas have related brodifacoum efficacy work represented in the materials upon which this review was based. It is not possible to discuss each area and all relevant literature in detail within the confines of this review. Accordingly, only a few major areas representative of the diversity of pest problems and the corresponding utility of brodifacoum will be covered through the use of selected examples from the literature. Further details and a listing of reviewed published efficacy trials, as well as much unpublished work, are contained in the appendices, and in the U.S. efficacy section to follow.

#### COMMENSAL PEST FIELD EFFICACY TRIALS

##### Urban Rodent Control

City trials have generally been conducted by government authorities or representatives responsible for rodent control, frequently with the objective of reducing rodents as known or potential disease vectors. Urban pest species generally include any or all of the three main commensal species, R. norvegicus, R. rattus, and M. musculus.

Sao Paulo, Brazil, is a city of some 12 million people, containing pockets of makeshift habitations termed "favelas" heavily infested with commensal species. A smaller favela with a population

of about 300 people in 56 dwellings was the subject of a brodifacoum trial (Richards 1986a). Two 50-ppm brodifacoum blocks were applied in each room, inside active burrows where possible. Two applications at a 14-day interval gave a rodent activity reduction of 98% utilizing tracking patches. Aleppo, Syria, is a city of some 1.3 million people. Richards (1986a) reports the organizing of the city into 12 districts, each further divided into 12 zones, allowing each zone to be baited by project staff in 1 day and a complete district in every 4 weeks. Six baiting teams were involved and a pilot project involved premise inspection and baiting in active areas with brodifacoum pellets or blocks. Evaluation teams used tracking patches before and after treatment to determine rat activity. Use of brodifacoum in the test district resulted in 92% reduction of activity 12 days after the second bait application.

Brodifacoum trials in Zhuo Xian, Hebei Province, China (a city of 50,000 people), are reviewed by Richards (1986). The city was divided into 10 areas for the trial. Some 474 technicians were trained and worked under the supervision of 49 technical leaders, with more than 2,000 additional persons in the city assisting in baiting, collecting and disposing of dead rats and distribution of baiting information. Talon was baited inside structures at the rate of 10 to 50g per room in 2 to 5-g covered piles and at two intervals of 5 days. Three independent census methods showed an average reduction of rodents of about 90% after treatment.

Trials with brodifacoum in a town of 18,000 persons were conducted, in Hlegu, Burma. Rodent control teams incorporating governmental health staff conducted thorough surveys of dwellings. Wax brodifacoum baits of 25-g each were placed in active burrows for *B. bengalensis*. Additional blocks were placed in bait stations inside homes to control other species (*R. rattus*, *R. exulans*, *M. musculus* and *Suncus murinus*). Census baiting before and after treatment showed that 73% of houses had initial infestations. Only 1.5% of homes showed any signs of rodent activity after the treatment (Richards 1986a).

#### Village and Farm Structures

Small towns, villages, and housing clusters (such as in farming areas) may often experience rodent problems, especially of a seasonal nature, when rodents find less alternate food in surrounding croplands or other habitat and then invade structures to establish a commensal existence. Trials to establish the efficacy of a rodenticide in such circumstances are difficult without an organizational infrastructure present to facilitate a systematic, consistent, thorough and area-wide treatment for rodents. Such research can best give meaningful results when pest immigration and movement effects can be reduced.

Trials in village housing clusters in Bangladesh (Bruggers and Valvano 1981, Rahman and Brooks 1982) evaluated 50-ppm brodifacoum baits during the monsoon season when rodents had deserted plowed fields for higher, inhabited areas. Tracking tiles were placed before and after treatment, and concluding snap-trapping was conducted. Of the compounds tested, brodifacoum gave consistently greater reduction in animal activity in each of the three housing clusters in the evaluations, producing an overall reduction of *R. rattus*, *M. musculus*, and *S. murinus* of 97% from initial activity levels. Baiting rodents around structures was judged easier and more effective than baiting in adjacent field crop situations, and it was recommended to do large-scale village baiting programs during the monsoon season to reduce rodent populations to nondestructive levels by the onset of the dry-season cropping period.

Similar village-level work in Vietnam is reported by Richards (1986a,b). Mai Xa cooperative had a population of about 2,400 persons and 660 dwellings within a mosaic of gardens, rice fields, and canals. Baiting was conducted in February after harvest and before the next rice planting. Much movement of rats, predominantly *R. r. molliculus*, from fields to dwellings was recorded. An organization for baiting was created and 50-ppm brodifacoum wax blocks each weighing 5 g were applied in active village areas. The approximate rate was 15 baits per house, 400 baits per ha garden and 100 baits per ha in adjacent rice fields. Two applications at intervals of 14 days gave a 95% reduction in rodent activity. Subsequent damage estimates to rice showed a significant protective effect from the village treatment.

#### AGRICULTURAL PEST RODENT FIELD EFFICACY TRIALS

The introduction in recent years of high-yielding, improved quality grain and other crop varieties, has resulted in significant commitments to the production of these crops in many countries, both for self-sufficiency and for export. Such crops are often extremely vulnerable to rodent damage at certain crop stages. Rodent control in crop situations under the conditions and needs of modern agriculture is shifting to area- and crop-wide organizational pest management strategies in some countries, relying less on the initiative of individual farmers and growers. New control materials such as brodifacoum and associated new application techniques, such as pulsed baiting, have received considerable interest and evaluation under this new impetus.

Rodenticide evaluation techniques in crop situations as utilized in the subsequent section describing brodifacoum field work have been the subject of previous reviews (e.g., Buckle and Rennison 1986), and such methodologies will not be reviewed here. Suffice it to say that the potential for pest rodent movement and test plot immigration, uneven pest distribution within fields, uneven crop density or attractiveness, crop stage and seasonal effects on infestations, and the laborious needs of most crop damage assessment or pest activity measurements in crops can be listed as some of the difficulties inherent in such work. Particularly important goals are to develop and utilize techniques which allow for ongoing monitoring efforts to determine optimum timing and duration of control efforts, and those which can demonstrate cost benefits of control and the economic threshold of damage. Most of the evaluation examples as described below and in Appendices 9, 11, and 12 also included trials of other anti-coagulant or acute rodenticides. The clear superiority of brodifacoum, often when applied at lower rates, over other materials can be readily determined by a review of the citations given in the following section and corresponding appendices.

## Rice

Rice in Malaysia is the second most important crop (after rubber) and, as elsewhere in much of the southeast Asian area, R. argentiventer is the principal pest, causing 2 to 10% yearly damage (Buckle et al. 1985). Following laboratory evaluations, brodifacoum wax blocks of 50 ppm weighing 5 or 15 grams were applied in Malaysian rice fields under different experimental regimes (Lam 1980, Buckle and Rowe 1981, Buckle et al. 1982). Baiting began before transplanting and effectiveness was measured by the use of census baits applied before and after treatment. The larger blocks gave the best activity reduction (87%) when applied twice a week for 4 weeks. Using the 5 g-blocks, applications weekly for 4 weeks gave 80% reduction, far better than could be achieved with conventional anticoagulants (warfarin) at considerable savings of bait and labor. Other work in Malaysian rice fields (Majid and Chye 1984) found a local 30-ppm brodifacoum wax block product weighing 4 g to also be effective within an overall control strategy.

In the Philippines, initial laboratory studies with brodifacoum and Rattus species infesting rice were described in Anon. (1977). Subsequently, sustained baiting and weekly baiting in the field were compared utilizing 50-ppm brodifacoum in rice bait or wax blocks. Yield losses were reduced by both techniques but the weekly baiting was judged more economical to use (Hoque and Ollvida 1986). Philippine trials with 5-g brodifacoum wax blocks at 50 ppm during the wet season in lowland rice involved an application of 1.24 to 1.71 kg/ha. Damage was significantly reduced and the crop yield was 42% greater than expected (R. Brown, pers. comm. 1985).

In trials of brodifacoum in rice fields in Venezuela, one report (Williams and Vega 1984) concerns Portuguesa State where Holochilus was found to predominate. A 24-ha nonirrigated study area was selected and rodents live-trapped before treatment and trapped again after treatment. Rice was 50 to 60 cm in height at the time of the evaluation and was receiving rodent damage. About 2,000 bait stations were established on dikes and around edges of the study area. Stations were each filled with 30 g of brodifacoum bait, giving a rate of 2.5 kg/ha. Stations were checked regularly and replenished as necessary. Consumption had reached near-zero levels by the ninth day of treatment and stations were removed. Eight days later, posttreatment trapping was initiated until heavy rains prevented further work. A reduction of 89% in rodent captures from initial levels was recorded. A companion report (Williams and Pereira 1984) from Venezuela describes research in another area, this one irrigated and with two Sigmodon spp. accounting for 75% of initial captures, with the remainder Holochilus. A 30-ha site received 900 stations as described previously. Treatment lasted for 7 days and final trapping revealed 100% reduced activity, as no rodents could be recovered. Observations extended until harvest and no damage to the rice from any residual population was observed.

## Sugarcane

A thorough review of rodent problems in sugarcane and evaluations of damage and rodenticide efficacy, including for brodifacoum, is presented by Hampson (1984). It is noted that some 100 countries with a total of about 13 million ha of cane provide 60% of the world's sugar needs annually. Losses from rodents in the range of 10 to 30% are reported common. The crop is a difficult one for baiting and damage evaluations once canes become grown and nearly impenetrable, although many techniques involving crop borders and in-crop transects are described. Bait application strategies to be recommended vary with the area, economics, and pest species present, but theoretical calculations suggest that a yield increase of less than 0.5% can justify rodent control. The susceptibility of a principal cane pest, Sigmodon, to brodifacoum (Gill and Redfern 1980) combined with the properties of brodifacoum, suggest that the compound has much promise for use in cane in the Americas, and will allow for reductions in baiting quantities and intervals needed for rodent control in sugarcane. Hampson reports a trial of brodifacoum in Mexican sugarcane, principally against Sigmodon, in which a trapping index was reduced from 38% capture to zero, 7 days after a single application of 3 kg/ha of 50-ppm brodifacoum bait. In Nicaragua, this species was also reduced in cane following aerial application of 4 kg/ha of 50-ppm brodifacoum bait, based on trapping results before and after treatment. Similar work in Mexican cane is also reported by Humbert (1983) in which only brodifacoum baits of those materials tested reduced trap success posttreatment to zero levels.

In the Far East and Pacific area, trials in cane in Australia involved aerial broadcast of 50-ppm brodifacoum baits against R. sordidus (previously R. conatus). A rate of 1.68 kg/ha appeared more effective than a 0.84 kg/ha rate, and suggested an anticoagulant such as brodifacoum might be a suitable replacement for the more hazardous acute products in general use (Hitchcock et al. 1983).

## Oil Palm

Considerable evaluations of brodifacoum baits, principally involving 30 or 50-ppm wax block formulations of 4 to 20 g, have been undertaken in Malaysia (Khoo 1979, 1980, 1984; Khoo and Dubock 1981), where this major crop suffers about 5% damage yearly equivalent to M\$ 115 million based on 1981 prices. The principal pest species is R. tiomanicus. Trapping or other census methods are difficult in this crop because of the arboreal nature of the environment, which may even necessitate baiting in crowns of trees. The initial trials reported involved 13-g brodifacoum blocks of 30 ppm which were placed at the base of each palm according to different schedules of application. Eight rounds at 3 to 4-day intervals with a total application of 7.5 kg/ha gave 78% reduction in activity as determined from fruit damage surveys and bait-take observations. A similar baiting interval carried for 5 rounds (total 5.1 kg/ha) gave 85% control, and 7-day baiting intervals and 2 rounds (2.3 kg/ha) gave 83% control. Four rounds at 7-day intervals used 5.7 kg/ha and gave 97% reduction. Even a 10-day baiting interval with 3 rounds (5.0 kg/ha) gave 72% control with brodifacoum. These authors also report the successful use of

4-g 30-ppm brodifacoum wax baits placed at the base of every palm in the grid planting system. Taken baits were replaced every 7 to 10 days for 4 weeks for a total application of 2.0 kg/ha. Damage assessments and bait takes revealed a 71% reduced activity at considerable savings in bait and labor over other materials tested. Interval (pulsed) baiting was considered highly suitable for this crop.

#### Fruit Orchards

Fruit orchard damage by rodents occurs in temperate areas in North America, Europe, Africa, Asia, and the Nordic countries, and has been the subject of extensive research efforts. Examinations over the years comparing cultural, mechanical, and chemical control generally have concluded that few alternatives exist to the use of rodenticidal baits, and that baits are generally more economical and preferred by growers, whether used alone or within an integrated management system. Microtines are especially important orchard pests in northern latitudes. In Canada, Bouchard (1978, 1979) found that 9 kg/ha of 50-ppm brodifacoum applied in apple orchards resulted in a 73% vole reduction. In another Canadian study, brodifacoum was considered efficacious in orchard trials when applied in special bait stations which would provide continued opportunities for voles to feed beneath snow cover (Siddiqi 1982, Siddiqi et al. 1983b). While the economy, practicality and effectiveness of bait station use in orchards has not been sufficiently verified in actual use, the approach has merit for areas subject to heavy snows, and also reduces opportunities for accidental feedings by other animals. Myllymaki (1984) suggests application to Finnish orchards after snowfall and directly to vole breathing holes (perhaps in paper or plastic sachets to help protect the bait) to allow feeding and to provide similar protection against nontarget animals. Baiting with brodifacoum in vole burrows in orchards in the Soviet Union resulted in 97% control (Khryanina 1981).

The 10-ppm ICI VOLID pelletized formulation has been found surprisingly efficacious against Microtus, not only in North America but also in Denmark (Lund 1984a) and in Finland (Myllymaki 1984) where it was also judged sufficiently effective against Arvicola, a species normally difficult to control with prepared baits. Multiple-feeding, older anticoagulants have been rejected in Scandinavia due to lack of efficacy (Myllymaki 1984).

#### RODENT THREAT TO INSULAR FAUNA

Old world rodents have become established within many endemic insular faunas, endangering native birds and mammals alike. Proposals have been made to "eradicate" commensal rodents from such islands utilizing rodenticides, especially to protect nesting seabirds, but this approach has been seldom attempted. Vertebrate toxicants generally lack specificity, and no available rodenticides are entirely pest rodent-specific. Selectivity can be enhanced with special formulations and application strategies. Good results have been obtained with brodifacoum in insular situations against pest rodents where other small mammals were absent. Brodifacoum was one of two rodenticides evaluated to remove rats from islands in New Zealand. Wax blocks and a specially prepared paste of brodifacoum (rodenticidal forms not readily taken by birds) successfully removed rats on three of four islands (Moors 1984). Successful experiences on the Galapagos Islands with Talon for rat control have also been reported (Coulter et al. 1982).

#### BRODIFACOU DEVELOPMENT AND EFFICACY RESULTS IN THE UNITED STATES

Much of the early research in determining and verifying the characteristics of brodifacoum was conducted in the United States, including efficacy to warfarin- and pival-resistant Norway rats (Dubock and Kaukeinen 1978) and warfarin- and diphacinone-resistant roof rats (Ecke and Lewellan 1979) in the laboratory. Table 3 gives additional unpublished U.S. data on warfarin-resistant Norway rats and house mice.

Table 3. Efficacy of Talon to warfarin-resistant rats and mice in the laboratory.

Treatment	Concentration	Length of feeding	Average dose (mg/kg)	Kill
HOUSE MICE				
Warfarin	250 ppm	no-choice 21 days	970.4	8/29
Talon	50 ppm	choice 3 days	12.9	10/10
NORWAY RATS				
Warfarin	60 ppm	no-choice 6 days	NA	0/20
Talon	50 ppm	choice 3 days	3.5	19/20*

\* one nonfeeder survived (from S. Frantz, pers. comm., June 1977).



## COMMENSAL RODENT TRIALS

The experimental use permit allowed by the U.S. Environmental Protection Agency (EPA) for 20,000 pounds of 50-ppm brodifacoum in the pelletized formulation TALON, generated over 235 trials around the United States with commensal rodents in a variety of industrial, residential, commercial, and agricultural situations (Anon. 1979b, Kaukeinen 1979a). The pest control industry and the National Pest Control Association in the United States were instrumental in these field characterizations, providing verification of product utility. Nearly 75% of respondents considered their trial results with TALON as producing "good" to "excellent" results, even though the material was often evaluated only on problem accounts. Appendix 10 lists representative data for those additional 35 ICI-conducted commensal TALON trials in cities, villages, and farms as submitted to EPA as product performance data for the three U.S. commensal species in support of TALON and WEATHERBLOK registrations. These trials were conducted according to standardized protocols as described by Kaukeinen (1979b). Since the U.S. registrations for brodifacoum rodenticidal formulations, over 12 million pounds of these products have been sold in the U.S.

In the United States, published reports of urban trials with brodifacoum are noted for Cleveland, Ohio (Marsh 1979); Chicago, Illinois (Anon. 1982a, Ashton and Jackson 1979); New York City (McClelland 1979); Trenton, New Jersey (Anon. 1982a); Lincoln, Nebraska (Anon. 1979c); and as reported in appendix 10, for a city sewer trial in Ohio and a business building trial in Colorado. Most urban trials involved outside baiting in burrows around structures. Field trials against roof rats in a warfarin- and diphacinone-resistance area of Saratoga, California (Ecke et al. 1979), utilized baiting with 50-ppm paraffin brodifacoum blocks on utility poles, giving effective control.

During the period 1972 to 1982, warfarin-resistance was determined from field-collected rat samples from federally funded cities by the Bowling Green, Ohio, and the Troy, New York, Resistance Testing Laboratories, and recommendations made for cities to discontinue use of anticoagulants when resistance reached levels of 10% or more in the samples tested. Rat sample incidence of resistance in Chicago at 75% or more left the city without a ready control alternative, and the Chicago rat population exploded during the period 1975 to 1981. Blocks designated by various criteria as infested increased from 40% in 1975 to 93% in 1980. Initial trials in the Chicago resistance areas were successful (Ashton and Jackson 1979). Following the adoption and use of TALON rodenticide by the City of Chicago, overall infestation rates were reduced to less than 2% and rat bites were reduced 64% during the period 1980 to 1984 (T. Howard, pers. comm. 1985). Today, most U.S. city rodent control projects are using brodifacoum baits on a regular basis.

Unpublished data from representative farm trials with brodifacoum in the United States are included in Appendix 10. These trials generally involved the use of bait stations or burrow stuffing. A trial at a ranch near Pendleton, Oregon, is discussed in Anon. (1979c). A rat and mouse infestation among stored crops and livestock was treated with bait stations containing 50-ppm brodifacoum pellets and produced a 95 to 100% reduction in activity. Trials in poultry houses against Norway rats first determined as warfarin resistant in the laboratory were carried out near Raleigh, North Carolina. Brodifacoum pelletized bait applied in bait stations inside and within active burrows and stations outside of four poultry houses resulted in an average reduction in rodent activity of 85 to 99% (Apperson et al. 1981). Bait exposure in a California dairy farm building resulted in 92% control of Norway rats (Gorenzel 1982).

## AGRICULTURAL RODENT TRIALS

### Orchards

The development of brodifacoum for *Microtus* control in apple orchards in North America was initially involved with research of the 50-ppm pellets (see Appendix 11). Subsequent developments involved the creation of a new, 10-ppm pelletized formulation, VOLID (Kaukeinen 1984), especially regarding the properties of the ICI pelletized 10-ppm VOLID formulation. Appendix 12 gives results of ICI, cooperator, and independent researcher results with VOLID against *Microtus* species. Good results were generally obtained from hand baiting at rates as low as 2 kg/ha of 10-ppm material. Broadcast rates at 5 to 15 kg/ha also gave effective control, even of the more fossorial species such as *M. pinetorum*. Broadcast trials generally involved the use of tractor-mounted seeder or fertilizer spreaders, and hand-bait trials at affected trees were in runway systems, with bait covered with wood, stone or ceramic slabs, can lids, or portions of roofing paper. In the United States, large-scale experimental use in eastern orchards during 1979 to 1982 produced extensive efficacy data as illustrated by Appendix 12. However, hazard evaluations accompanying some orchard vole efficacy studies gave equivocal results in determining effect levels to populations of nontarget animals, particularly raptors such as screech owls (Kaukeinen 1982, Hegdal et al. 1984). Currently, VOLID research and development for U.S. orchard use against *Microtus* is continuing, and is the subject of a recent additional experimental permit submitted by ICI for the U.S. Fish and Wildlife Service to better allow evaluation of environmental effects in orchards. VOLID use in other crop situations, for example in artichokes in California, is also promising. Work by the University of California during 1984-85 found the VOLID formulation gave 90% control of California voles in 2 days (Marsh and Tunberg 1985).

### Forestry

Trials of 10-ppm VOLID in Christmas tree plantations of Scotch pines in upper Michigan showed good efficacy against *M. pennsylvanicus* (Haigh and Jackson, pers. comm. 1980). Two 1-A plots each, contained about 1,200 trees. One plot was treated with VOLID at 15 lb/A and the other plot left untreated. The treated plot showed 100% reduction in activity after the hand application, whereas the untreated plot showed 33% of trees with fresh damage. Reinspection at 10 mo after treatment showed fresh damage in the

treated plot at 8.5% compared with 26.5% in the untreated. Lab evaluations (see Appendices 2 and 5) also show brodifacoum exhibited good efficacy against gophers and Peromyscus species which can also constitute significant forestry pests in the United States.

#### Nut Trees

Nut tree crops, such as walnuts and almonds, are often severely damaged by pest rodents. Experimental trials with TALON pellets in a California walnut orchard involved baiting 460 Spermophilus beecheyi burrows. Only 10% of bait remained after 48 hrs and all disappeared within 5 days. Census observations revealed an 88% reduction in squirrel activity from the treatment. Gophers (Thomomys bottae) infesting an almond orchard in California were controlled in experimental trials in which tunnel systems in treated plots were baited with 30-g placements using a hand probe. Although the soil was not ideal for burrow baiting and the probe use caused some tunnel collapse, it was still possible to show a 74% reduction in gopher activity 32 days after treatment.

#### Grassland/Rangeland

Grazed land in the western United States is often subject to intensive ground squirrel populations, causing much reduction of forage quantity and quality. Brodifacoum has been experimentally tested in the United States in the laboratory or in the field against six species of Spermophilus (Citellus), in the states of California, Montana, Wyoming, New Mexico, Washington, Oregon, and elsewhere. Brodifacoum formulations tested against ground squirrels in the United States involved either TALON pellets or an ICI oat groats 50-ppm bait (see Appendix 11).

In California, Marsh (pers. comm. 1982) conducted field trials in Tulare County which indicated 90% or better control of S. beecheyi fisheri following 6 lb/swath/A aerial treatment with 100-ppm oat groats or with hand baiting with 50-ppm oat groats at 12 lb/A. Brodifacoum so applied was judged equal to or superior to conventional 1080 baiting at the same rate. In an extensive evaluation of brodifacoum control of ground squirrels in pasture, the U.S. Fish and Wildlife Service and the Montana Department of Agriculture in 1981 conducted trials with S. richardsonii. Three 1-ha plots (each surrounded by 250-m buffer strips which were also treated) were treated at either 1.56, 2.38 or 1.68 lb/A with 50-ppm brodifacoum oat groats bait. Oats were placed near burrows at 16 to 19 g-quantities, and control plots received a blank, unpoisoned oats bait. Control was measured by three methods. Recovery of the 22 squirrels from each plot which had been fitted with radio-telemetry transmitters revealed a 98% kill. A trapping index comparing pre- and posttreatment trapping indicated 99% reduction, and a more formal CMR trap study indicated a 97% population reduction (Matschke, pers. comm. 1982).

In general, brodifacoum has been evaluated against most genera of agricultural pest rodents in the United States. Efficacy has been superior to other materials tested when applied at the same or lower rates and concentrations of bait.

#### NEW RESEARCH AREAS AND FUTURE DEVELOPMENTS

Brodifacoum has principally been incorporated into grain-based baits for various trials and registrations around the world, including many innovative bait formulations. The characteristics of the compound have also stimulated the development of alternative application approaches. Anticoagulant liquid or water baits have been utilized for many years. Water baits containing brodifacoum have been proposed and tested in India by Soni and Prakash (1984b, 1985). Laboratory trials against Meriones, Tatera and Rattus species with 50-ppm water-based liquid bait gave 83.80 and 90% kill, respectively, after 24 hr exposure. Extending exposure to 48 or 72 hr gave 100% kill. Liquid brodifacoum baits have also been developed in Taiwan (Ku 1984), where the waterer is placed inside a feeding station allowing only rodent entry.

Tracking powders are another conventional form of rodenticide for which developments incorporating brodifacoum have been made. Dubock and Kaukeinen (1978) report initial work with brodifacoum tracking dusts as developed by Davis and Moran. Dubock (1979b) reports potential use of brodifacoum tracking powder with an artificial burrow-building machine for control of Cricetus in Hungary. Brodifacoum tracking powders were also made and tested against suspected warfarin-resistant house mice in Finland (Myllymaki 1986), and gave 92% kill in the laboratory.

A more novel form of contact rodenticide involves the development of a paste or gel which, as with tracking powders, is ingested by the pest species while grooming. A research newsletter from New Zealand (1981a) notes that 0.015% brodifacoum paste baits were evaluated there for rabbit control and were judged as effective as 0.025% 1080 paste. For use against rodents, a brodifacoum paste made of edible fat was described by Davis (1983) for house mouse control. Use of a 0.01% paste for rat control in New Zealand is described by Moors (1984).

A contact rodenticidal device specifically developed for house mouse control with brodifacoum has been described by Gibson and Barratt (1979), Gibson (1982), and Morris et al. (1984). The device consists of wicks containing brodifacoum which are enclosed within a protective tube housing. As mice enter and traverse the tube, the brodifacoum is taken up on their fur and later groomed off. The device offers advantages over baits for house mouse control in many situations. A commercial version is currently undergoing trials in the United Kingdom and will be the subject of future publications (Proc. 7th British Pest Control Conference, in prep., 1986).

It is possible to create rodenticides with advantages for specific situations through formulation research and development. The inclusion of safening agents and protective colorants, olfactory stimulants (including pheromones) and other materials are being investigated. The addition of emetics (as rodents are normally unable to vomit) may provide an additional safety factor for nontarget animals. However, as with all additives and chemical modifications, resulting baits must still retain their attractiveness and efficacy to the target species.

#### SUMMARY AND CONCLUSIONS

As noted in this review, brodifacoum has been successfully evaluated against most small mammal pests which plague mankind around the world, and in a variety of both commensal and agricultural situations. Brodifacoum offers reduced rodenticide requirements to lower costs and hazard, and makes new baiting strategies, such as pulsed baiting, practical for large-scale use. Broad spectrum activity enables effective control with mixed-species infestations and against those normally tolerant of other anticoagulants, such as house mice. As developed as a material for use against warfarin-resistant commensal rodents, brodifacoum has retained its ability to give effective control in urban and other problem situations where first-generation anticoagulants have previously been extensively used. Brodifacoum has the same mode of action and has the same antidote (vitamin K) as other anticoagulants, providing the advantages of delayed action in the pest species as well as assurances for successful antidoting for the user and domestic animals. Brodifacoum is a palatable and stable compound, which has been successfully incorporated into various baits, contact toxicants, and control devices.

The discovery of new candidate rodenticides is a combination of intent and serendipity. Not until at least preliminary laboratory and field characterizations are in hand, are the immutable laws and interrelationships of chemistry and biology sufficiently unfolded to reveal what imperfections toward its intended use the new molecule possesses. There has never been, nor is there likely ever to be, a "perfect rodenticide." Somewhere within the broad profile for each vertebrate control compound--including specificity, mode of action and antidote, acceptability to the pest, stability, formulating characteristics, and cost of synthesis and development--will be unknowns and limitations. Brodifacoum's proximity to a near uniformly excellent profile as a rodenticide has stimulated great interest and effort to make it work for man's benefit in a variety of ways against vertebrate pests during the past decade. In achieving its present successful status worldwide, brodifacoum promises to show continued momentum toward further popularity and future developments.

#### REFERENCES

- ANON. 1976. Assessment of PP581 in Wild Norway and Ricefield Rats, Vert. Damage Control Research in Agric., USFWS, Denver Wildlife Research Center, USAID, Annual Report. p. 12.
- ANON. 1977. Toxicity of Commercial Rodenticides to Agricultural Rodents in Developing Countries, Vert. Damage Control Research and Agriculture, USFWS, Denver Wildlife Research Center, USAID, Annual Report. pp. 37-39.
- ANON. 1978. Brodifacoum, A New Anticoagulant Rodenticide for the Control of Rats and Mice, UK Ministry of Agriculture, Fish and Food, Pest Infest. Control Lab., Tech. Circular 36. 4 pp.
- ANON. 1979a. Controlling Rodents in Deepwater Rice; Field Testing for Rodenticides in Deep Water Rice (Bangladesh), Vert. Damage Control Research and Agriculture, USFWS, Denver Wildlife Research Center, USAID, Annual Report. pp. 25-26.
- ANON. 1979b. TALON™ - A New Rodenticide, U.S. National Pest Control Assoc, ESPC 06335, Tech. Rel. 4 pp.
- ANON. 1979c. TALON® Field Trials Show Promise, Pest Control Technology 7(2):19-23.
- ANON. 1981a. A Gnawing Problem (Egypt, 1981). Middle East 79:40.
- ANON. 1981b. KLERAT - A Single Feed Rodenticide. World Crops 33(4):89.
- ANON. 1981c. Research News (New Zealand, Brodifacoum). Counterpest (Suppl.) 5.
- ANON. 1982a. How Urban "Pied Pipers" are Taking on the Rats. American City and County Magazine, April. pp. 45-46.
- ANON. 1982b. Instructions for Determining the Susceptibility or Resistance of Rodents to Anticoagulant Rodenticides. WHO/VBC/82843.
- ANON. 1983. Rats on the Run--A New Generation of Rodenticides. West African Farming, May/June. pp. 40-41.
- ANON. 1985. Effective Rodent Control Saves Transvaal Poultry Farmers Thousands of Rands. Pluimvee Bulletin (S. Africa), May. pp. 255-256.
- APPERSON, C. S., O. T. SANDERS, and D. E. KAUKAINEN. 1981. Laboratory and Field Trials of the Rodenticide Brodifacoum Against Warfarin-Resistant Norway Rats. Pesticide Science 12(6):662-668.
- ASHTON, A. D., and W. B. JACKSON. 1979. Field Testing of Rodenticides in a Resistant-Rat Area of Chicago. Pest Control 47:14.
- ASHTON, A. D., W. B. JACKSON, and H. PETERS. 1986. Comparative Evaluation of LD<sub>50</sub> Values for Various Anticoagulant Rodenticides. In: Proc. Symp. Control Mammal Pests (C. G. J. Richards and T. Y. Ku, Eds.), 4 Intl. Theriol. Cong., Edmonton, Canada. Tropical Pest Management (In press).
- BACHMAN, K. A., and T. J. SULLIVAN. 1983. Dispositional and Pharmacodynamic Characteristics of Brodifacoum in Warfarin-Sensitive Rats. Pharmacology 27:281-288.
- BAJOMI, D. 1984. Hungarian Experiences with "TALON-B" Containing Brodifacoum. In: Proc. Conf. Organ. Practice Vertebrate Pest Control (A. C. Dubock, Ed.), Elvetham Hall, Hampshire, England. ICI-PPD. pp. 163-179.
- BALASUBRAMANDYAM, M., M. J. CHRISTOPHER, and K. R. PURUSHOTHAM. 1984. Laboratory Trials of 3 Anticoagulant Rodenticides (Warfarin, Bromadiolone, Brodifacoum) for Use Against the Indian Field Mouse Mus booguda Gray. J. Hygiene 93(3):575-578.

- BALASUBRAMANDYAM, M., M. J. CHRISTOPHER, and K. R. PURUSHOTHAM. 1985. Laboratory Evaluation of Anticoagulant Treated Baits (Warfarin, Bromadiolone, Brodifacoum) Against Indian Field Mouse Mus booguda Gray. Proc. Indian Academy of Science, Animal Sciences 94(2):93-98.
- BENTLEY, E. W., and Y. LARTHE. 1959. The Comparative Rodenticidal Efficacy of Five Anticoagulants. J. Hygiene 57(2):135-149.
- BHARDWAJ, D., and I. PRAKASH. 1984. Efficacy of Three Anticoagulant Rodenticides (Brodifacoum, Coumatetralyl, Warfarin) for the Control of Poison Shy Rattus rattus. In: Proc. 11th Vert. Pest. Conf. (D. O. Clark, Ed.), Sacramento, CA. pp. 82-84.
- BOUCHARD, C. 1978. Control of Meadow Voles in Apple Orchards (in French). Canada Pesticide Research Report. pp. 70-71.
- BOUCHARD, C. 1979. Control of Field Mice (Microtus pennsylvanicus) in Apple Orchards (in French). Canada Pesticide Research Report. p. 7.
- BRADFIELD, A. A. G., and J. E. GILL. 1984. Laboratory Trials of Five Rodenticides (Warfarin, Difenacoum, Brodifacoum, Calciferol, Zinc Phosphide) for the Control of Mesocricetus auratus. J. Hygiene 93(2): 389-394.
- BRECKINRIDGE, A. M. et al. 1985. A Study of the Relationship Between the Pharmacokinetics and the Pharmacodynamics of the 4-hydroxycoumarin Anticoagulants Warfarin, Difenacoum and Brodifacoum in the Rabbit. British J. Pharmacol. 84:81-91.
- BROOKS, J. E., P. T. HTUN, and H. MAING. 1980. The Susceptibility of Bandicota bengalensis from Rangoon, Burma to Several Anticoagulant Rodenticides. J. Hygiene 84:127-135.
- BROOKS, J. E. et al. 1979. Laboratory Evaluations of Rodenticides for Use Against South-East Asian (Burma) Commensal Small Mammals. WHO/VBC 79.720, 15 pp.
- BRUGGERS, R. L. (Ed.). 1980. Rodent Control in Wheatfields (Bangladesh). Vert. Damage Control Research in Agric, USFWS, Denver Wildlife Research Center, USAID, Annual Report. pp. 19-25.
- BRUGGERS, R. L., and A. VALVANO (Eds.). 1981. Anticoagulant Rodenticide Studies; Comparative Field Trials of Two Rodenticides in Village Housing Clusters (Bangladesh). Vert. Damage Control Research in Agric., USFWS, Denver Wildlife Research Center, USAID, Annual Report. pp. 22-29.
- BRUGGERS, R. L., and A. VALVANO (Eds.). 1982. Comparative Field Trials of Two Rodenticides in Wheat-fields (Bangladesh). Vert. Damage Control Research in Agric. USFWS, Denver Wildlife Research Center, USAID, Annual Report. pp. 20-24.
- BRUGGERS, R. L., and A. VALVANO (Eds.). 1983. Operation OSKER (Bangladesh), Vert. Damage Control Research and Agriculture, USFWS, Denver Wildlife Research Center, USAID, Annual Report. pp. 42-46.
- BUCKLE, A. P. 1983. The Organization and Practice of Vertebrate Pest Control, Elvetham Hall, Hampshire, August-Sept. 1982 (Review). Tropical Pest Management 29(1):72-76.
- BUCKLE, A. P., and B. D. RENNISON. A Review of Methods for Measuring and Evaluating the Losses Caused in Rice and Other Crops by Rodents. In: Proc. Symp. Control Mammal Pests (C. G. J. Richards and T. Y. Ku, Eds.). 4. Intl. Theriol. Cong., Edmonton, Canada; Tropical Pest Management (In press).
- BUCKLE, A. P., and F. P. ROWE. 1981. Rice Field Rat Project, Malaysia, Technical Report 1977-1980. Dept. Agric. Malaysia and Cent. Overseas Pest Res., London. 99 pp.
- BUCKLE, A. P., F. P. ROWE, and A. R. HUSIN. 1982. Laboratory Evaluation of the Anticoagulants Coumatetralyl and Brodifacoum Against Rattus argentiventer in Peninsular Malaysia. Tropical Pest Management 28(2):126-130.
- BUCKLE, A. P., F. P. ROWE, and A. R. HUSIN. 1984. Field Trials of Warfarin and Brodifacoum Wax Block Baits for the Control of the Rice Field Rat, Rattus argentiventer, in Peninsular Malaysia. Tropical Pest Management 30(1):51-58.
- BUCKLE, A. P., Y. C. YONG, and A. R. HUSIN. 1985. Damage by Rats to Rice in South-East Asia with Special Reference to an Integrated Management Scheme Proposed for Peninsular Malaysia. In: Proc. 3 Intl. Theriol. Cong. (A. Myllymaki, Ed.), Helsinki, Finland; Acta Zool. Fennica 173, Vol. 5, p. 139.
- BYERS, R. E. 1977. Pine Vole Control Research in Virginia. Proc. 1. Eastern Pine and Meadow Vole Symposium, Winchester, VA, March 10-11. p. 89.
- BYERS, R. E. 1978a. Cultural and Toxicant Control of Pine and Meadow Voles in Apple Orchards. Hort Science 13(3):365.
- BYERS, R. E. 1978b. Performance of Rodenticides for the Control of Pine Voles in Orchards. J. American Society Horticultural Science 103(1):65-69.
- BYERS, R. E. 1978c. Pine Vole Control Studies in Virginia--1977. Proc. 2. Eastern Pine and Meadow Vole Symposium, Beltsville, MD, February 23-24. p. 62.
- BYERS, R. E. 1979a. Meadow Vole Control Using Anticoagulant Baits. HortScience 14(1):44-45.
- BYERS, R. E. 1979b. Results of Pine Vole Control Studies in 1978 (Virginia). Proc. 3. Eastern Pine and Meadow Vole Symposium, New Paltz, NY. p. 77.
- BYERS, R. E. 1980. Pine Vole Control in 1979 Field Plots (Virginia). Proc. 4. Eastern Pine and Meadow Vole Symposium, Hendersonville, NC. p. 68.
- BYERS, R. E. 1981. Pine Vole Control With Anticoagulant Baits in Apple Orchards. J. American Society Horticultural Science 106(1):101-105.
- BYERS, R. E. 1983. Economics of Microtus Control in Eastern US Orchards. Proc. 7. Eastern Pine and Meadow Vole Symposium, Harpers Ferry, WV. p. 1.
- BYERS, R. E. 1984. Economics of Microtus Control in Eastern US Orchards. In: Proc. Conf. Organ. Practice Vertebrate Pest Control (A. C. Dubock, Ed.), Elvetham Hall, Hampshire, England; ICI-PPD. pp. 297-302.
- BYERS, R. E., and M. H. MERSON. 1981. Meadow and Pine Vole Control in 1980 Field Plots (Virginia). Proc. 5. Eastern Pine and Meadow Vole Symposium, Gettysburg, PA. p. 7.
- BYERS, R. E., and M. H. MERSON. 1982a. Current Improvements in Baiting Pine and Meadow Voles. In: Proc. 10 Vert. Pest Conf. (R. E. Marsh, Ed.), Monterey, CA. pp. 139-142.
- BYERS, R. E., and M. H. MERSON. 1982b. Effect of Pellet Size and Packaged Commercial Baits for the Control of Pine Voles. Proc. 6. Eastern Pine and Meadow Vole Symposium Ferry, Harpers Ferry, WV p. 22.

- CHMELA, J., and V. P. RUPES. 1983. Testing the Efficiency of the Rodenticide Brodifacoum on Norway Rats and House Mice. *Vesnick Ceskoslovenske Spolecnosti Zoologicke* 47(1):6-12.
- CHMELA, J., M. DUB, and V. RUPES. 1985. Testing the Efficacy of VOLID Rodenticide (in Czech.). *Agrochemia* 25(5):155-158.
- CHOPRA, G., and V. R. PARSHAD. 1985. Efficacy of 4 Anticoagulants (Brodifacoum, Bromadiolone, Coumatetralyl, Warfarin) in Controlling the House Rat Rattus rattus. *Indian J. Agricultural Sciences* 55(2):125-128.
- COLVIN, H. W., and W. L. WANG. 1974. Toxic Effects of Warfarin in Rats Fed Different Diets. *Toxicology and Applied Pharmacology* 28:337-348.
- CONWAY, J. A. 1984. The Use of Brodifacoum Formulations for Rodent Control Treatments Against Bandicota bengalensis in Food Godowns in Bagladesh. *Tropical Stored Products Information* 47:10-14.
- COULTER, M. et al. 1982. Experiments on the Effectiveness of TALON Controlling Populations of Black Rats (Rattus rattus) in Galapagos Island Ecuador. Annual Report, Darwin Research Station, Guayaquil. 9 pp.
- DAVIS, R. A. 1983. Edible Fat As A Carrier for Contact Rodenticides. *International Pest Control* 25(2):46-47.
- DENG, Z., and C. WANG. 1984. Rodent Control in China. In: Proc. 11 Vert. Pest Conf. (D. O. Clark, Ed.), Sacramento, CA. pp. 47-53.
- DUBOCK, A. C. 1978. Rodent Control in Crop Stores. *Outlook on Agriculture* 9(5):220-224.
- DUBOCK, A. C. 1979a. Alternate Strategies for Safety and Efficacy of Rodenticides. In: Proc. 5 British Pest Control Conf., Stratford-Upon-Avon. Session 5, Paper 14. 15 pp.
- DUBOCK, A. C. 1979b. Rodent Control in Hungary. *Anglo-Hungarian Plant Protection Symposium*, Cambridge, England. 28 pp.
- DUBOCK, A. C. 1980. The Development and Practical Use of the Novel Anticoagulant Rodenticide Brodifacoum. *Plant Protection Bulletin, Plant Protection Society, Republic of China (Taiwan)* 22(2):223-238.
- DUBOCK, A. C. 1982. Pulsed Baiting--A New Technique for High Potency, Slow-Acting Rodenticides. In: Proc. 10 Vert. Pest Conf. (R. E. Marsh, Ed.), Proc. 10 Vert. Pest Conf., Monterey, CA. pp. 123-136.
- DUBOCK, A. C. 1984a. Economic Benefits of Vertebrate Pest Control. In: Proc. Conf. Organ. Practice Vertebrate Pest Control (A. C. Dubock, Ed.), Elvetham Hall, Hampshire, England. ICI-PPD. pp. 316-326.
- DUBOCK, A. C. 1984b. Pulsed Baiting--A New Technique for High Potency, Slow Acting Rodenticides. In: Proc. Conf. Organ. Practice Vertebrate Pest Control (A. C. Dubock, Ed.), Elvetham Hall, Hampshire, England, ICI-PPD. pp. 106-142.
- DUBOCK, A. C., and D. E. KAUKKINEN. 1978. Brodifacoum (TALON Rodenticide), a Novel Concept. In: Proc. 8 Vert. Pest Conf. (W. E. Howard, Ed.), Sacramento, CA. pp. 127-137.
- ECKE, D. H., and L. L. LEWALLEN. 1979. Susceptibility of Anticoagulant Resistant Roof Rats (Rattus rattus) to TALON. *California Vector Views* 26(7/8):66-69.
- ECKE, D. H., M. A. DENNIS, and M. GODFREY. 1979. Testing 0.005% Brodifacoum Against Roof Rats (Rattus rattus) in Saratoga, California. *J. Environmental Health* 42(3):128-129.
- GIBSON, J. A., and P. B. BARRATT. 1979. The Constant Need to Improve Pest Control Techniques and Standards. In: Proc. 5, British Pest Control Conf., Stratford-Upon-Avon, England; Session 7, Paper 20. 6 pp.
- GIBSON, J. A. 1982. Field Trials of a Contact Rodenticide Device for Control of House Mice Mus musculus. *International Pest Control* 24(2):38-40.
- GILL, J. E., and R. REDFERN. 1979. Laboratory Tests of Seven Rodenticides (Warfarin, Coumatetralyl, Difenacoum, Brodifacoum, Bromadiolone, Calciferol, Zinc Phosphide) for the Control of Mastomys natalensis. *J. of Hygiene* 83(2):345-352.
- GILL, J. E., and R. REDFERN. 1980. Laboratory Trials of Seven Rodenticides (Warfarin, Coumatetralyl, Difenacoum, Brodifacoum, Bromadiolone, Calciferol, Zinc Phosphide) for Use Against the Cotton Rat Sigmodon hispidus. *J. Hygiene* 85(3):443-450.
- GILL, J. E., and R. REDFERN. 1983. Laboratory Tests of Seven Rodenticides for the Control of Meriones shawi (Warfarin, Coumatetralyl, Difenacoum, Brodifacoum, Bromadiolone, Calciferol, Zinc Phosphide). *J. Hygiene* 91(2):351-357.
- GODFREY, M. E. R. 1985. Non-target and Secondary Poisoning Hazards of "Second Generation" Anticoagulants. In: Proc. 3. Intl. Theriol. Cong. (A. Myllymaki, Ed.), Helsinki, Finland. *Acta Zoologica Fennica* 173 No. 5, p. 209.
- GODFREY, M. E. R., and C. P. LYMAN. 1980. Preliminary Dosing Trials of a New Anticoagulant, Brodifacoum, as a Toxicant for the Rabbit, Oryctolagus cuniculus (L.). *New Zealand J. Experimental Agriculture* 8(1):1-6.
- GODFREY, M. E. R., T. C. REID, and H. J. F. McALLUM. 1981. The Oral Toxicity of Brodifacoum to Rabbits. *New Zealand J. Experimental Agriculture* 9:23-25.
- GORENZEL, W. P., R. E. MARSH, and T. P. SALMON. 1982. Single Feeding Anticoagulants--Are They What They Claim? *Pest Control* 50(2):32.
- GOSNEY, J. 1981. ICI's New Rodenticide Kills After One Feed. *Intl. Agric. Develop.*, July/August. pp. 22-23.
- GREAVES, K. J. 1985. The Present Status of Resistance to Anticoagulants. In: Proc. 3. Intl. Theriol. Cong. (A. Myllymaki, Ed.), Helsinki Finland; *Acta Zoologica Fennica* 173, no. 5, p. 159.
- GREAVES, J. H., D. S. SHEPHERD, and R. QUY. 1982. Field Trials of Second Generation Anticoagulants (Brodifacoum, Bromadiolone) Against Difenacoum Resistant Norway Rat Rattus norvegicus Populations. *J. Hygiene* 89(2):295-301.
- HADLER, M. R. 1979. Brodifacoum--A Potent New Rodenticide. In: Proc. 5. British Pest Control Conf., Stratford-Upon-Avon; Session 5, Paper 13. 8 pp.
- HADLER, M. R., and R. S. SHADBOLT. 1975. Novel 4-Hydroxycoumarin Anticoagulants Active Against Resistant Rats. *Nature* 253:275-277.

- HAMPSON, S. J. 1984. A Review of Rodent Damage to Sugarcane with Criteria for the Use of Rodenticides. In: Proc. Conf. Organ. Practice Vertebrate Pest Control (A. C. Dubock, Ed.), Elvetham Hall, Hampshire, England. ICI-PPD. pp. 227-251.
- HAN, K. J., and S. BOSE. 1980. Some Studies (Warfarin, Brodifacoum Trials) on Mammalian Pests in Cocoa Planted Under Coconuts (Malaysia). Planter (Kuala Lumpur) 56:273-283.
- HEGDAL, P. L., B. A. COLVIN, and R. W. BLASKIEWICZ. 1984. Field Evaluation of Secondary Hazards to Barn Owl (Tyto alba) and Screech Owls (Otus asio) Associated with Brodifacoum Baits Used for Rodent Control. In: Proc. Conf. Organ. Practice Vertebrate Pest Control (A. C. Dubock, Ed.), Elvetham Hall, Hampshire, England. ICI-PPD. pp. 647-662.
- HITCHCOCK, B. E., R. E. KERKWAYCK, and M. A. HETHERINGTON. 1983. Evaluation of Some Anticoagulant Rodenticide in Queensland Cane Fields. Proc. Australian Society of Sugar Technologists. 6 pp.
- HONE, J., and H. MULLIGAN. 1982. Brodifacoum. In: Vertebrate Pesticides. Science Bulletin 89, Dept. Agric. NSW, Australia. pp. 3-5.
- HOPPE, A. 1979. Biennial Report 1977/78-Pest Rodent Research Lab, Morocco. (in French). Ministry of Agriculture, Marrakech. 55 pp.
- HOPPE, A. H., and A. KRAMBIAS. 1984. Efficacy of Three Anticoagulant Rodenticides (Brodifacoum, Difenacoum, Bromadiolone) Against Rattus rattus fugivorus. In: Proc. Conf. Organ. Practice Vertebrate Pest Control (A. C. Dubock, Ed.), Elvetham Hall, Hampshire, England. ICI-PPD. pp. 336-339.
- HOQUE, M. 1981. Rat Control in Pineapple. Crop Protection News (Philippines) 2:14-15.
- HOQUE, M. M. 1983a. Development of an Anticoagulant Resistance Monitoring Program for Philippine Rats. Philippine Agriculture (Los Banos) 66(1):36-46.
- HOQUE, M. M. 1983b. Rat Control in Coconut-Pineapple Intercrop. Philippine Agriculture (Los Banos) 66(1):82-89.
- HOQUE, M. M., and J. L. OLIVIDA. 1986. Comparison of Baiting Methods for Ricefield Rats in the Philippines. In: Proc. Symp. Control Mammal Pests, 4 (C. G. J. Richards and T. Y. Ku Eds.), Intl. Theriol. Cong., Edmonton, Canada, Tropical Pest Management (in press).
- HTUN, P. T., W. W. MULLER, and H. NAING. 1984. Paired Rodent Control Field Trials with Zinc Phosphide and Brodifacoum in Rangoon, Burma. WHO/VBC/84.902. 14 pp.
- HUMBERT, R. P. 1983. Control of Rodents - New Rodenticide Gives Excellent Results in Sugarcane Fields (in Spanish). Agricultura de las Americas, Dec. pp. 6-7, 26-27.
- INDRARTO, N. 1984. Five-Year Rat Control Programme in Indonesia. In: Proc. Conf. Organ. Practice Vertebrate Pest Control (A. C. Dubock, Ed.), Elvetham Hall, Hampshire, England. ICI-PPD. pp. 475-485.
- JACKSON, W. B. et al. 1985. Present Status of Rodent Resistance to Warfarin in the United States. In Proc. 3. Intl. Theriol. Cong. (A. Myllymaki, Ed.), Helsinki, Finland; Acta Zoologica Fennica 173 no. 5. p. 163.
- JAIN, U., Y. SAXENA, and J. P. NAG. 1982. Laboratory Evaluation of Brodifacoum, A New Anticoagulant Rodenticide Against Rattus rattus. Pestology 6(3):21-22.
- KADHIM, A. H., K. T. MUHSEN, and A. M. MUSTAFA. 1984. Field Trials of the Anticoagulant KLERAT (Brodifacoum) for Control of the Norway Rat, Rattus norvegicus Berk., in Baghdad. JBS 15(2):1-6.
- KALOTAS, Z., and Z. KALOTAS. 1984. The Oral Toxicity of the Rodenticide "VOLID" to the Field Vole (Microtus arvalis palo.) and the Hamster (Cricetus cricetus L.) (in Hungarian). Novenyvedelem 20 (11):484-488.
- KARASEVA, E. V., Y. G. CHERNUKHA, and E. V. STRIKHANOVA. 1984. Natural Focus of Leptospirosis in the Ricefields of Krasnodar Krai - SFSR USSR and the Ways (Rotindan, Brodifacoum) for its Sanitation (in Russian). Zh. Mikrobiol. Epidemiol. Immunobiol. (3):58-62.
- KAUKEINEN, D. E. 1977. Development of PP581 Rodenticide by ICI-United States, Inc. Proc. 1. Eastern Pine and Meadow Vole Symposium, Winchester, VA. p. 105.
- KAUKEINEN, D. E. 1978. Status of PP581 (VOLAK) Rodenticide Development. Proc. 2. Eastern Pine and Meadow Vole Symposium, Beltsville, MD. p. 101.
- KAUKEINEN, D. 1979a. Experimental Rodenticide (TALON) Passes Lab Tests; Moving to Field Trials in Industry. Pest Control 47(1):19-21, 46.
- KAUKEINEN, D. E. 1979b. Field Methods for Census Taking of Commensal Rodents in Rodenticidal Evaluations. ASTM STP 680. pp. 68-83.
- KAUKEINEN, D. E. 1979c. Vole Control with VOLAK Rodenticide. In: Proc. 3 Eastern Pine and Meadow Vole Symposium, New Paltz, NY. pp. 77-81.
- KAUKEINEN, D. E. 1982. A Review of the Secondary Poisoning Hazard to Wildlife from the Use of Anticoagulant Rodenticides. In: Proc. 10 Vert. Pest. Conf. (R. E. Marsh, Ed.), Monterey, CA. pp. 151-158. (Also published in Pest Management 1(11):10, 12-14; 1(12):16, 18-19, 1982).
- KAUKEINEN, D. E. 1984. Microtus Problems and Control in North America and the Development of VOLID® Rodenticide. In: Proc. Conf. Organ. Practice Vertebrate Pest Control (A. C. Dubock, Ed.), Elvetham Hall, Hampshire, England. ICI-PPD. pp. 589-618.
- KAUKEINEN, D. E. 1984b. Potential Non-Target Effects from the Use of Vertebrate Toxicants. In: Proc. Conf. Organ. Practice Vertebrate Pest Control (A. C. Dubock, Ed.), Elvetham Hall, Hampshire, England. ICI-PPD. pp. 619-629.
- KAUKEINEN, D. E. 1986. Management of Harmful Rodents: Published Literature Sources. In: Proc. Symp. Control Mammal Pests. (C. G. J. Richards and T. Y. Ku, Eds.), 4 Intl. Theriol. Cong. Edmonton, Canada; Tropical Pest Management (in press).
- KHAN, A. A. 1981. Field Trial of Some Rodenticides (Brodifacoum, Zinc Phosphide, Vacor, Thallium Sulfate) Against the Collared Pika Ochotona rufescens in Apple Orchards (Pakistan). International Pest Control 23(1):12-13.
- KHAN, A. A., and W. R. SMYTHE. 1980. The Problem of Pika (Ochotona rufescens) Control (Brodifacoum, Vacor, Thallium Sulfate) in Baluchistan Pakistan. In: Proc. 9. Vert. Pest Conf. (J. P. Clark, Ed.), Fresno, CA. pp. 130-134.
- KHAN, A. A., S. AHMED, and M. A. CHOUDRY. 1984. Comparative Evaluation of Brodifacoum and Bromadiolone Against Field Rats in Wheat and Paddy Crops. In: Proc. Conf. Organ. Practice Vertebrate Pest Control (A. C. Dubock, Ed.), Elvetham Hall, Hampshire, England; ICI-PPD. pp. 363-379.

- KHOO CHIN KOK. 1979. Developing an Agricultural Rodenticide. Proc. Intl. Public Health Seminar, England; ICI-PPD. paper 22. 9 pp.
- KHOO CHIN KOK. 1980. "Pulsed Baiting" with Brodifacoum Baits to Control Oil Palm Rats in Malaysia. Selangor Planters Association Annual Report/Journal 198:42-46.
- KHOO CHIN KOK. 1984. The Practice of Rodent Control in Malaysian Plantation Crops. In: Proc. Conf. Organ. Practice Vertebrate Pest Control (A. C. Dubock, Ed.), Elvetham Hall, Hampshire, England; ICI-PPD. pp. 209-226.
- KHOO CHIN KOK and A. C. DUBOCK. 1981. Brodifacoum, A Potent Anticoagulant Rodenticide for the Control of Oil Palm Rats. Proc. Intl. Conf. Oil Palm in Agriculture in '80s, Kuala Lumpur; Paper AP15. 18 pp.
- KHRYANINA, R. A. 1981. Results of Rodenticide Testing (in Russian). Zashchita Rastenii (10):31.
- KU, T. Y. 1984. Distribution and Population Fluctuations of Field Rodents and Their Control in Taiwan. In: Proc. Conf. Organ. Practice Vertebrate Pest Control (A. C. Dubock, Ed.), Elvetham Hall, Hampshire, England; ICI-PPD. pp. 487-519.
- LANTING, F. O., F. L. ANDRES, and R. B. RANDON. 1981. Efficacy of Brodifacoum Baits Against Rodents in Storage Areas (Philippines). Intl. Rice Research Institute Newsletter 6(5):21-22.
- LAM YUET-MING. 1978. Brodifacoum--A New Rodenticide Against the Rice Field Rat, Rattus argentiventer. Malaysian Plant Protection Society Newsletter 2(3):3-4.
- LAMB YUET-MING. 1980. Laboratory Evaluation of Brodifacoum for Use Against the Rice Field Rat, Rattus argentiventer (Robinson & Kloss). Malaysian Agricultural J. 52(4):1-7.
- LUND, M. 1981. Comparative Effect of the Three Rodenticides Warfarin, Difenacoum and Brodifacoum on Eight Rodent Species in Short Feeding Periods. J. Hygiene 87(1):101-108.
- LUND, M. 1982. Rat Control. In: Danish Pest Infestation Laboratory Annual Report for 1981. pp. 58-61.
- LUND, M. 1983. Rat Control. In: Danish Pest Infestation Laboratory Annual Report for 1982. pp. 89-101.
- LUND, M. 1984a. Control of Mice and Voles (Brodifacoum). In: Danish Pest Infest. Lab. Ann. Rept. 1983. pp. 70-72.
- LUND, M. 1984b. Resistance to the Second-Generation Anticoagulant Rodenticides (Difenacoum, Bromadiolone). In: Proc. 11. Vert. Pest. Conf. (D. O. Clark, Ed.), Sacramento, CA. pp. 89-94.
- LUND, M. 1985. The "Second Generation" Anticoagulants: A Review. In: Proc. 3 Intl. Theriol. Cong. (A. Myllymaki, Ed.), Helsinki, Finland; Acta Zool. Fennica 173, Vol. 5, p. 149.
- LUND, M., and J. LODAL. 1984. Current Work at the Danish Pest Infestation Laboratory, Vertebrate Department. In: Proc. Conf. Organ. Practice Vertebrate Pest Control (A. C. Dubock, Ed.), Elvetham Hall, Hampshire, England; ICI-PPD. pp. 253-264.
- LUND, M., and J. LODAL. 1986. Rodent Research. In: Danish Pest Infest. Lab. Ann. Rept. 1985. pp. 74-83.
- MAHMOUD, W., and R. REDFERN. 1981. The Response of the Egyptian Spiny Mouse (Acomys cahirinus) and Two Other Species of Commensal Rodents to Anticoagulant Rodenticides (Rattus rattus, Rattus norvegicus; Warfarin, Difenacoum, Brodifacoum). J. Hygiene 86(3):329-334.
- MAJID, T. B., and O. S. CHYE. 1984. The Organization and Practice of Rice Field Rat Control in Malaysia. In: Proc. Conf. Organ. Practice Vertebrate Pest Control (A. C. Dubock, Ed.), Elvetham Hall, Hampshire, England. ICI-PPD. pp. 465-473.
- MARSH, B. T. 1979. Cleveland Tests Rodenticides (TALON, Zinc Phosphide). J. Environmental Health 42(3):131-132.
- MARSH, R. E., and A. D. TUNBERG. 1984. Research on Meadow Mouse (Microtus californicus) Biology and Its Control Relative to Artichoke Production. Univ. Calif., Davis, Progress Rept. No. 1. 105 pp.
- MARSH, R. E., and A. D. TUNBERG. 1985. Research on Meadow Mouse (Microtus californicus) Biology and Its Control Relative to Artichoke Production. Univ. Calif., Davis, Progress Rept. No. 2. 118 pp.
- MATHUR, R. P., and I. PRAKASH. 1980a. Acceptability and Toxicity of Six Anticoagulants to the Palm Squirrel (Funambulus pennanti Wroughton). Zeitschrift Angew. Zool. 67:477-482.
- MATHUR, R. P., and I. PRAKASH. 1980b. Laboratory Evaluation of Anticoagulant-Treated Baits (Warfarin, Fumarin, Chlorophacinone, Brodifacoum) For Control of the Northern Palm Squirrel Funambulus pennanti J. Hygiene 85(3):421-426.
- MATHUR, R. P., and I. PRAKASH. 1981. Evaluation of Brodifacoum Against Tatera indica, Meriones hurrianae and Rattus rattus. J. Hygiene 87(2):179-184.
- MATHUR, R. P., and I. PRAKASH. 1984a. Comparative Efficacy of Some Anticoagulant Rodenticides Against Indian Rodents. In: Proc. Conf. Organ. Practice Vertebrate Pest Control (A. C. Dubock, Ed.), Elvetham Hall, Hampshire, England. ICI-PPD. pp. 381-393.
- MATHUR, R. P., and I. PRAKASH. 1984b. Field Trials of Brodifacoum, Chlorophacinone and Coumatetralyl Against Desert Rodents in India. Tropical Pest Management 30(1):59-61.
- MATHUR, R. P., and I. PRAKASH. 1984c. Reduction in Population of Indian Desert Rodents with Anticoagulant Rodenticides. Proc. Indian Academy of Science, Animal Sciences 93(6):585-589.
- MCCLELLAND, R. 1979. TALON Trial Successful in NYC Infestations. Pest Control Technology, Vol. 7, August.
- MCDONALD, D. 1983. Rodent Control in the Tropics. International Pest Control, May/June.
- MEEHAN, A. P. 1984. Brodifacoum. In: Rats and Mice--Their Biology and Control. Rentokil Limited, Sussex UK. pp. 205-208.
- MERSON, M. H., and R. E. BYERS. 1983. Results of 1982 Rodenticide Field Tests (Virginia). Proc. 7. Eastern Pine and Meadow Vole Symposium, Harpers Ferry, WV. p. 13.
- MEYLAN, A. 1985. Control of Small Mammals in Specialty Crops (Orchards, Grapes) (in French). Revue Suisse Vitic. Arboric. Hort. 17:64-65.
- MITCHELL, G. C., and A. VALVANO (Eds.). 1984. Rodent Control (KLERAT blocks, TALON Pellets) in the Maldives, Indian Ocean. Vert. Damage Control Research in Agric., USFWS, Denver Wildlife Research Center, USAID Annual Report. pp. 41-44.

- MO, G., and L. GUOGENG. 1984. An Experimental Comparison of Poisoning Rats by Using Intermittent and Saturated Doses of Brodifacoum (in Chinese). *Acta Theriologica Sinica* 4(1):79-80.
- MOORS, P. J. 1984. Eradication Campaigns Against *Rattus norvegicus* on the Noises Islands, New Zealand, Using Brodifacoum and 1080. In: Proc. Conf. Organ. Practice Vertebrate Pest Control (A. C. Dubock, Ed.), Elvetham Hall, Hampshire, England. ICI-PPD. pp. 395-412.
- MORRIS, K. D., R. D. PROCTOR, and D. E. KAUKAINEN. 1984. Design and Evaluation Criteria for Development of Toxic Wicks for Rodent Control. In: ASTM STP817 (D. E. Kaukeinen, Ed.). pp. 165-182.
- MUHR, A. C. 1984. Practical Experience with Difenacoum and Brodifacoum in the Pest Control Servicing Business in Switzerland. In: Proc. Conf. Organ. Practice Vertebrate Pest Control (A. C. Dubock, Ed.), Elvetham Hall, Hampshire, England. ICI-PPD. pp. 329-333.
- MYLLYMAKI, A. 1984. Efficacy of a Number of Toxic Baits and Baiting Against the Voles, *Microtus agrestis* and *Arvicola terrestris*. In: Proc. 11. Vert. Pest Conf. (D. O. Clark, Ed.), Sacramento, CA. pp. 38-46.
- MYLLYMAKI, A. 1986. Efficacy of Anticoagulants and Flupropadine on Wild Strains of the Finnish Mouse, (*Mus musculus* L.). In: Proc. 2. Symp. Recent Advances Rodent Control, Kuwait. Feb., 1985 (in press).
- NIKODEMUSZ, E., and G. NECHAY. 1982. The Common Vole (*Microtus arvalis* Pall. 1758) in the Laboratory. 2. Evaluation of Rodenticides. *Zool. Jb. Anat.* 107:306-318.
- NIKODEMUSZ, E., G. NECHAY, and R. IMRE. 1980. The Toxicity of Brodifacoum on Hamsters (*Cricetus cricetus* L.), Field Voles (*Microtus arvalis* Pall.), Hares (*Lepus europeus* L.) and Pheasants (*Phasianus colchicus* L.) (in Hungarian). *Novenyvedelem* 16(12):608-611.
- O'CONNOR, B. P. 1979. Vertebrate Pest Control in New Zealand. Proc. Intl. Public Health Seminar. ICI-PPD, England, UK. paper 24. 5 pp.
- PAGANO, R., and J. McANINCH. 1983. The Efficacy of Several Broadcast Rodenticides in the Mid-Hudson Valley, New York. Proc. 7. Eastern Pine and Meadow Vole Symposium, Harpers Ferry, WV. p. 25.
- PARSHAD, V. R., N. AHMAD, and G. CHOPRA. 1985. Laboratory and Field Evaluation of Brodifacoum for Rodent Control. *International Biodeterioration* 21(2):107-112.
- POCHE, R. M. et al. 1980. Rodent Control in Wheat Fields. Bangladesh Agricultural Research Institute, Tech. Rept. 10. 17 pp.
- RAHMAN, S. A. M., and J. E. BROOKS. 1982. Comparative Field Trials of Two Rodenticides in Small Farm Housing Clusters. Bangladesh Agric. Res. Inst., Vert. Pest Sect., Tech. Rept. No. 14.
- RAI, R. S., P. IAL, and P. K. SRIVASTAVA. 1984. Efficacy of Brodifacoum Against House Rat (*Rattus rattus*). CAZRI (Jodhpur), ICAR Rodent Newsletter 8(1-4):16.
- REDFERN, R., J. E. GILL, and M. R. HADLER. 1976. Laboratory Evaluation of WBA 8119 as a Rodenticide for Use Against Warfarin-Resistant and Non-Resistant Rats and Mice. *J. Hygiene* 77:419-426.
- RENAPURKAR, D. M., and V. R. KAMATH. 1982. Laboratory Evaluation of Brodifacoum, A New Anticoagulant Rodenticide. *Bulletin Haffkine Institute (India)* 10(1):17-20.
- RENNISON, B. D., and A. C. DUBOCK. 1978. Field Trials of WBA 8119 (PP581, Brodifacoum Against Warfarin Resistant Infestations of *Rattus norvegicus*. *J. Hygiene* 80(1):77-82.
- RICHARDS, C. G. J. 1983. Cost-Effective Use of High Potency Anticoagulant Rodenticides. In: Proc. 6. British Control Conf., Cambridge, England; Session 5, Paper 12. 11 pp.
- RICHARDS, C. G. J. 1986. Cost Effective Approaches to Large-Scale Rodent Control Programmes. In: Proc. 2. Symp. Recent Advances Rodent Control. Kuwait, 2-6 Feb. 1985 (in press).
- RICHARDS, C. G. J. 1986. Approaches to Small-Holder Rodent Control. In: Proc. 12 Vert. Pest Conf., March 4-6, 1986, San Diego, CA. (in press).
- RICHARDS, C. G. J., and L. W. HUSIN. 1985. Toward the Optimal Use of Anticoagulant Rodenticides. In: Proc. 3. Intl. Theriol. Cong. (A. Myllymaki, Ed.), Helsinki Finland. *Acta Zool. Fennica* 173, Vol. 5. p. 155.
- RICHMOND, M. E., and P. N. MILLER. 1980. Field Evaluation of Candidate Rodenticides (New York). Proc. 4. Eastern Pine and Meadow Vole Symposium, Hendersonville, NC. p. 78.
- ROTHERT, H. 1985. New Anticoagulants and Acute Poisons Against Brown Rats and House Mice (Difenacoum, Brodifacoum, Bromadiolone, Bromethalin, Flocoumafen) (in German). *Praktische Schaedlingsbekaempfung* 37(8):165-169.
- ROWE, F. P., and A. BRADFIELD. 1976. Trials of the Anticoagulant Rodenticide WBA8119 Against Confined Colonies of Warfarin-Resistant House Mice (*Mus musculus* L.). *J. Hygiene* 77:427-431.
- ROWE, F. P., T. SWINNEY, and C. PLANT. 1978. Field Trials of Brodifacoum (WBA 8119) Against the House Mouse *Mus musculus*. *J. Hygiene* 81(2):197-202.
- SAXENA, Y., and R. K. SHARMA. 1981. Laboratory Evaluation of Brodifacoum (TALON) Bait Against Indian Desert Gerbil, *Meriones hurrianae* Jerdon. *Pestology* 5(4):22-23.
- SAXENA, Y., and R. K. SHARMA. 1982. Relative Susceptibility of Zinc Phosphide and Brodifacoum Baits to *Funambulus pennanti*. *Bulletin of Grain Technology* 20(1):43-46.
- SAXENA, Y., and R. K. SHARMA. 1984. Efficacy of Brodifacoum (TALON) Bait Against Three Rodent Species (*Meriones hurrianae*, *Rattus rattus* and *Funambulus pennanti*. In: Proc. 11. Vert. Pest Conf. (D. O. Clark, Ed.), Sacramento, CA. pp. 101-102.
- SHIEN, T. T. 1981. The Experimental Report on the Toxicity of the New Anticoagulant Rodenticide KLERAT. *Taiwan Sugar J.* 28(3):92-95.
- SIDDIQI, Z. 1982. Meadow Voles--Enemy in the Grass. Proc. Ontario Horticulture Conference. pp. 117-120.
- SIDDIQI, Z., and W. D. BLAINE. 1982a. Anticoagulant Resistance in House Mice in Toronto, Canada. *Pest Management* 1(14):10, 12-14. (Also in *Environmental Health Review* 26(2):49-51, 1982)
- SIDDIQI, Z., and W. D. BLAINE. 1982b. Long-Term Vole Control in Ontario Apple Orchards. Proc. 6. Eastern Pine and Meadow Vole Symposium, Harpers Ferry, WV. p. 12.
- SIDDIQI, Z., W. W. D. BLAINE, and S. TAYLOR. 1983a. Long-Term Vole Control in Ontario Apple Orchards. Proc. 7. Eastern Pine and Meadow Vole Symposium, Harpers Ferry, WV. p. 44.
- SIDDIQI, Z., W. D. BLAINE, and S. TAYLOR. 1983b. Meadow Vole Control in Ontario Apple Orchards. Proc. 1. Eastern Animal Damage Control Meeting, Cornell University, New York. pp. 207-208.



- SIDDIQI, Z., W. D. BLAINE, and S. TAYLOR. 1983c. Single Feeding Anticoagulants. *Pest Control* 51(7): 36, 41.
- SONI, B. K. 1981. Efficacy of WBA 8119 (Brodifacoum) to Indian Rodents. *Rodent Newsletter* 5(4):28-29.
- SONI, B. K., and I. PRAKASH. 1981. Laboratory Evaluation of WBA 8119 (Brodifacoum) Against Gerbillus gleadowi Murray. *Pestology* 5(9):23-24.
- SONI, B. K., and I. PRAKASH. 1983. Evaluation of Brodifacoum (WBA8119) Against the Northern Palm Squirrel, (Funambulus pennanti). CAZRI (Jodhpur), ICAR Rodent Newsletter 7(3):10.
- SONI, B. K., and I. PRAKASH. 1984a. Efficacy of Brodifacoum Against the House Mouse Mus musculus. *Pesticides (Bombay)* 18(7):15-17.
- SONI, B. K., and I. PRAKASH. 1984b. Efficacy of Liquid Brodifacoum (PP581) Against Two Gerbils and House Rat. CAZRI (Jodhpur), ICAR Rodent Newsletter 8(1-4):1-2.
- SONI, B. K., and I. PRAKASH. 1984c. Evaluation of Brodifacoum for the Control of Rattus meltada and Golunda ellioti. *Indian J. Plant Protection* 12(1).
- SONI, B. K., and I. PRAKASH. 1985. Evaluation of Liquid Brodifacoum Against Gerbils and Rats. *Pestology* 9(1):21-24.
- SONI, B. K., A. P. JAIN, and G. R. SONI. 1984. Trials of Wax-Blocks of Brodifacoum (WBA8119) Against Desert Rodents. CAZRI (Jodhpur), ICAR Rodent Newsletter 8(1-4):10-11.
- SONI, B. K., B. D. RANA, and A. P. JAIN. 1985. Field Trials of Some Rodenticides (Aluminum Phosphide, Brodifacoum, Bromadiolone) to Control Rodents in Various Crop Fields of Western Rajasthan Desert. *Pestology* 9(1):25-27.
- STEBLEIN, P. F., P. N. MILLER, and M. E. RICHMOND. 1983. Efficacy of Spring Broadcast Rodenticides in the Hudson Valley, New York. *Proc. 7. Eastern Pine and Meadow Vole Symposium, Harpers Ferry, WV.* p. 19.
- SULTANA, P., et al. 1981. Comparative Toxicity of Several Anticoagulant Rodenticides to Bandicota Bengalensis. Bangladesh Agriculture Research Institute, Vertebrate Pest Section, Technical Report No. 13. 5 pp.
- TANTAWY OMAR, M. 1984. The National Rat Control Campaign in Egypt. *In: Proc. Conf. Organ. Practice Vertebrate Pest Control (A. C. Dubock, Ed.), Elvetham Hall, Hampshire, England. ICI-PPD.* pp. 443-458.
- TAYLOR, K. D. 1983. Practical Considerations in Large Scale Rodent Control with Special Reference to the Situation in Egypt. *In: Proc. 1. Symp. Recent Advances in Rodent Control, Kuwait, 1982.* pp. 64-70.
- TONGTAVEE, K. 1980. Efficacy Tests of Different Rodenticides on Some Species of Rats in Thailand. *In: Proc. 9 Vert. Pest Conf. (J. P. Clark, Ed.), Monterey, CA.* pp. 143-145.
- TONGTAVEE, K. 1984. Experience with Brodifacoum in Laboratory and Field Conditions in Thailand. *In: Proc. Conf. Organ. Practice Vertebrate Pest Control (A. C. Dubock, Ed.), Elvetham Hall, Hampshire, England. ICI-PPD.* pp. 357-362.
- TONGTAVEE, K. et al. 1986. The Safety and Efficacy of Brodifacoum ("KLERAT" Wax Blocks) and Zinc Phosphide for Rodent Control in Thailand. *In: Proc. Symp. Control Mammal Pests (C. G. J. Richards and T. Y. Ku, Eds.), 4. Intl. Theriol. Cong., Edmonton, Canada. Tropical Pest Management (in press).*
- VANUROVA, E. 1980. Evaluation of Rodenticide Approved for Use in Czechoslovakia and Proposed New Products. *Agrochemia* (3):84-85.
- WANG, C., and Z. DENG. 1984. Rodent Control in China. *In: Proc. Conf. Organ. Practice Vertebrate Pest Control (A. C. Dubock, Ed.), Elvetham Hall, Hampshire, England. ICI-PPD.* pp. 512-531.
- WANG, P. Y. 1978. Effects of Brodifacoum on Five Taiwan Rodent Species and Warfarin Tolerance Testing with Sugarcane Rodents, Bandicota Nemorivaga and Rattus losea (in Chinese). Taiwan Sugar Research Institute Report. p. 363.
- WANG, P. Y. 1981. Effectiveness of New Anticoagulant Rodenticide Brodifacoum for the Control of Wild Rats in Sugarcane Fields (in Chinese). Report of Taiwan Sugar Research Institute (94):33-40.
- WANG, P. Y. 1982. Control of Wild Rats (KLERAT, Glyzophrol). *Taiwan Sugar Journal* 29(1):28.
- WILLIAMS, J. M. 1984. Rabbit Control Strategies Using Anticoagulants, in New Zealand. *In: Proc. Conf. Organ. Practice Vertebrate Pest Control (A. C. Dubock, Ed.), Elvetham Hall, Hampshire, England. ICI-PPD.* pp. 543-552.
- WILLIAMS, J. O., and E. M. PEREIRA. 1984a. Brodifacoum as a Rodenticide to Control Rodent Damage in Rice Fields in Venezuela: II. Calabozza, State of Guarico. *In: Proc. Conf. Organ. Practice Vertebrate Pest Control (A. C. Dubock, Ed.), Elvetham Hall, Hampshire, England. ICI-PPD.* pp. 347-351.
- WILLIAMS, J. O., and C. VEGA. 1984b. Brodifacoum as a Rodenticide to Control Rodent Damage in Rice Fields in Venezuela: I. State of Portuguesa. *In: Proc. Conf. Organ. Practice Vertebrate Pest Control (A. C. Dubock, Ed.), Elvetham Hall, Hampshire, England. ICI-PPD.* pp. 341-345.
- WOLF, Y. 1980. Report on Field Trials for the Evaluation of the Efficacy of the Rodenticide Brodifacoum for the Control of Rodents on Farms. Israel Ministry of Agriculture, Plant Protection Department Report. pp. 2-5.
- YOUNG, R. S. 1979. Pine Vole Control 1978-1979 Experiment (West Virginia). *Proc. 3. Eastern Pine and Meadow Vole Symposium, New Paltz, NY.* p. 60.
- YOUNG, R. S. 1980. Update of Pine Vole Research at the Kearneysville Experiment Farm (West Virginia). *Proc. 4. Eastern Pine and Meadow Vole Symposium, Hendersonville, NC.* p. 66.
- YOUNG, R. S. 1981. Pine Vole Activity Results for 1979-1980 Toxicant Applications (West Virginia). *Proc. 5. Eastern Pine and Meadow Vole Symposium, Gettysburg, PA. March 4-5.* p. 15.

## APPENDIX 1. Brodifacoum efficacy by region and country

Region and country	Reference	Pest research area covered
Europe		
Cyprus	Hoppe & Krambias 1984	Lab Work, General Ag. & Commensal, <u>Rattus</u> spp.
Czechoslovakia	Chemla & Rupes 1983 Chemia, Dub. & Rupes 1985 Vanurova 1980	Lab and Field Trials, Commensals General Microtine, Alfalfa General Microtine, Alfalfa
Denmark	Lund 1981, 1982, 1983, 1984a, 1984b Lund & Lodal 1984	Microtine Lab and Field, Commensal Microtine Lab and Field, Commensal
England	Anon. 1978 Bradfield & Gill 1984 Gibson 1982 Greaves, Shepherd & Quy 1982 Redfern, Gill & Hadler 1967 Rennison & Dubock 1978 Richards & Husin 1985 Rowe & Bradfield 1976 Rowe, Swinney & Plant 1978	Lab and Field Trials, Commensals Lab Trials, Introduced Hamsters House Mouse Field Trials Field Trials Resistance - Commensals Lab Resistant Study, Commensals Field Trials Resistant Commensals Commensal Field Trials Lab Field Trials, Mice Field Trials, Mice
Finland	Millymaki 1984 Millymaki 1986	Lab and Field Trials, Voles Lab Studies, Mice
Germany	Rothert 1985	General Considerations, Commensals
Hungary	Bajomi 1984 Dubock 1979	Field Trials Ag. and Industrial, Commensal Lab and Field Trials Commensal & Ag. (Microtines and Hamsters)
	Kalotas & Kalotas 1984 Nikodemusz & Nechay 1982 Nikodemusz, Nechay and Imre 1980 Meylan 1985 Muhr 1984	Lab Work, Voles and Hamsters Microtus Lab Work Lab Work, Voles, Hamsters, Hares Microtus Control Materials Commensal Field Experiences
Switzerland		
USSR	Karaseva, Chernukha & Strikhanova 1984 Khryanina 1981	Field Trials in Rice, Vector Control Lab and Field Trials - Commensals
Middle East		
Iraq	Kadhim, Muhsen & Mustafa 1984	Urban Commensal Field Trials
Israel	Wolf 1980	Commensal Field Trials - Poultry Farms
Syria	Richards 1986	Urban Commensal Trials
Africa		
General	Anon. 1981a Anon. 1983	Country-wide Field Use and Training General Characteristics
Egypt	Gill & Redfern 1979, 1983 Anon. 1981 Mahmoud & Redfern 1981 Tantawy Omar 1984 Taylor 1983	<u>Mastomys</u> , <u>Meriones</u> Lab Studies Country-wide Field Use and Training <u>Acomys</u> and Commensal Lab Studies General and Agricultural Trials Agricultural and Commensal Field Trials
Morocco	Hoppe 1979	Lab Work, <u>Meriones</u>
South Africa	Anon. 1985	Field Use, <u>Poultry</u> Houses
South Asia		
Bangladesh	Anon. 1979a, Bruggers, 1980, Bruggers & Valvano, 1981, 1982, 1983 Conway 1984 Mitchell & Valvano 1984a Poche 1980 Rahman & Brooks 1982 Sultana 1981 Brooks 1979	Ricefield Rat Trials, Crop and Village Bandicoot Rats, Crop Stores Lab Trials, Ag. Species Wheat Field Trials Farm and Village Commensal Trials Bandicoot Rat Lab Work
Burma	Brooks, Htun & Naing 1980 Htun, Muller, & Naing 1984 Richards 1986	Lab Evaluation Urban Species Lab Trials Bandicoot Rats Field Trials Urban Species Field Trials Urban Review
India	Balasubramandyam, Christopher & Purushotham 1984, 1985 Bhardwaj & Prakash 1984 Chopra & Parshad 1985 Jain, Saxena & Nag 1982 Mathur & Prakash 1980ab Mathur & Prakash 1981, 1984a Mathur & Prakash 1984b, 1984c Parshad, Ahmad & Chopra 1985 Rai, Lal & Srivastava 1984 Renapurkar & Kamath 1982 Saxena & Sharma 1981 Saxena & Sharma 1982 Saxena & Sharma 1982 Soni, 1981	Lab Tests, <u>Mus</u> Lab Trials, <u>Rattus rattus</u> Field Trials Commensal Rats Lab Trials <u>Rattus rattus</u> Lab Trials, <u>Squirrel</u> Ag. Pest Lab Evaluation, Ag. & Commensal Species Desert Grassland Field Trials, <u>Meriones</u> and Other Spp. Lab and Field Trials, Agricultural Species Commensal Rat Trials Lab Trials, Commensal & Ag. Spp. Lab Evaluation, <u>Meriones</u> Lab Trials, <u>Squirrel</u> Ag. Pest Lab Trials, Three Ag. Spp. Lab Trials, Three Ag. Spp.

South Asia (cont'd)

	Soni & Prakash 1981	Lab Trials, Gerbillus
	Soni & Prakash 1983	Lab Trials, Squirrel Ag. Pests
	Soni & Prakash 1984abc	Lab Trials, Commensals
	Soni & Prakash 1985	Lab Evaluation, Three Species Gerbils, One Rat
	Soni, Jain & Soni 1984	Lab Trials, Commensal & Ag. Species
	Soni, Rana & Jain 1985	Crop Field Trials
Pakistan	Khan 1981	Orchard Field Trials, Pikas
	Khan & Smythe 1980	General Trials, Pikas
	Khan, Ahmed & Choudry 1984	Wheat and Rice Field Trials
Maldives	Mitchell & Valvano 1984	General Trials
Far East		
China	Deng Zhi & Wang Chengxin 1984	General Commensal and Ag., 7 Spp. Lab and Field Data
	Mo & Liang 1984	Commensal Trials
	Richards 1985	Review Urban Trials
	Wang Chengxin & Deng Zhi 1984	Results General Lab and Field Commensal and Ag. Trials
China (Taiwan)	Ku 1984	General Commensal and Ag., Field Use Island-wide
	Dubock 1980	General Review Lab and Field Trials
	Shien Tay Tseng 1981	Lab and Field Trials, Ag. Crops
	Wang 1978, 1981, 1982	Lab and Cane Field Trials, 5 Species
Philippines	Hoque 1981	Field Pineapple Trials
	Hoque 1983a	Coconut/Pineapple Intercrop Field Trial
	Hoque 1983b	Resistant Studies, Commensals
	Hoque 1986	Field Trials, Baiting Techniques
	Lanting, Andres & Randon 1981	Commensal Field Trials
South East Asia		
Indonesia	Indrarato 1984	General Ag. and Rice Trials
Malaysia	Buckle & Rowe 1981	Lab and Rice Field Rat Trials
	Buckle, Rowe & Husin 1984	Ricefield Rat Field Trials
	Buckle, Yong & Husin 1985	Ricefield Rat Field Trials
	Han & Bose 1980	Field Trials, Cocoa
	Khoo Chin Kok 1979, 1980	Oil Palm Field Trials
	Khoo Chin Kok 1984	Rat and Squirrel Ag. Field Trials
	Khoo Chin Kok & Dubock 1981	Oil Palm Field Trials
	Lam Yuet Ming 1978, 1980	Ricefield Rat Trials
	Majid & Chye 1984	Ricefield Rat Trials
Thailand	Dubock 1984	Ricefield Rat Trials
	Tongtavee 1984, 1986	Lab, Rice and Other Field Trials
	Tongtavee 1980	Commensal and Ag. Species, Lab Trials
	Richards 1986	Village Field Trials
Vietnam		
Oceania		
Australia	Hitchcock, Kerkwyck & Hetherington 1983	Rat Field Trials, Cane
	Anon. 1981c	Rabbit Field Trials, Islands
	Godfrey & Lyman 1980	Lab Trials Rabbits
	Godfrey, Reid & McAllum 1981	Lab Trials Rabbits
	Moors 1984	Rat Trials, Islands
	O'Connor 1979	Rabbit, Rat and Possum Field Trials
	Williams 1984	Rabbit Field Trials
North America		
Canada	Bouchard 1978, 1979	Orchard Vole Field Trials
	Siddiqi 1982	Orchard Field Trials, Voles
	Siddiqi & Blaine 1982b	Orchard Field Trials, Voles
	Siddiqi & Blaine 1982a	Lab Resistance Study, Mus
	Siddiqi, Blaine, & Taylor 1983c	Lab Resistance Study, Mus
	Siddiqi, Blaine, & Taylor 1983ab	Orchard Field Trials Voles
United States	Anon. 1979c, 1982b	Urban Commensal Field Trials
	Apperson, Sanders, & Kaukeinen 1981	Lab, Field Rat Resistance Trials
	Ashton & Jackson 1979	Urban Trials, Commensal Resistant
	Byers 1977, 1978a, 1978b, 1978c, 1979a, 1979b, 1980, 1981, 1983, 1984	Lab and Field Research, Orchard Voles
	Byers & Merson 1981, 1982a, 1982b	Lab and Field Research, Orchard Voles
	Ecke & Lewallen 1979	Lab Resistance, Rattus rattus
	Ecke, Dennis & Godfrey 1979	Field Trials Urban Rattus rattus
	Gorenzel, Marsh & Salmon 1982	Commensal Field Trials, Farm
	Jackson et al. 1985	Resistance Status
	Kaukeinen 1979a, 1979b	Urban Commensal Field Trials
	Kaukeinen 1977, 1978, 1984	Lab, Orchard Field Vole Trials
	Marsh 1979	Urban Rat Trial
	Marsh & Tunberg 1984, 1985	Lab & Field Research Artichokes, Voles
	McClelland 1979	Urban Commensal Trial
	Merson & Byers 1983	Orchard Vole Field Trial
	Pagano & McAninch 1983	Orchard Vole Field Trial
	Richmond & Miller 1980	Orchard Vole Field Trial

## North America (cont'd)

	Steblein, Miller & Richmond 1983	Orchard Vole Field Trial
	Young 1979, 1980, 1981	Orchard Vole Field Trial
Mexico	Gill & Redfern 1980	Lab Work, <u>Sigmodon</u>
	Hampson 1984	Cane Field Trials
	Humbert 1983	Cane Field Trials
Central America		
General	Gill & Redfern 1980	Lab Work, <u>Sigmodon</u>
Nicaragua	Hampson 1984	Cane Field Trials
South America		
General	Gill & Redfern 1980	Lab Work, <u>Sigmodon</u>
Argentina	Humbert 1983	Cane Field Trials
Brazil	Richards 1986	Urban Commensal Trials
Ecuador	Coulter 1982	Island <u>Rattus</u> Control
Venezuela	Williams & Peiteira 1984	Rice Field Trials, <u>Sigmodon</u>
	Williams & Vega 1984	Rice Field Trials, <u>Holochilus</u>

## APPENDIX 2. Vertebrate pest acute LD50 values, brodifacoum (determined by intubation unless noted).

Species	Strain/source	LD50	Reference
<u>Bandicota bengalensis</u>	Bangladesh	0.20 (0.14-0.28) <sup>a</sup>	Sultana et al. 1981
<u>Citellus columbianus</u>	US	Male 0.168 (0.138-0.206) Female 0.180 (0.143-0.226)	Matschke, Pers. Comm.
<u>Citellus dauricus</u>	China	0.093	Deng Zhi & Wang Chengxin 1984
<u>Citellus richardsonii</u>	US	0.13 (0.063-0.188)	Pallister & Baril, Pers. Comm.
<u>Cricetulus triton</u>	China	0.86	Deng Zhi & Wang Chengxin 1984
<u>Cricetus cricetus</u>	Hungary	0.33 <sup>b</sup>	Nikodemusz, Nechay & Imre 1980
<u>Lepus europaeus</u>	Hungary	0.15 <sup>b</sup>	Nikodemusz, Nechay & Imre 1980
<u>Meriones hurrianae</u>	India	0.083 (0.05-0.13)	Mathur & Prakash 1981
<u>Meriones unguiculatus</u>	China	0.002-0.003	Deng Zhi & Wang Chengxin 1984
<u>Mesocricetus auratus</u>	Domestic	0.56	Dubock & Kaukeinen 1978
<u>Microtus arvalis</u>	Hungary	0.22 <sup>b</sup>	Nikodemusz, Nechay & Imre 1980; Nikodemusz & Nechay 1982
<u>Microtus pinetorum</u>	US	0.36 (0.22-0.59)	Byers 1978
<u>Microtus pennsylvanicus</u>	US	0.72 (0.53-0.98)	Byers 1978
<u>Mus musculus</u>	LAC Grey China	Male 0.40 (0.30-0.63) 0.85	Redfern, Gill & Hadler 1976 Deng Zhi & Wang Chengxin 1984
<u>Myospalax fontanieri</u>	China	0.44	Deng Zhi, Pers. Comm.
<u>Ochotona curzoniae</u>	China	0.14	Deng Zhi & Wang Chengxin 1984
<u>Oryctolagus cuniculus</u>	New Zealand	0.20 (0.15-0.28)	Godfrey, Reid & McAllum 1981
<u>Rattus argentiventer</u>	Malaysia	0.18 (0.15-0.22)	Lam Yuet Ming 1978
<u>Rattus flavipectus</u>	China	0.39	Deng Zhi & Wang Chengxin 1984
<u>Rattus norvegicus</u>	Wistar US Wild China Wild	Male 0.26 (0.20-0.37) Female 0.22 0.32	Redfern, Gill & Hadler 1976 Dubock & Kaukeinen 1978 Deng Zhi & Wang Chengxin 1984
<u>Rattus rattus</u>	US	Male 0.73 (0.55-0.91) Female 0.65 (0.40-0.90)	Dubock & Kaukeinen 1978
<u>R. r. rufescens</u>	India	0.77 (0.40-1.28)	Mathur & Prakash 1981

<u>Rattus rattus mindansis</u>	Philippines	Male 0.28 Female 0.30	Dubock & Kaukeinen 1978
<u>Rattus tiomanicus</u>	Malaysia	0.33	Khoo Chin Kok 1980
<u>Tatera indica</u>	India	0.10 (0.08-0.17)	Mathur & Prakash 1981
<u>Trichosurus vulpecula</u>	New Zealand	0.2	Bell, Pers. Comm.

a Feeding Protocol

b ALD (approximate lethal dose)

APPENDIX 3. Vertebrate pest sub-acute LC50 values, brodifacoum (determined by intubation unless noted).

Species	Source/strain	LC50	x Days	Reference
<u>Bandicota bengalensis</u>	Bangladesh	0.18 (0.56-1.16) <sup>a</sup>	4	Sultana, et al. 1981
<u>Cricetulus triton</u>	China	0.11	3	Deng Zhi & Wang Chengxin 1984
<u>Mus musculus</u>	Grey LAC	0.035 (0.021-0.050)	5	Dubock & Kaukeinen 1978
	China Wild	0.099	5	Deng Zhi & Wang Chengxin 1984
<u>Oryctolagus cuniculus</u>	New Zealand Wild	0.22 (0.15-0.31)	3	Godfrey, Reid & McAllum 1981
		0.16 (0.12-0.21)	5	
<u>Rattus flavipectus</u>	China	0.07	5	Deng Zhi & Wang Chengxin 1984
<u>Rattus norvegicus</u>	Wistar	Male 0.06 (0.04-0.08)	5	Redfern, Gill & Hadler 1976
	Wistar	Female 0.05	5	Dubock & Kaukeinen 1978
	China Wild	0.07	5	Deng Zhi & Wang Chengxin 1984
	UK Resistant	Male 0.05	5	Dubock & Kaukeinen 1978

a feeding protocol

APPENDIX 4. Vertebrate pest lethal feeding period (days), brodifacoum.

Species	Source/ strain	Form	Conc. %	LFP50 (days)	LFP98 (days)	Reference
<u>Acomys cahirinus</u>	Egypt	Oatmeal	0.002	0.88	291.4	Mahmoud & Redfern 1981
<u>Bandicota bengalensis</u>	Burma	Fish meal, rice, corn, peanuts	0.001	1.12 (0.87-1.44)	3.26 (2.02-5.25)	Brooks, Htun, & Naing 1980
<u>Funambulus pennanti</u>	India	Millet	0.005	1.1 (0.7-2.0)	--	Mathur & Prakash 1984a
<u>Meriones hurrianae</u>	India	Millet	0.002	0.79 (0.50-1.26)	2.52 (1.55-4.18)	Mathur & Prakash 1981
			0.005	0.74 (0.36-1.55)	2.23 (1.26-4.17)	
<u>Mastomys natalensis</u>	Africa	Oatmeal	0.002	1.9 (0.8-1.5)	3.6 (2.7-7.0)	Gill & Redfern 1979
<u>Meriones shawi</u>			0.005	4.8 (4.0-5.3)	10.3 (8.1-18.1)	Gill & Redfern 1983
<u>Mus musculus bactrianus</u>	India	Millet, oil	0.002	1.52 (1.03-2.24)	8.32 (3.9-17.8)	Soni & Prakash 1984a
			0.005	1.26 (1.18-1.35)	7.25 (5.76-9.12)	
<u>Rattus rattus</u>	India	Millet	0.002	0.76 (0.40-1.51)	3.02 (1.35-6.76)	Mathur & Prakash 1981
			0.005	0.68 (0.38-1.23)	2.76 (1.59-4.79)	
<u>Sigmodon hispidus</u>			0.002	0.9 (0.6-1.2)	3.3 (2.4-7.1)	Gill & Redfern 1980
<u>Tatera indica</u>	India	Millet	0.002	0.69 (0.32-1.48)	2.34 (1.10-5.0)	Mathur & Prakash 1981
			0.005	0.64 (0.32-1.39)	2.10 (1.25-4.16)	

APPENDIX 5. Vertebrate pest restricted feeding periods - brodifacoum (no-choice exposure in diet).

Species	Source/ strain	Form.	Conc. (%)	Days given	Mortality		Reference	
					no.	%		
<u>Acomys cahirinus</u>	Egypt	oatmeal	0.002	2	7/10	70	Mahmoud & Redfern 1981	
				4	7/10	70		
				8	6/9	67		
				10	7/10	70		
				11	7/10	85		
				14	8/10	80		
				18	17/20	85		
				20	9/10	90		
				22	8/10	80		
				23	10/10	100		
				24	8/10	80		
				25	10/10	100		
<u>Akodon spp.</u>	Argentina	ICI Pellet	0.005	1	27/30	80	Dubock & Kaukeinen 1978	
<u>Apodemus flavicollis</u>	Czech, Denmark	ICI Pellet	0.001	1	14/14	100	Chmela, Dub & Rupes 1985 Lund 1981	
				2	2/5	40		
		Ground Oats	0.005	1	4/8	80		
				2	20/20	100		
<u>A. sylvaticus</u>	Denmark	Ground Oats	0.0005	1	10/10	100	Lund 1981	
				2	9/10	90		
		Ground Oats	0.005	1	10/10	100		
				2	10/10	100		
<u>Arvicanthis niloticus</u>	Sudan Egypt	ICI Pellet	0.005	1	20/20	100	Poche, Pers. Comm. 1982 ICI, Unpub.	
		ICI Pellet	0.005	1	10/10	100		
			0.001	1	19/20	95		
<u>Arvicola terrestris</u>	W. Europe Finland Denmark	Grain Meal	0.0025	1	5/5	100	Dubock & Kaukeinen 1978 Myllymaki 1984 Lund 1983	
		ICI Pellet	0.001	1	8/8	100		
		ICI Pellet	0.001	1	3/3	100		
<u>Bandicota bengalensis</u>	Burma	Fish Meal, Rice, Corn, Peanuts	0.001	1	13/32	41	Brooks, Htun & Naing 1980	
				2	18/29	90		
				3	18/20	90		
				4	11/11	100		
	India	Wheat Corn, Oil, Sugar NA	0.005	1	21/21	100		
				0.005	1	13/13		100
					1	20/20		100
				0.005	3	20/20		100
					4	0/6		0
				Bangladesh	Millet	0.00003		4
	0.00006	4	7/12			58		
	0.000125	4	11/11			100		
	0.00025	4	11/11			100		
			0.0005	4	11/11	100		
0.0010			4	6/6	100			
0.0020	4	7/7	100					
<u>B. indica</u>	Thailand	Rice	0.005	1	10/10	100	Tongtavee 1980	
<u>B. nemorivaga</u>	Taiwan	Rice	0.0025	1	10/10	100	Shien-Tay Tseng 1981	
			0.005	1	12/12	100		
			0.010	1	5/5	100		
<u>Citellus beecheyi</u>	US	ICI Oat Groats	0.005	1	12/12	100	Marsh, Pers. Comm.	
				2	12/12	100		
				3	20/20	100		
<u>C. richardsoni</u>	US	ICI Pellet	0.005	1	14/14	100	ICI, Unpub.	
<u>C. variegatus</u>	US	ICI Pellet	0.005	1	9/10	90	Maupin, Pers. Comm.	
<u>Cricetus cricetus</u>	Hungary	ICI Pellet	0.001	1	10/12	83	Kaiotas & Kaiotas 1984	
				6	12/12	100		
<u>Clethrionomys glareolus</u>	Czech, Denmark	ICI Pellet	0.001	1	9/9	100	Chmela, Dub & Rupes 1985 Lund 1981 Lund 1983 Lund 1981	
		Ground Oats	0.0005	1	10/10	100		
		ICI Pellet	0.001	1	10/10	100		
		Ground Oats	0.005	1	10/10	100		

Species	Source/ strain	Form.	Conc. (%)	Days given	Mortality		Reference
					no.	%	
		Wheat	0.005	2 1	10/10 20/20	100 100	Lund 1982
<u>Funambulus pennanti</u>	India	Wheat, Corn Sugar, Oil Millet	0.005 0.005	1 1 2 4 6	8/8 8/12 7/10 9/10 12/12	100 67 70 90 100	Parshad, Ahmad & Chopra 1985 Mathur & Prakash 1980
		Wheat, Oil, Sugar Millet	0.005 0.0025 0.002	3 3 1 2 4 6	5/5 5/5 NA NA NA NA	100 100 50 60 80 100	Saxena & Sharma 1982 Soni & Prakash 1983
		Wheat, Oil, Sugar	0.005 0.0025 0.00125	7 7 7	10/10 10/10 10/10	100 100 100	Saxena & Sharma 1984
<u>Gerbillus gleadowi</u>	India	Millet	0.005	1 2 3	5/10 9/10 10/10	60 90 100	Soni & Prakash 1981
<u>Golunda ellioti</u>	India	Millet	0.005	1 2	8/10 10/10	80 100	Soni & Prakash 1984c
<u>Holochilus brasiliensis</u>	Argentina	ICI Pellet	0.005	1	20/21	95	Dubock & Kaukeinen 1978
<u>Mastomys natalensis</u>	Africa	Oatmeal	0.002	1 2 3 4	7/20 18/20 18/20 20/20	35 90 90 100	Gill & Redfern 1979
<u>Meriones hurrianae</u>	India	Millet Millet Wheat Liquid ICI Wax Bait Wheat, Oil, Sugar	0.005 0.005 0.0125 0.005 0.005 0.005 0.0025 0.00125	1 3 3 1 1 2 1 7 7 7	10/12 12/12 12/12 NA NA 10/12 12/12 10/10 10/10 10/10 10/10	83 100 100 100 100 83 100 100 100 100 100	Soni 1981 Mathur & Prakash 1981 Saxena & Sharma 1981 Soni & Prakash 1984b, 1985 Soni, Jain & Soni 1984 Saxena & Sharma 1984
<u>Meriones shawi</u>	Morocco	Oatmeal Corn	0.005 0.005	3 4 5 6 7 8 1 3	1/20 4/10 4/10 7/10 9/10 10/10 27/50 20/20	5 40 40 70 90 100 54 100	Gill & Redfern 1983 Hoppe 1979
<u>M. unguiculatus</u>	US, Domestic	ICI Pellet	0.005	1	20/20	100	Marsh, Pers. Comm.
<u>Mesocricetus auratus</u>	Europe, Domestic UK, Ferai	Meal Oatmeal	0.001 0.005	1 1 2 3	NA 7/9 9/10 10/10	100 78 90 100	Dubock & Kaukeinen 1978 Bradfield & Gill 1984
<u>Microtus agrestis</u>	Finland	Apple Bait ICI Pellet ICI Pellet	0.005 0.005 0.001	1 1 2 1 2	11/12 6/10 7/10 10/16 15/16	92 60 70 62 94	Myllymaki 1984



Species	Source/ strain	Form.	Conc. (%)	Days given	Mortality		Reference
					no.	%	
	Denmark	ICI Pellet	0.001	1	5.5	100	Lund 1983
		Ground Oats	0.0005	1	10/10	100	Lund 1981
				2	10/10	100	
<u>M. arvalis</u>	Czech.	ICI Pellet	0.001	1	18/19	95	Chmela, Dub & Rupes 1985
	E. Europe	Grain Meal	0.005	1	52/52	100	Dubock & Kaukeinen 1978
	Denmark	Ground Oats	0.005	1	10/10	100	Lund 1981
				2	10/10	10	
		ICI Pellet	0.001	1	5/5	100	Lund 1983
		Ground Oats	0.0005	1	10/10	100	Lund 1981
				2	10/10	100	
	Hungary	ICI Pellet	0.001	1	17/20	85	Kalotas & Kalotas 1984
				5	19/20	95	
<u>M. californicus</u>	California	ICI Oat Groats	0.005	1	14/15	93	Marsh, Pers. Comm.
		Artichoke Bait	0.01	1	10/10	100	Marsh & Tunberg 1984
				2	10/10	100	
				3	10/10	100	
				4	10/10	100	
		Artichoke Bait	0.001	1	10/10	100	Marsh & Tunberg 1984
			0.005	1	8/10	80	
		ICI Pellet	0.001	2	9/10	90	
<u>M. pinetorum</u>	US	ICI Pellet	0.005	1	10/10	100	ICI, Unpub.
<u>Mus booduga</u>	India	Millet	0.00125	1	2/6	33	Balasubramanyam, Christo- pher & Purushotham 1984, 1985
				2	3/6	50	
				3	4/6	67	
			0.0025	1	4/6	67	
				2	5/6	83	
				3	6/6	100	
			0.005	1	5/6	83	
				2	5/6	83	
			0.01	1	6/6	100	
				2	6/6	100	
				3	6/6	100	
			0.02	1	6/6	100	
				2	6/6	100	
				3	6/6	100	
<u>Mus musculus</u>	UK LAC Grey	Meal	0.005	1	30/30	100	Dubock & Kaukeinen 1978
	Denmark	Ground Oats	0.0005	1	5/10	50	Lund 1981
				2	10/10	100	
		Ground Oats	0.005	1	10/10	100	
				2	10/10	100	
	India	Wheat, Corn, Sugar, Oil	0.005	1	11/11	100	Parshad, Ahmad & Chopra 1985
	Finland	ICI Pellet	0.005	1	10/12	83	Myllymaki 1986
		Rolled Oats		1	11/12	92	
<u>M. m. (warfarin resis.)</u>	Denmark	Ground Oats	0.0005	1	0/10	0	Lund 1981
				2	0/10	0	
		Ground Oats	0.005	1	9/10	90	
				2	9/10	90	
				3	10/10	100	
	Canada	ICI Pellet	0.005	3	17/23	74	Siddiqi, Blaine & Taylor 1983
	UK	Oatmeal, Oil	0.002	21	10/10	100	Rowe & Bradfield 1976
			0.005	21	18/18	100	
			0.01	21	20/20	100	
<u>M. m. bactrianus</u>	India	Millet	0.005	1	6/10	60	Soni & Prakash 1984
				2	7/10	70	
				3	8/10	80	
				4	9/10	90	
				5	10/10	100	
			0.002	1	7/12	58	
				3	10/12	58	



Species	Source/ strain	Form.	Conc. (%)	Days given	Mortality		Reference
					no.	%	
				5	11/12	92	
				7	12/12	100	
<u>Mystromys albicaudatus</u>	South Africa	ICI Pellet	0.005	1	20/20	100	Marsh, Pers. Comm.
<u>Peromyscus maniculatus</u>	USA	ICI Pellet	0.005	1	20/20	100	Dubock & Kaukeinen 1978
<u>Rattus argentiventer</u>	Malaysia	Rice, Oil	0.001	1	16/20	80	Lam Yuet Ming 1978
			0.005	1	20/20	100	
		Rice, Oil	0.005	1	10/10	100	Buckle, Rowe & Husin 1982
			0.0005	1	2/20	90	
				2	9/10	90	
			0.001	1	16/20	80	
				2	9/10	90	
			0.002	1	10/10	100	
	Thailand	Rice	0.005	1	10/10	100	Tongtavee 1980
	Bangladesh	ICI Pellet	0.005	1	9/10	90	Dubock & Kaukeinen 1978
	Indonesia	ICI Pellet	0.005	1	10/10	100	ICI, Unpub.
<u>R. exulans</u>	USA, Hawaii	ICI Pellet	0.005	1	5/5	100	Marsh, Pers. Comm.
				3	10/10	100	
<u>R. linntus</u>	Taiwan	Rice	0.005	1	3/3	100	Shien-Tay Tseng 1981
			0.010	1	3/3	100	
<u>R. losea</u>	China	Rice	0.010	1	5/5	100	ICI, Unpub.
	Taiwan		0.005	1	9/10	90	
		Rice	0.0025	1	10/10	100	Shien-Tay Tseng 1981
			0.0005	1	24/24	100	
			0.010	1	11/11	100	
<u>R. meltada</u>	India	Wheat, Corn, Sugar, Oil	0.005	1	10/10	100	Parshad, Ahmad & Chopra 1985
		ICI Wax Block	0.005	1	NA	80	Soni, Jain & Soni 1984
				2	NA	100	
		Millet	0.005	1	8/10	80	Soni 1981
		Liquid	0.005	1	18/22	82	Soni & Prakash 1985
				2	12/12	100	
<u>R. norvegicus, wild</u>	Hungary	Pellet	0.0075	1	5/5	100	Bajomi 1984
	Denmark	Rolled Oats	0.0005	1	5/10	50	Lund 1981
				2	8/10	80	
		Rolled Oats	0.005	1	10/10	100	Lund 1981
				2	15/16	94	Lund 1981
	UK	Oatmeal	0.002	2	60/60	100	Anon. 1978
	India	NA	0.005	1	16/20	80	Renapurkar & Kamath 1982
				3	20/20	100	
	Egypt	Oatmeal	0.002	2	9/9	100	Mahmoud & Redfern 1981
	UK	Oatmeal, Oil	0.001	2	20/20	100	Redfern, Gill & Hadler 1976
				2	29/30	97	
			0.010	1	10/10	100	
				2	20/20	100	
			0.0005	1	17/20	100	
				2	20/20	100	
	Taiwan	Rice	0.005	1	6/6	100	Shien-Tay Tseng 1981
			0.010	1	5/5	100	
	US	ICI Pellet	0.005	1	20/20	100	ICI, Unpub.
<u>R. n., warfarin, coumatetralyl &amp; bromadiolone resistant</u>	Denmark	Oatmeal	0.005	6	20/20	100	Lund 1982
<u>R. n. warfarin resist.</u>	UK	Oatmeal	0.002	2	20/20	100	Redfern, Gill & Hadler 1986
				2	39/40	97	Anon. 1978
		Oatmeal, Oil	0.001	1	10/10	100	Redfern, Gill & Hadler 1976
				2	20/20	100	
			0.0005	1	6/10	60	
				2	9/9	100	

Species	Source/ strain	Form.	Conc. (%)	Days given	Mortality		Reference	
					no.	%		
<u>R. rattus</u>	Egypt	Oatmeal	0.002	2	9/10	90	Mahmoud & Redfern 1981	
				3	20/20	100		
	US	ICI Pellet	0.005	1	18/20	90	Dubock & Kaukeinen 1978	
						100		
						100		
	India	ICI Block	0.005	1	10/12	83	ICI, Unpub.	
				1	10/10	100		
		Rolled Oats	0.005	1	10/10	100	Lund 1981	
				2	10/10	100		
		Wheat, Oil, Sugar	0.005	0.0025	7	10/10	100	Saxena & Sharma 1984
					7	10/10	100	
					7	10/10	100	
					1	10/12	83	
					1	15/20	75	
		Millet NA	0.005	0.005	1	10/12	83	Soni 1981
					3	20/20	100	
	Grain Bait Liquid	0.005	0.005	1	24/24	100	Jain, Saxena & Nag 1982	
				1	9/10	90		
	ICI Wax Block	0.005	0.005	1	NA	100	Soni, Jain & Soni 1984	
	Millet	0.002	0.005	4	12/12	100	Mathur & Prakash 1984a	
				4	16/16	100		
	Wheat, corn, Oil, Sugar	0.005	0.005	1	10/10	100	Chopra & Parshad 1985	
1				9/11	82			
ICI Pellet	0.005	0.005	2	12/12	100	Ikeda, Pers. Comm.		
UK	Oatmeal, Oil	0.002	2	29/30	97	Anon. 1978		
			2	20/20	100			
<u>R. rattus</u>	Denmark	Rolled Oats	0.0005	1	2/10	20	Lund 1981	
				2	6/10	60		
			0.005	1	10/10	100		
				2	10/10	100		
	India	Wheat, Corn, Sugar, Oil	0.005	0.005	1	10/10	100	Chopra & Parshad 1985
					1	24/20	100	
		ICI Wax Block	0.005	0.005	1	19/19	100	Parshad, Ahmad & Chapra 1985
		Wheat, Corn, Sugar, Oil Wheat	0.001	0.001	1	6/6	100	Rai, Lal & Srivastava 1984
					2	6/6	100	
					3	6/6	100	
					4	6/6	100	
					5	6/6	100	
		US	ICI Pellet	0.005	2	8/10	80	Ecke, Dennis & Godfrey 1979
	<u>R. r.</u> , warfarin resist.	UK	Oatmeal, Oil	0.005	2	5/5	100	Redfern, Gill & Hadler 1976
					2	4/5	80	
	<u>R. r.</u> , warfarin & pival resistant	US	ICI Pellet	0.005	3	7/7	100	Ecke & Lewallen 1979
	<u>R. r. frugivorus</u>	Cyprus	Barley, Wheat, Corn, Oil	0.005	1	10/10	100	Hoppe & Krambias 1984
	<u>R. r. mindanensis</u>	Philippines	Grain Meal Rice	0.005	3	8/10	80	Savarie, Pers. Comm. Hoque 1983b
					3	20/20	100	
	<u>R. tiomanicus</u>	Philippines	Grain Meal	0.005	1	17/17	100	Anon. 1976
	<u>Sigmodon hispidus</u>	US	Meal Bait ICI Pellet	0.005	1	5/5	100	Dubock & Kaukeinen 1978
1					8/10	80		
UK	Oatmeal	0.002	1	17/30	57	Gill & Redfern 1980		
			2	24/30	80			
			3	20/20	100			
<u>Spermophilus (See Citellus)</u>								
<u>Suncus murinus</u>	Burma	Lab Diet	0.005	4	4/4	100	Brooks et al. 1979	
<u>Tatera indica</u>	India	Millet	0.002	3	12/12	100	Mathur & Prakash 1984a,b	
				3	12/12	100		
				1	9/10	90		
			0.005	1	9/10	90	Soni 1981	

Species	Source/ strain	Form.	Conc. (%)	Days given	Mortality no.	%	Reference
		Wheat, Corn, Sugar, Oil	0.005	1	10/10	100	Parshad, Ahmad & Chopra 1985
		Liquid Bait	0.005	1	8/10	80	Soni & Prakash 1984b, 1985
				2	11/12	92	
				3	20/20	100	
		Wax Block	0.005	1	NA	100	Soni, Jain & Soni 1984
<u>Thomomys bottae</u>	US	ICI Oat Groats	0.005	1	2/2	100	Marsh, Pers. Comm.
<u>T. mazama</u>	US	ICI Milo Bait	0.005	3	19/23	83	Matschke, Pers. Comm.

NA - Information not available.

APPENDIX 6. Restricted feeding study results. No-choice 6-hr and 12-hr tests - ICI 0.005% brodifacoum formulations (ICI unpub., unless noted).

Species	Hr. feed <sup>a</sup>	Formulation type	Mortality	Av. dose (mg/kg)	Av. DOD <sup>b</sup>
<u>Articanthis niloticus</u>	6	pellet	12/12	1.2	6
	6	block	12/12	1.8	6
<u>Geomys bursarius</u>	12	milo	21/24	0.5	8 <sup>c</sup>
<u>Mus musculus</u> (wild)	6	block	5/9	3.9	8
	12	block	11/12	8.0	6
<u>Rattus argentiventer</u>	6	block	10/12	2.1	4
	6	pellet	12/12	1.9	7
<u>Rattus norvegicus</u> (wild)	6	pellet	23/24	2.4	7
<u>Rattus rattus</u>	6	block	10/12	2.3	8
	6	pellet	8/8	1.7	6
<u>Sigmodon hispidus</u>	6	block	10/12	1.8	9

<sup>a</sup> unfasted animals, offered bait beginning 1800 hrs, normal 12/12 light cycle, 22 C 2 C, 50% 5% R.H.

<sup>b</sup> DOD = Day of Death

<sup>c</sup> R. Case, pers. comm., May, 1979

APPENDIX 7. ICI brodifacoum formulations-acceptance and mortality (3-day single-cage choice tests vs EPA meal, unless noted; 1 S.D. in paren., ICI unpub. unless noted).

Species	VOLID 10 ppm pellet		TALON/KLERAT 50 ppm pellet		TALON/KLERAT 50 ppm block	
	Acc.	Mort.	Acc.	Mort.	Acc.	Mort.
<u>Arvicantis niloticus</u>	49.0(20.6) <sup>b</sup>	19/20	62.6(10.3) <sup>c</sup>	12/12		
<u>Citellus richardsoni</u>			31.1(7.7) <sup>c</sup>	20/20 <sup>d</sup>		
<u>Citellus tridecemlineatus</u>					20.5(18.6)	11/12
<u>Citellus variegatus</u>			39.0(28.7) <sup>c</sup>	9/10 <sup>e</sup>		
<u>Cynomys ludovicianus</u>			60.8(14.7) <sup>c</sup>	10/10 <sup>e</sup>		
<u>Meriones unguiculatus</u>					51.0(19.9) <sup>cb</sup>	10/10
<u>Microtus pennsylvanicus</u>					31.5(20.3) <sup>cb</sup>	10/10

Species	VOLID 10 ppm pellet		TALON/KLERAT 50 ppm pellet		TALON/KLERAT 50 ppm block	
	Acc.	Mort.	Acc.	Mort.	Acc.	Mort.
<u>Microtus pinetorum</u>	53.1(32.3) <sup>b</sup> 72.8(10.3) <sup>b</sup>	10/10 10/10	75.7(10.0) <sup>b</sup>	10/10		
<u>Mus musculus</u> (wild)	39.6(27.3)	5/10	57.5(35.8) 34.2(17.0) 36.2(28.1) 37.5(21.0) 57.4(27.0)	19/20 9/10 19/20 19/20 20/20	33.6(32.5) 24.5(10.8) 41.4(24.0)	19/20 10/10 10/10
<u>Peromyscus maniculatus</u>	40.6(19.6) <sup>a</sup>	18/20			36.8(16.3) <sup>b</sup> 40.2(21.4)	10/10 10/12
<u>Rattus exulans</u>			55.0(14.2)	10/10 <sup>f</sup>		
<u>Rattus norvegicus</u> (wild)	72.8(17.0)	10/10	59.7(26.3) 53.2(34.0)	10/10 19/20	48.9(24.0) 54.3(grp) 48.9(41.0) 59.4(35.6)	20/20 19/20 7/10 19/20
<u>Rattus rattus</u>			58.0(24.0)	18/20	54.2(39.0) <sup>b</sup>	8/10
<u>Sigmodon hispidus</u>			54.2(39.0) <sup>c</sup> 53.8(14.3) <sup>c</sup> 54.3(14.9) <sup>b</sup>	8/10 9/10 10/10	88.4(7.7) <sup>b</sup>	10/10

a - EPA meal consists of 65% ground whole corn, 25% ground rolled oats, 5% sugar and 5% corn oil

b - versus Microtus challenge diet (50% ground rolled oats, 50% ground rodent chow)

c - 4-day choice test

d - G. Pallister and S. Baril, pers. comm., Dec., 1980

e - G. Maupin, pers. comm., Dec., 1979

f - R. Marsh, pers. comm., Jan., 1978

#### APPENDIX 8. Non-U.S. commensal field efficacy trial results.

Reference	Subject
URBAN - PUBLIC HEALTH RELATED	
Brooks, et al. 1979, Richards 1986a	plague importance and brodifacoum efficacy for <u>Bandicota</u> and <u>Rattus</u> spp. from Burma
Gill and Redfern 1979	plague importance and brodifacoum efficacy for <u>Mastomys</u> from Africa
Karaseva, et al. 1984	control of rodent leptospirosis focus with brodifacoum in USSR
URBAN - GENERAL	
Brooks, et al. 1979, Htun, et al. 1984, Dubock 1984a, Brooks et al. 1980	trials against commensal <u>Bandicota</u> and <u>Rattus</u> species in Rangoon, Burma, giving effective control
Kadhim, Muhsen & Mustafa 1984	Baghdad, Iraq, Norway rat trials, 25 g per bait station
Muhr 1984	successful urban PCO experiences in Switzerland, esp. against <u>Mus</u>
Richards 1986a	urban trials in Sao Paulo, Brazil; Zhuo Xian, China; and Hlegu, Burma
VILLAGE AND FARM STRUCTURES	
Anon. 1985	reports successful control on S. African poultry farms

Reference	Subject
Bajomi 1984	75 ppm baiting on dairy and sheep farms in Hungary showed effective control
Bruggers & Valvano 1981, Rahman & Brooks 1982	village housing cluster trials in Bangladesh, giving 97% control
Chmela & Rupes 1983	farm structure baiting for rats and mice in Czechoslovakia gave good results with TALON pellet; has baiting density advice
R. Poche, pers. comm., Apr. 1982	complete rat control in Sudan poultry houses with 2 rounds of 10-15-g 50-ppm baits in burrows or near signs
Richards 1986a,b	village trial in Vietnam with baiting of structures and adjacent areas gave 95% reduction in activity
Wolf 1980	commensal trials among 5 farm sites, e.g., poultry houses, near Yaffo, Israel, giving 85-100% control.
CROP STORES	
Anon. 1980 rept. to ICI	50 ppm-pellets gave good control in 3 rat-and mouse-infested grain stores in USSR
Conway 1984	trials in Bangladesh godown against <u>Bandicota bengalensis</u> with population reduction, but immigration or inadequate baiting problems
Dubock 1978	useful general review of rodent problems in crop stores and uses of brodifacoum
Hoppe 1979	superior control of <u>Meriones</u> pest of stored crops in Morocco
Khryanina 1981	5-ppm wheat bait with 20-30 g placements for rats and 4-6 g for mice in USSR storehouses showed overall 96% reduction in activity
Lanting, Andres & Randon 1981	successful house mouse control in 26-day trial in Philippines with high density of bait points
R. Poche, pers. comm., Apr., 1982	2 baitings at 2-wk intervals in Sudan flour mill gave 93% reduced activity

APPENDIX 9. Agricultural pest rodent field efficacy trials (non-U.S.).

References	Subject
RICE	
Anon. 1979a	deepwater rice rodent control in Bangladesh gave 90% reduction using bait boxes
R. Brown, pers. comm., Dec., 1985	5-g wax block trials in Philippines at 1.2-1.7 kg/ha in rice gave 42% yield gain. Thailand rice application 5-g wax blocks at 0.77 kg/ha during dry season in 2 baitings at 2-wk intervals in 480-ha plot. Damage significantly reduced
Dubock 1980, Tongtavee 1980, 1984	Thailand rice trials with <u>R. arventiventer</u> and <u>Bandicota indica</u> using 10-g rice sachets or 5-g wax blocks gave 74-86% reduced tiller damage at rates of 1.25-1.65 kg/ha in 3 baiting rounds 1 mo. apart
Hoque & Olivida 1986	Philippine comparisons of sustained vs pulsed baiting in rice

References	Subject
Indrarto 1984	50-ppm KLERAT reduced rice losses Indonesia from 27% pre-trt. during 1979-80 to 16% during 1980-81 on 248,255 ha, saving 110,230 metric tons worth about US \$1 million
Khan, Ahmed & Choudry 1984	trials in Pakistan rice showed 2% rodent activity in treated vs. 37% in control of <u>Bandicota bengalensis</u> , <u>Millardia meltada</u> and <u>Mus</u> spp.
Ku 1984	<u>Mus formosanus</u> , <u>Rattus losea</u> and <u>R. norvegicus</u> in Taiwan rice controlled in island-wide campaign in 1978-82 using over 1 million tons 50-ppm wax bait yearly with good results
Lam Yuet-Ming 1980, Buckle & Rowe 1981, Buckle, Rowe & Husin 1982	5 or 15-g wax blocks were applied in Malaysian rice fields under various application regimes, giving 80-87% reductions
Taylor 1983, Tantawy Omar 1984	country-wide control campaign in Egypt against rodent pests
Tongtavee 1986	characteristics of KLERAT wax blocks and their use in Thailand
Williams & Vega 1984, Williams & Pereira 1984	Venezuela rice trials with <u>Sigmodon</u> or <u>Holochilus</u> in non- and irrigated rice
WHEAT	
Bruggers & Valvano 1982	3-4 g of 50-ppm bait cakes were applied per burrow in Bangladesh wheat fields, with rat damage after trtmt. at 2.6% vs 7.6% in untreated
Bruggers & Valvano 1983	Bangladesh demo trials in 1 sq. km. with 50-ppm bait cakes against <u>B. indica</u> in wheat fields and nearby structures, 4 baitings over 3 mo gave 86-90% reduced tracks or active burrows
Dubock 1980	trials in Pakistan wheat resulted in 87% reduced damage
Khan, Ahmed & Choudry 1984	85% fewer <u>B. bengalensis</u> , <u>M. meltada</u> and <u>Mus</u> were trapped after baiting over 3-4 days at each of 3 monthly applications; damage reduced 88% and yield up 7-fold
Parshad, Ahmad & Chopra 1985	50-ppm bait in 2 baitings of 3 days each gave activity redn. 3 census methods of 61-93% in Pakistan
Poche, et al. 1980, Bruggers 1980	after 12% losses to Bangladesh wheat crop to rodents for 1978-79, trials against <u>B. bengalensis</u> with weekly 50-ppm baiting gave 40% reduced tracks and trappings
SUGAR CANE	
Hampson 1984	thorough general review of rodent problems and evaluations in Mexico, Nicaragua and elsewhere
Hitchcock, Kerkwyck & Hetherington 1983	Australian trials of 50-ppm baits against <u>R. sordidus</u> at 1.68 kg/ha suggested possible 1080 replacement
Humbert 1983	cane trials in Mexico reduced rodents such that none could be trapped post-treatment
Wang 1978, 1981, 1982	Taiwan studies with cane species; field needs with 50-ppm bait in 10-15 g placements estimated at 1-2 kg/ha for good control
FRUIT TREES	
G. Anderson, pers. comm., Feb., 1979	<u>Thomomys talpoides</u> in Canadian orchard work with 50-ppm bran bait applied with hand probe gave 89% mound-building activity reduction

References	Subject
Bouchard 1978, 1979	Canadian orchard trials with 9 kg/ha 50-ppm bait gave 73% vole reduction
V. Kneifl, pers. comm., Dec., 1984	VOLID trials in Czech orchards gave 80% reduced activity of <u>M. arvalis</u> after broadcast at 5,10 or 20 kg/ha
Khryanina 1981	baiting vole burrows in Soviet Union gave 97% control
Myllymaki 1984	applications for Finnish orchards
Siddiqi, Blaine & Taylor 1983b, Siddiqi 1982	50-ppm pellets efficacious in Canadian orchard trials when used in bait stations
K. Taylor, pers. comm., Jan., 1981	<u>Arvicantis</u> attacking oranges in Egypt were completely controlled with 50-ppm wax blocks applied at the base of each tree
OTHER TREE CROPS	
Han & Bose 1980	in Malaysian cocoa under coconuts, <u>R. tiomanicus</u> and <u>R. argentiventer</u> reduced after baiting
Hoque 1983a	Philippine coconut-pineapple intercrop trials compared crown with tree base baiting in 50 or 200-g sachets; both gave effective control but pineapples better protected with ground baiting
Khoo Chin Kok 1979, 1980, 1984, Khoo Chin Kok & Dubock 1981	Yearly av. 5% losses Malaysian oil palm cut by applications 13-g wax blocks of 30 ppm placed at base trees under different schedules, giving 72-97% activity reduction from totals of 2.0-7.5 kg/ha applied
Lund & Iodal 1986	Danish trials near young forest plantings with 50-ppm wax block against <u>M. agrestis</u> and <u>A. sylvaticus</u> showed good bait take and significant population reductions
Mitchell & Valvano 1984	severe coconut damage <u>R. rattus</u> in Maldives, Indian Ocean prompted preliminary bait comparisons; Talon pellet take higher than for other toxic baits tested
GRASSLAND AND RANGELAND	
Anon. 1980 rept. to ICI	Soviet field trials with <u>Rhombomys opimus</u> gave 96% control
Chmela, Dub & Rupes 1985	Czech VOLID trials against <u>M. arvalis</u> in grassland at 10 kg/ha gave 92% reduced activity
Mathur & Prakash 1984a,b,c	desert scrub grassland in India treated for 10 days using bait stations; census results averaged 90.5% reduction <u>Meriones</u> activity
O'Connor 1979, Williams 1984	range and crop damage New Zealand from rabbits, hares and possums described; trials of 50-ppm bait at 1.6 kg/ha gave good rabbit control, with 3.2 kg/ha recommended for higher rabbit densities (to 33 rabbits/ha)
Vanurova 1980	field voles in Czech alfalfa successfully controlled even though this crop rich in vitamin K and other anticoagulants had failed
OTHER CROPS AND DAMAGE AREAS	
Anon., 1980 rept. to ICI	in USSR crop trials against common voles, burrow baiting with 50-ppm pellets gave 97% control
Hoque 1981, 1983b	Philippine research found 50-ppm bait effective in pineapples for protection against <u>R. r. mindanensis</u> and <u>R. exulans</u> , and returned a 1:5 cost benefit ratio
Soni, Rana & Jain 1985	crop trials in Indian desert gave 94% reduction in rodent activity after baiting

References	Subject
K. Taylor, pers. comm., Oct., 1983	trials in barley against <i>M. socialis</i> in Iraq with 4-17 kg/ha 50-ppm pellets applied; census bait take and active burrow counts revealed 71-92% reduction in activity
Tantawy Omar 1984	efforts in Egypt in wheat, beans, maize, cotton and other crops

APPENDIX 10A. USA registration trials - TALON pellets (1977-79) ICI development field trials (bait station or burrow stuffing).

Site & state	Bait cons. (g)	No. of points	Trtmt. days	%RDN census bait	%RDN tracks	Species
Storage barn, NY	860	35	11	90	70	NR
Corn crib, WV	1434	19	32	100	NA	NR
Seed warehse., GA	860	25	8	79	83	NR
Pig farm, MS	1451	19	18	95	92	NR
Feed store, OK	575	27	12	98	99	NR
Feed room, NM	206	19	5	78	65	R/M
Feed mill, TX	893	22	13	86	65	R/M
Grain Elev., CA	1051	5	13	100	100	RR
Poultry hse., LA	9031	64	11	64	95	R/M
Storage bldg., TX	109	10	11	98	100	HM
Storage bldg., GA	198	19	6	96	98	HM
Barn, MS	1451	19	26	95	92	R/M
Poultry hse., IL	238	18	7	96	99	HM
Dog kennel, FL	3240	16	11	83	98	RR
Poultry hse., IL	1745	18	10	92	84	NR
Poultry hse., MI	1698	60	8	96	79	R/M
Seed plant, MN	296	33	10	82	80	HM
Storage bldg., MO	13	10	7	81	85	HM



Site & state	Bait cons. (g)	No. of points	Trtmt. days	%RDN census bait	%RDN tracks	Species
Seed plant, IL	536	30	13	99	100	HM
Feed barn, NY	435	10	25	70.8	79	HM
Hog farm, FL	3006	28	11	70	53	RR
Seed storage, FL	409	8	15	100	100	RR
Horse barn, OR	3509	21	17	99	NA	NR
Farm bldg., OR	1319	33	16	95	NA	NR
Turkey farm CA	8052	10	11	99	100	NR
Hog farm, OH	3089	42	10	58	80	R/M

NR = Norway rat, RR - roof rat, HM or M = house mouse

APPENDIX 10B. USA registration field trials - Talon weatherbloks ICI development field trials (1979-81).

Site & state	Bait cons. (g)	No. of points	Trtmt. days	%RDN census bait	%RDN tracks	Species
Turkey farm, NC	3630	100	16	83	98	NR
Grain elev., OR	908	6	10	100	100	NR
Poultry hse., GA	24062	50	10	92	88	NR
City sewers, OH	4767	10	48	90	NA	NR
Duck farm, CA	31780	400	14	99	81	NR
Hog farm, LA	13393	200	6	88	NA	NR
Bus. office, CO	681	22	20	86	95	HM
Horse barn, OK	681	20	6	100	97	HM
Cotton shed, CA	3745	25	5	98	97	RR

NR = Norway rat, RR = roof rat, HM = house mouse

APPENDIX 11. U.S. agricultural pest rodent field efficacy trials - 50-ppm brodifacoum.

Reference	Subject
ORCHARDS	
Byers 1977	50-ppm apple bait and pellets applied by hand in Virginia at 10 lb/A gave excellent vole control
Byers 1978a,b,c	handbait trtmt. of 50-ppm pellets at 5.6 kg/ha gave 99% vole control
Byers 1979a	broadcast trtmt. of 50-ppm pellets at 13.4 kg/ha gave 88-100% control; handbait at 5.4 kg/ha gave 100% meadow vole reduction
Byers 1979b	pine voles showed 93% control after 12 kg/ha pellets broadcast; and 99% control using 1 50-g sachet per tree
ICI, unpub., Aug., 1979	<u>C. beecheyi</u> in Calif. walnut orchard treated 460 burrows with TALON pellets; activity reduced by 88% from trtmt.
ICI, unpub., July, 1979	<u>Thomomys bottae</u> in Calif. almond orchard received 30-g bait in tunnels with hand probe; showed 74% reduced activity
ICI, unpub., July, 1979	<u>C. beecheyi</u> in Calif. almond orchard were completely controlled following 15 days of trtmt. with TALON pellets in bait stations.
Kaukeinen 1977	reviews preliminary studies as orchard rodenticide
Kaukeinen 1978	reviews lab data and 3 handbait and 3 broadcast trials from Virginia or Indiana
Kaukeinen 1979	gives results of 19 field trials with 50-ppm pellets against 4 <u>Microtus</u> spp. in apple and pear orchard trials throughout the U.S.
Richmond and Miller 1980	a 10-lb/A broadcast treatment of 50-ppm pellets gave good control
Young 1979	50-ppm pellets were applied by air at diff. rates, ground broadcast at 10 lb/A, and handbaited at 10 lb/A in runs or stations
Young 1980	describes air and ground broadcast and hand-placement trials at 8-14 lb/A, with 72-81% average activity reduction
Young 1981	50-g sachets or loose bait were applied 1 per tree; more of loose bait was taken than sachets. Vole reductions after 6 mo noted
RANGELAND/TURF	
ICI, unpub., July, 1979	<u>C. columbianus</u> trials in Washington mt. meadow used TALON pellets maintained in 10 bait boxes within 10 A plots. Activity was reduced 82-95% following treatment
ICI, unpub., May, 1979	<u>Thomomys</u> spp. were controlled in a Washington meadow with TALON applied at 1-1.4 lb/A in a burrow-building machine on 30-ft centers; mound-building was reduced 89-93%
ICI, unpub., Aug., 1979	<u>Thomomys bottae</u> in Washington was controlled with TALON equally well as strychnine when both were applied with hand probe baiter at same rate
ICI, unpub., July, 1979	<u>C. beecheyi</u> damage at a Calif. golf course was reduced with TALON after baiting 317 burrows with 30-50 g; 90% activity reduced
ICI, unpub., Oct., 1979	<u>C. beecheyi</u> in Calif. turf near industrial area controlled 100% after 35-40 g applied to 104 burrows

Reference	Subject
ICI, unpub., Nov., 1979	<i>C. beecheyi</i> activity reduced 90-97% at Calif. airport using 25 bait stations each with 500-g TALON pellets over 5 days
ICI, unpub., July, 1979	<i>T. bottae</i> showed 87% reduced mound-building activity at a Calif. golf course following 50-ppm milo bait applied by hand at 8 g per active tunnel
ICI, unpub., June, 1979	gopher activity at a Calif. football field was reduced by 94% at 21 days after trtmt. when 30 g of TALON placed in each tunnel system
G. Matschke, pers. comm., July, 1982	<i>Geomys bursarius</i> in Minnesota pastureland was studied with telemetry and closed-hole technique before and after trtmt. on 10-ha plots with 50-ppm milo bait using burrow builder; 81-88% reduction was noted
R. Marsh, pers. comm., Nov., 1982	Calif. rangeland trials against <i>C. beecheyi</i> fisheri used 6 lb/A aerial applic. of 100 ppm oat groats or 12 lb/A hand bait of 50-ppm oat groats. Control equalled or surpassed 1080

#### OTHER CROP SITUATIONS

ICI, unpub., Mar., 1980	<i>C. fereticaudus</i> colonies on desert perimeters of soybean and cotton fields showed 70-89% reduced activity following 200-400 g TALON placement in bait stations or broadcast trials in Arizona
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APPENDIX 12. USA Volid rodenticide orchard field trials (10 ppm brodifacoum pellet, pine or meadow voles, *Microtus* spp.).

Rate kg/ha	Application	Crop	State	Redn. activity (%)	Year	Reference
19	broadcast	apples	VA	98	1979	Byers 1980, 1982a
23	broadcast	apples	VA	89-98	1980	Byers & Merson 1981
11	hand bait	cherries	OR	100	1981	ICI unpub., Nov., 1981
11	hand bait	apples	WA	80	1981	ICI unpub., Nov., 1981
18	broadcast	apples	WA	100	1981	ICI unpub., Nov., 1981
6	hand bait	apples	NY	67-100	1981	Steblein & Miller, pers. comm., Jan., 1982
14	broadcast	apples	NY	99	1982	Steblein, Miller & Richmond 1983
11	hand bait	apples	NY	89	1981	Pagano & McAninch 1983
15	broadcast	apples	VA	91	1982	Merson & Byers 1983
11	broadcast	apples	VA	100	1984	R. Byers, pers. comm., Feb., 1985
3	handbait	apples	VA	89	1984	R. Byers, pers. comm., Feb., 1985