

## EPIDEMIOLOGY OF HEARTWATER IN GUADELOUPE AND IN THE CARIBBEAN

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### ABSTRACT

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At present, heartwater in the Caribbean is known with certainty only on Guadeloupe, Marie Galante and Antigua; the first 2 islands are widely infected.

The most important factors responsible for particular aspects of heartwater in Guadeloupe are:

- *Cowdria ruminantium* of high virulence.
- A very resistant cattle population (Creole), not normally clinically affected.
- A fairly susceptible goat population (Creole) (22 % goats born in endemic areas die after experimental inoculation) which, fortunately, includes breeding lines with inherited resistance characteristics.
- *Amblyomma variegatum* which is present all over the island and all through the year, but with a low infection rate (1-2 % of adult ticks are infected) because of the short period of rickettsaemia in infected animals. The low rate of tick infection results in a low endemicity of the disease.

For goats, the epidemiologic situation can be regarded as unstable because the low rate of infection in ticks does not allow a natural immunization of the majority of young kids when they still have a non-specific resistance.

The possible evolution of heartwater in the Caribbean and in the United States is considered.

### INTRODUCTION

Heartwater was probably introduced into Guadeloupe 150 years ago with zebu cattle which were harbouring *Amblyomma variegatum* imported from Senegal (Curasson, 1943). The disease was only diagnosed in 1980 (Perreau, Morel, Barré & Durand), and it was the first case outside Africa and Madagascar apart from an accidental case in Brazil (Alves de Souza & De Abreu Martins, 1937). The risk of introducing the disease to the American mainland (Uilenberg, 1982), necessitated a survey on the distribution of heartwater in the Lesser Antilles (which was the objective of a joint United States-French-Dutch research project) and to study the epidemiology of heartwater in Guadeloupe (IEMVT-CIRAD project).

Guadeloupe (Basse-Terre and Grande-Terre) and Marie Galante, small islands with large numbers of cattle (100 000) and goats (35 000), numerous *A. variegatum* and very few diseases other than heartwater and dermatophilosis, appear to be a privileged place to study the epidemiology of heartwater, some aspects of which are still largely unexplored.

### MATERIALS AND METHODS

#### *Distribution of heartwater in the Lesser Antilles*

Details of the methods have been published (Barré, Camus, Birnie, Burrige & Uilenberg, 1984; Camus, Barré, Birnie, Burrige & Uilenberg, 1984) and only a summary is given here.

Adult *A. variegatum* (*Amblyomma cajennense* in French Guyana) were collected from cattle, sheep and goats (by the IEMVT team on Guadeloupe, Marie Galante, Martinique and French Guyana, and by E. F. Birnie, University of Florida, on other islands) and ground up in PBS\*. Supernates were cryopreserved in liquid nitrogen, pooled in batches of about 100 ticks and each pool was inoculated intravenously (i.v.) into a susceptible goat or sheep. Experimental animals originated from La Désirade, an island free from *A. variegatum* until 1983. Thereafter, animals were bought in Les

Saintes, so far free from ticks. Inoculated animals were monitored by recording daily rectal temperatures, by examining brain biopsies (method of Syngé, 1978) and brain smears after death, and by challenging the surviving animals with the Gardel strain of *Cowdria ruminantium* (Uilenberg, Camus & Barré, 1985).

The distribution of the disease in Guadeloupe and Marie Galante was determined by inoculating pools of 100 ticks collected from cattle and goats of each district into susceptible goats, as described above.

#### *Clinical and histological diagnosis*

After obtaining animals with suspected heartwater and information on heartwater from veterinarians, agricultural development agents and stock breeders (specially those at the INRA farm at Gardel, see Fig. 2), laboratory examinations were made of the brains of goats, cattle and sheep that had died suddenly or after fever and nervous symptoms. The number of deaths was noted, the age and breed of the animals, and the presence of *A. variegatum*. Diagnosis was made microscopically on brain samples, collected in accordance with the method of Schreuder (1980), by demonstrating the presence of colonies of *Cowdria* after fixation and Giemsa staining.

#### *Serological survey*

##### (a) *Collection of sera*

On all islands, with the exception of Guadeloupe and Marie Galante, blood samples were collected from cattle, sheep and goats at the same time that ticks were collected (by L. Birnie on all the non-French islands).

On Guadeloupe and Marie Galante a random survey was first made on cattle and goats. Altogether 638 bovine samples were collected at random, a single sample of blood being taken from 1 animal in each herd. Of the samples taken from goats, 373 were collected from 39 flocks, 1-18 samples being taken from each flock, depending on the number of animals in the flock. The breed, age and sex of the animals were recorded, as well as their origin (born in the herd or outside), whether the herd was confined or roamed free on the pasture, the presence of *Amblyomma*, the frequency of acaricide spraying, and a note was made of the presence of goats in the cattle herds.

\* Phosphate buffered saline  
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A second survey was later made on 350 cattle in the herds. They were twice sampled for sera at an interval of 1 year (1985 and 1986). Observations on zootechnical parameters and on tick infestation were made monthly.

(b) *Serological test*

The indirect fluorescent antibody (IFA) test described by Du Plessis (1981) and Du Plessis & Malan (1987), using the Kümm strain of *Cowdria* as antigen, was employed with slight modifications. The time of incubation for the serum and antigen as well as immunoglobulin and antigen was 30 min instead of 60, and the serum dilution considered positive was 1:80 for cattle and goats (instead of 1:20 for cattle). Results of the surveys were analysed by computer using the multidimensioned scale procedure. In order to detect the appearance and persistence of antibodies, some animals were first monitored weekly and then monthly.

*Tick infection rate*

In order to determine the infection rate of *A. variegatum*, one partially engorged adult tick, male or female, was collected from every infested bovine in the herds mentioned above. Each tick was triturated in sterile PBS and the supernatant inoculated into a mouse by the i.v. route, according to the method described by Du Plessis (1985). Five weeks later, the mice were bled and their sera tested with the IFA test at a 1:10 dilution.

To confirm the infection rate observed, results of the surveys made with the pools of ticks were used. Knowing the number of pools found infected, the number of districts infected (clinical cases) and the number of ticks (about 100) in each pool, it is easy to estimate the infection rate of ticks from statistical tables (Cannon & Roe, 1982). The infection rate was also estimated on the Gardel farm by collecting ticks from cattle, inoculating pools of 10 ticks into susceptible goats and re-inoculating individual ticks from positive pools into susceptible goats.

*Genetic resistance of goats to heartwater*

This subject is dealt with in another publication (Matheron, Barré, Camus & Gogué, 1987) and is only summarized here. Ninety Creole goats, born on the INRA farm of Duclos which is free from *A. variegatum*,

were experimentally inoculated with the Gardel strain of *Cowdria*, and the heritability of resistance estimated. The rate of resistance to *Cowdria* infection of different populations of Creole goats was studied in relation to the previous heartwater history of each population.

*Non-specific resistance of newborn kids*

Twenty-one kids, 2–4 weeks of age, were inoculated i.v. with a homogenate of 0.2 infected nymph (proved to be infective by inoculation into a susceptible goat). Inoculated kids were monitored by recording daily temperatures and by determining the antibody titre 1 month after inoculation.

*The Gardel strain of C. ruminantium*

The virulence of this strain was studied in Guadeloupe on Creole cattle, sheep and goats and the resulting immunity challenged with an African strain (Umm Banein from Sudan). Uilenberg, Camus & Barré (1985) also inoculated 12 Dutch goats with the Gardel strain and challenged their immunity with other strains (Ball 3 and Kwanyanga).

To determine the minimal infective doses (m.i.d.) of blood, blood was taken on the second day of the thermal reaction of a goat, serially diluted, and each dilution was inoculated by the i.v. route into a susceptible goat.

*Persistence of Cowdria in the blood*

Larvae of *A. variegatum* were fed on infected goats before, during and after the thermal reaction, or after a challenge, and fed in the nymphal stage on susceptible goats to test their infectivity.

RESULTS

*Geographical distribution of heartwater in the Caribbean and in French Guyana*

The results of the inoculation of tick homogenates and of the serological surveys are summarized in Table 1 and Fig. 1. If heartwater has been diagnosed in a goat inoculated with a tick homogenate (death with typical colonies of *Cowdria* in the brain, or brain biopsy with typical colonies, or recovery and no reaction to challenge), it can be concluded that the disease exists. This is the case

TABLE 1 Heartwater in the Caribbean: Results of inoculation of tick homogenates and of serological surveys

	Inoculation of tick homogenates		Serological survey: Number and % positive						Conclusion
	Number of ticks inoculated	Number of reacting small ruminants after inoculation	Cattle		Sheep and goats		Total		
			No.	%	No.	%	No.	%	
French Guyana	60 ( <i>A. cayen.</i> )	0/2	14/574 = 2		—			14/574 = 2	0
Grenada	—	—	5/173 = 3		0/31 = 0			5/204 = 2	0
St Vincent	—	—	3/109 = 3		0/6 = 0			3/115 = 3	0
Barbados	—	—	1/121 = 1		0/3 = 0			1/124 = 1	0
St Lucia	212	0/4	3/71 = 4		2/36 = 6			5/107 = 5	?
Martinique	246	0/3	23/226 = 10		18/156 = 12			41/382 = 11	?
Dominica	28	0/2	4/110 = 4		0/13 = 0			4/123 = 3	0
Marie Galante	345	3/3	23/110 = 21		38/99 = 38			61/209 = 29	HW
Guadeloupe	1 741	9/16	111/528 = 21		74/274 = 27			185/802 = 23	HW
Les Saintes	—	—	—		0/61 = 0			0/61 = 0	0
La Désirade	—	—	2/14 = 14*		0/39 = 0			2/53 = 4	?
Montserrat	—	—	1/116 = 1		—			1/116 = 1	0
Antigua	500	1/5	7/157 = 4		1/27 = 4			8/184 = 4	HW
Barbuda	—	—	0/29 = 0		—			0/29 = 0	0
Nevis	85	0/2	ND		ND			ND	?
St Kitts	140	0/2	5/60 = 8		—			5/60 = 8	?
Statia	—	—	0/31 = 0		—			0/31 = 0	0
Saba	—	—	0/17 = 0		—			0/17 = 0	0
St Martin	35	0/1	11/42 = 26		—			11/42 = 26	?
St Maarten	62	0/5	2/72 = 3		2/32 = 6			4/104 = 4	?
Anguilla	—	—	0/47 = 0		0/14 = 0			0/61 = 0	0

HW = heartwater present; 0 = absent; ? = suspicious  
 \* Cattle imported from Grande-Terre a few months ago  
 ND = Not done

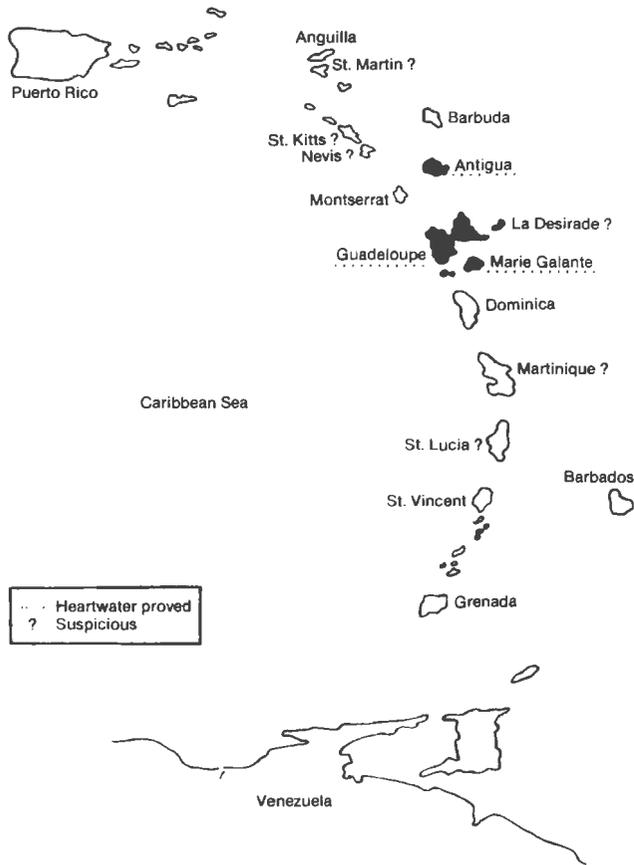


FIG. 1 Heartwater in the Caribbean

in respect of Guadeloupe, Marie Galante (Camus *et al.*, 1984) and Antigua (Birnie, Burrige, Camus & Barré, 1984). When the island is free from *Amblyomma*, or only a few *Amblyomma* are present, and the percentage of animals with antibodies is very low (2–3 % false positives are possible), heartwater should be absent: e.g. on Les Saintes, French Guyana, Grenada, St Vincent, Barbados, Dominica, Montserrat, Barbuda, Statia, Saba and Anguilla. In all other cases it cannot be stated positively that the disease is absent, i.e. on La Désirade, St Martin, Martinique, St Lucia, St Kitts and Nevis.

The detailed distribution of heartwater in Guadeloupe and Marie Galante, as revealed by inoculation of tick homogenates and the occurrence of clinical cases, is shown in Fig. 2. Twelve pools out of 19 inoculated were infective and clinical cases have also been diagnosed in municipalities where infectivity was not detected in tick homogenates. Therefore, widespread infection by heartwater was found in Guadeloupe and Marie Galante, and not a single municipality on the latter can be considered as free from the disease.

Even excluding clinical cases diagnosed on the Gardel farm, which was more carefully studied than anywhere else, heartwater cases in goats are more numerous on Grande-Terre (15 cases) than on Basse-Terre (6 cases), the number of goats being much the same on both islands, i.e. 13 500 and 11 400. More goat sera are positive on Grande-Terre than on Basse-Terre (Table 6), correlating with the degree of tick infestation. No clinical cases have been recorded on Marie Galante. This may possibly be explained by the absence of a veterinarian to diagnose the disease, and by the fact that Guadeloupe is too remote for easy communication.

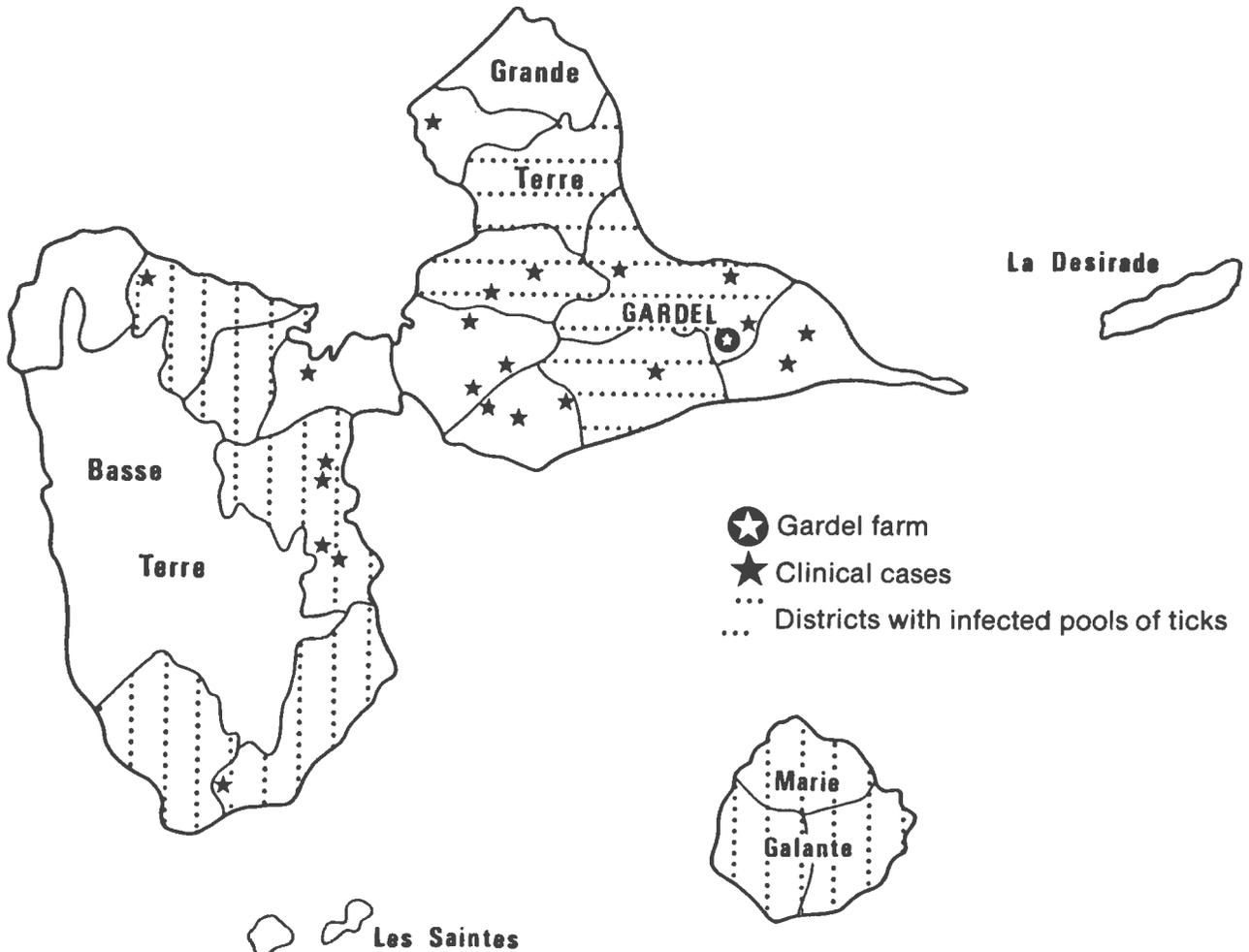


FIG. 2 Distribution of heartwater in Guadeloupe and Marie Galante districts

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TABLE 2 The minimal infective dose of blood

	Goat No.	Dilution	Reaction	Serology	Challenge	Reaction	Sero
Exp. 1	1	1/1	HW	+			
	2	1/1	HW	+			
	3	10 <sup>-1</sup>	HW	+			
	4	10 <sup>-1</sup>	HW	+			
	5	10 <sup>-2</sup>	HW	+			
	6	10 <sup>-2</sup>	HW	+			
	7	10 <sup>-3</sup>	0	-	+	HW	+
	8	10 <sup>-3</sup>	0	+	+	HW	+
	9	10 <sup>-4</sup>	0	-	+	HW	+
	10	10 <sup>-4</sup>	0	-	+	HW	+
Exp. 2	11	10 <sup>-2</sup>	HW	+	+	0	+
	12	10 <sup>-2.33</sup>	HW	-			
	13	10 <sup>-2.66</sup>	0	+	+	HW	+
	14	10 <sup>-3</sup>	0	-	+	HW	+

TABLE 3 Animals dead from natural heartwater/number of animals on Guadeloupe

	Cattle	Sheep	Goats
Creole	1 calf*/65000 head = 1,5 × 10 <sup>-5</sup>	1 adult/1600 = 6 × 10 <sup>-4</sup>	18 kids + 54 adults/24000 = 3 × 10 <sup>-3</sup>
Cross-bred	3 calves/3500 head 1 × 10 <sup>-3</sup>		3 adults/1000 3 × 10 <sup>-3</sup>
Pure-bred	2 calves, 2 heifers, 1 cow/1000 5 × 10 <sup>-3</sup>		

\* Mother died shortly after birth

TABLE 4 Appearance and persistence of antibodies in cattle and goats, after natural and experimental infection

		Cattle	Goats
		At birth	4/13
Colostr antibodies	Persistence	1 month (2 calves) 2 months (2 calves)	1 month (16 kids) 2 months (13 kids) 3 months (3 kids)
	Appearance	Natural infection	Experimental infection
		Persistence	4 months (2 calves) 5 months (4 calves) 6 months (1 calf)
	Average persistence	5 months	11 months

p.i. = post infection

*Characteristics of the Gardel strain*

The Gardel strain is very pathogenic: it killed all of the Dutch goats inoculated (Uilenberg *et al.*, 1985) whereas the Ball 3 strain killed only 15 out of 23. There is, in addition, complete cross protection between the Gardel strain and 2 African strains, Umm Banein (Sudan) and Ball 3 (South Africa). Cross protection, however, is not complete with the Kwanyanga strain (Uilenberg *et al.*, 1985) which is pathogenic to mice.

The disappearance of the parasite from the blood of infected animals is reflected by the fact that the infective period is limited to the thermal reaction and does not recur after a challenge (Barré & Camus, 1987).

The m.i.d. of blood collected 2 days after the onset of the fever, as determined by inoculating serial dilutions, is between 27 and 55 µl (Table 2).

The blood meal of an engorged larva represents from 1-5 times the m.i.d. and of a nymph 15-150 the m.i.d. This is based on the observation that ticks ingest 2-6 times more blood than their mass (Arthur, 1965).

*Inherited resistance and susceptibility of cattle, sheep and goats on Guadeloupe*

After experimental infection of goats removed decades ago from endemic areas (La Desirade), the observed rate of resistance is 25 %, while it is 54 % in a population that has been isolated from the disease for 10 years (Duclos) and reaches 78 % in a flock actually exposed to heartwater (Gardel). This resistance seems to be under genetic control, with an estimated heritability of 0,49 for half sibs and 0,85 for full sibs (Matheron, Barré, Camus & Gogué, 1987).

Table 3 summarizes the number of deaths from natural cases of heartwater on Guadeloupe. Natural cases were

TABLE 5 Analysis of the serological survey on goats by the multidimensional scale procedure

Class	Number of goats	Sero (+) %	<i>A. variegatum</i>	Acaricide	Mortality %	Average number of goats in flock	Management level	Municipalities
5	36	61	++	-	7,8	23	-	St Anne, St François Gosier, Petit-Canal
2	75	43	+	+	2,7	25	+	
6	25	40	+	-	7,3	9	-	
3	87	23	±	±	23,6	17	-	Le Moule, Goyave
1	93	20	±	-	0,4	14	-	
4	57	16	0	+	0	62	++	Capesterre 2, Deshaies Bouillante Capesterre 1, Anse-Bertrand

*A. variegatum* adults and nymphs: 0 = none; ± = very few (1 or 2/flock); + = few (1 or 2/goat); ++ = many (>2/goat)

Acaricide: + = regular (twice/month); ± = irregular; - = never

Mortality: number of deaths in the flocks during past year

Management level: - = poor; + = good; ++ = very good

TABLE 6 Comparison of serological results and tick infestation

	Grande-Terre	Basse-Terre	Marie Galante
<b>Cattle</b>			
No.	424	104	110
Sero-positives	19 %	31 %	21 %
Animals infested with <i>A. variegatum</i> adults	56 %	51 %	23 %
<b>Goats</b>			
No.	143	131	99
Sero-positives	37 %	16 %	38 %
Animals infested with <i>A. variegatum</i> adults and nymphs	29 %	4 %	15 %

compared with the total number of animals in each category present on Basse-Terre and Grande-Terre in 1982.

Susceptibility to heartwater decreases from Creole goats to Creole cattle, with Creole sheep in an intermediate position, but increases from Creole cattle to purebred European cattle (Table 3). The numbers of natural clinical cases shown in Table 3 are not exhaustive because all cases are not recorded in Guadeloupe, but they do allow a comparison between species and breeds.

The results are confirmed at Gardel where all cases are registered. On the Gardel farm in 1983, 21 out of 237 Creole goats died from naturally contracted heartwater (9 %), 34 recovered from the disease after treatment, and 13 died from other causes during 1983. Of 23 crossbred calves (Creole × Limousin and Creole × Charolais) 3 died from heartwater and 6 others recovered from the disease after treatment. Of 125 Creole calves 1 died from heartwater and another from a different cause.

None of the newborn kids which were experimentally infected reacted, but they were all susceptible to a challenge 3 months later, so the results have to be confirmed.

Serological results shown in Table 4 indicate that antibodies detected by the IFA test do not persist for a long time: 5 months on average for cattle and 8 months for goats.

Analysis of the serological survey by the multidimensional scale procedure yielded 6 classes of goat flocks (Table 5), 3 of which were highly infected and characterized by high or relatively high tick infestation and mortality. These were all small and middle sized flocks,

localized on Grande-Terre, and with a low level of management.

Infection rates lower than 20 % are found in 3 different classes of goats. There are, on the one hand, big flocks with a high level of management, as represented by Capesterre (Basse-Terre) and Anse Bertrand (Grande-Terre). On the other hand there are small flocks, with a low level of tick infestation but a very high mortality attributable with certainty to disease or diseases other than heartwater (not many sero-positives) in Grande-Terre (Le Moule) and Basse-Terre (Goyave). In an intermediate position are small flocks with a low level of management and no mortality, localized in the 1 Marie Galante district, and 2 of Basse-Terre. Other factors such as sex, origin and method of husbandry (tethered or free) do not play a role in the infection.

In the case of cattle from Guadeloupe and Marie Galante, the same analysis gave fewer results. The only influential factor identified was tick infestation, i.e. the number of ticks on each animal. Infection rates are higher (32 %) when many ticks parasitize cattle than when only few ticks are present (24 %) or when ticks are not observed (16 %).

#### Role of ticks in the disease

*A. variegatum* occurs all over Grande-Terre, Basse-Terre and Marie Galante, but the rate of infection by *Cowdria* does not always depend on the rate of infestation by ticks, as evidenced in Table 6.

Du Plessis (1982) found the same paradoxical result in South Africa, suggesting that different infection rates of ticks, depending on environmental conditions, may be the reason.

The monthly and yearly distribution of clinical cases of heartwater are shown in Fig. 3. The disease persists throughout the year, with a slight decrease in numbers in April and during the last quarter. There is no seasonal activity for *A. variegatum* on Guadeloupe (Barré *et al.*, 1985) because the dry season is not very marked. Ticks are active throughout the year.

The influence of acaricides on the infection rate and clinical heartwater is also paradoxical. Regularly sprayed goats on Guadeloupe are more often infected than goats that are sprayed only occasionally or not at all (36 % versus 24 % seropositives). Du Plessis (1982) also found many seropositive animals on farms with a strict dipping programme. Nevertheless, between 1985 and 1986, when a more persistent pyrethroid than the previous organophosphorous compound was used in the spray, a drop in seropositivity was observed on 25 farms from 30 % in 1985 to 19 % in 1986.

On the Gardel farm of INRA the regular dipping of goats with the same pyrethroid reduced the number of

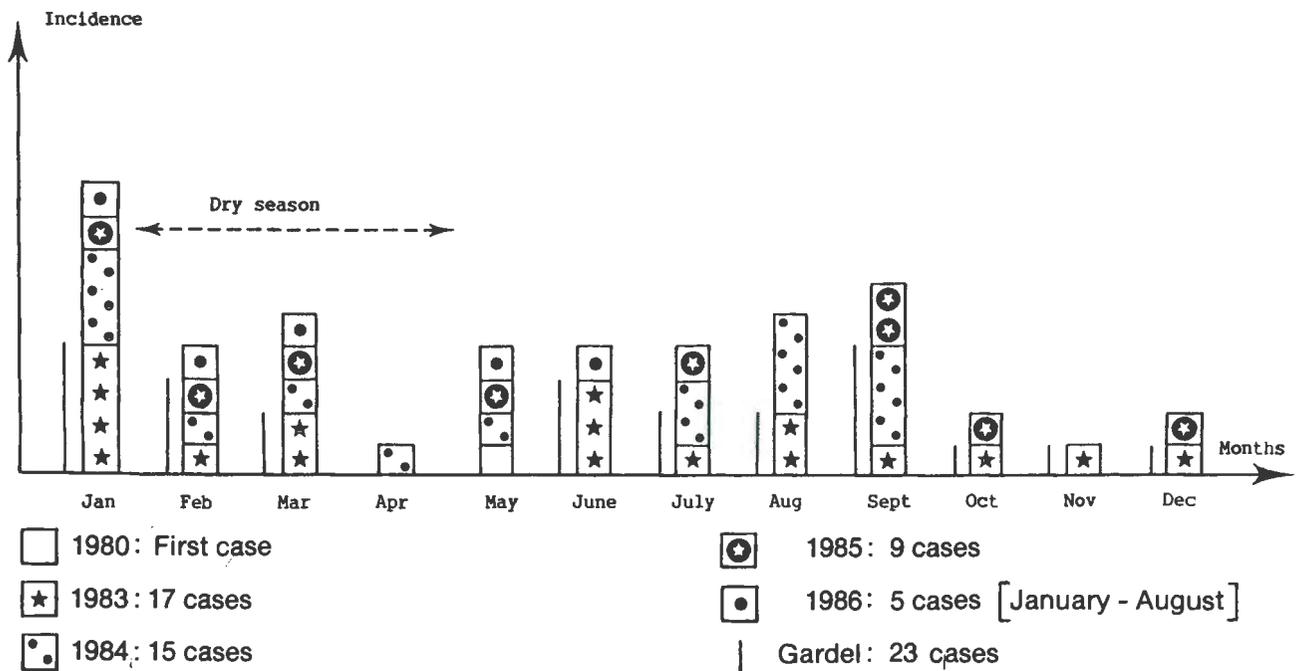


FIG. 3 Monthly and yearly clinical incidence of heartwater on Guadeloupe, each "case" representing 1 or more small ruminants and/or cattle dead

goats that died from heartwater from 21 in 1983 to 6 in 1984 and 2 in 1985.

Where the infection rate of *A. variegatum* was studied, only 3 out of 200 adult ticks collected on cattle and individually inoculated into mice, induced antibody formation (1 mouse was sero-positive at 1:10 dilution and 2 at 1:100). Similar results were obtained with tick homogenates collected in all municipalities on Guadeloupe. Twelve pools out of 19 tested were positive, therefore 7/19 (37%) were not detected by this method. However, clinical cases were observed in these 7 municipalities. With a sample of 100 ticks this corresponds to a rate of infection of 1% (Cannon & Roe, 1982), because 37% is the probability of failure to detect cowdriosis with pools of 100 ticks.

At Gardel, 5 pools of 10 ticks collected on cattle were inoculated into susceptible goats and 2 were infected. Individual ticks of each infected pool were then inoculated and 1 tick from each pool proved infected, i.e. 2 out of 50 ticks, or 4% (Barré & Camus, 1984). The infection rate is therefore very low, probably because of the short ricketsemia of infected animals and the fact that only about 60% of nymphs are infected, even when larvae feed under the ricketsemia (Barré & Camus, 1987), and the absence of transovarial transmission (very rare in fact, Bezuidenhout & Jacobsz, 1985). In 2 experiments with nymphs infected as larvae on a reacting goat and then individually fed on susceptible goats, 6/10 goats reacted in the first experiment and 5/8 in the second one. Negative nymphs were not infective in the adult state either. This experiment served as confirmation of the fact that 1 infected nymph is enough to transmit the disease (Neitz, 1971; Ilemobade & Leeflang, 1978). In addition, larvae and nymphs can feed on non-susceptible animals (Uilenberg, 1983), but these animals (dogs, mongooses, birds) play a very limited role on Guadeloupe harbouring only 4.3% of all larvae, 3.2% of all nymphs, and no adults at all (Barré *et al.*, 1985).

*General aspects of the disease*

In 26 out of 37 clinical outbreaks in goats, only 1 goat of the flock concerned died. In the other 11 outbreaks

from 2-17 goats died within a few days. We believe that these small "epizootics" coincided with the release onto the pasture of numerous engorged larvae by a reacting animal. These moult at about the same time and the emerging nymphs can infect several goats concurrently.

DISCUSSION

The islands where heartwater was found are characterized by heavy tick infestation and a variable percentage of seropositive animals (20-30% on Guadeloupe; only 4% on Antigua). The low incidence on Antigua is related to a low infection rate in ticks (only 1 pool out of 5 was infected), and perhaps to a recent introduction of the disease.

Some islands, mainly Martinique, St Martin and St Kitts where *A. variegatum* ticks are numerous and where there are some seropositive animals (8% and more), are possibly infected. On these islands it would be necessary to complete the survey by collecting and inoculating ticks (500 ticks have been necessary to demonstrate the presence of heartwater on Antigua, see Table 1), by asking veterinarians to collect brains of animals that died suddenly or showed nervous symptoms, and perhaps also by maintaining sentinel susceptible animals.

On Guadeloupe, clinical cases are not numerous but serve as indicators of the susceptibility of different species and breeds as well as other epidemiological aspects of the disease and its monthly and yearly evolution. The continuous occurrence of the disease seems typical in humid countries where *Amblyomma* is active throughout the year. It is not the same in Africa where most cases occur at the beginning of the rainy season, because ticks are more numerous and the poor condition of livestock after the dry season (Perreau, 1973). When cases do occur during the dry season in Africa, they are few (Aka-fekwa, 1986), contrary to what is observed on Guadeloupe (10 cases/41 during the dry season from February-April). Creole cattle are resistant not only to heartwater, but also to other diseases (less than 1% annual mortality rate: Salas, Roy & Planchenault, 1986).

Serological results indicate that the IFA test indicates a recent infection, underestimates the number of naturally infected animals and cannot be used to differentiate

between primary and secondary infection. Analysis of serological results for cattle does not identify any influential factor except possibly the level of tick infestation. A drop in the infection rate between 1985 and 1986 was recorded after using a new acaricidal compound.

Rickettsemia in reacting goats is limited to the fever period, which differs from the findings of Ilemobade (1976) (50 days) and Neitz (1939) (60 days). There is no rickettsemia infective to ticks after a challenge, so we confirm the opinion of Du Plessis & Bezuidenhout (1979).

The tick infection rate in Guadeloupe (1–2 %) is lower than in South Africa (5 % if sera of inoculated mice are considered positive at 1:10 dilution, Du Plessis, 1985). *A. hebraeum* is perhaps a better vector than *A. variegatum*, as proposed by Karrar (1968). It is reasonable to deduce that antibodies in mice injected with individual ticks cannot result from anything other than infection with *Cowdria* because the inoculation into goats of numerous non-infected ticks (637) did not produce any antibodies detected by IFA test (2 % of false positive reactions).

The Gardel strain appears to be very closely related to African strains. It protects against classical strains, but partially, or not at all, against mouse strains (Uilenberg *et al.*, 1985; Logan, Birnie, Endris & Mebus, 1985).

#### CONCLUSION

At the present time, heartwater in the Caribbean has been demonstrated conclusively only on Guadeloupe, Marie Galante and Antigua. The first 2 islands are heavily infected, Antigua apparently far less so.

On Guadeloupe, the most important factors responsible for particular aspects of heartwater epidemiology are:

- *Cowdria ruminantium* of high virulence;
- a resistant Creole cattle breed which represents 95 % of the livestock on the island;
- a fairly susceptible Creole goat breed (22 % of goats born in endemic area die after experimental inoculation) which, fortunately, has breeding lines with inherited resistance characters;
- *A. variegatum* widely spread all over the island and throughout the year, but with a low rate of infection (1–2 % of adults) because of the short period of rickettsemia in infected animals. The low rate of tick infection is the reason for the low endemicity of the disease.

The low endemicity can explain why the disease has not been identified for 150 years. The situation on Guadeloupe can be regarded as epidemiologically unstable for goats, because the low rate of tick infestation does not allow a natural immunization of the majority of young kids when they still have a non-specific resistance (if this resistance really exists).

Predicted evolution: the decrease in sero-positive cattle between 1985 and 1986, and of clinical cases in the same period, is correlated with the diminished numbers of *A. variegatum* after using a persistent pyrethroid acaricide. That is a positive point. The question is: is it possible to eradicate *A. variegatum* from Guadeloupe where 12 000 people each own from 1–50 head of cattle, and where immature stages of *A. variegatum* can feed on mongooses and birds? That is a negative point, especially when birds carrying infected ticks can spread over neighbouring islands, or even as far as South, Central and North America.

What remains to be known about the epidemiology of heartwater?

In general:

- How long does the rickettsemia in cattle last? Is it limited to the fever period, as is the case with goats? Is the rickettsemia in cross-bred goats, which are more susceptible than Creole goats, also limited to the fever period?
- Is *A. hebraeum* really a better vector than *A. variegatum*?
- Do other breeds of goats with inherited resistance exist?
- What is the nature of the resistance in young animals?

On Guadeloupe:

- Are cattle involved in the epidemiology of heartwater as reservoirs of the disease or as carriers of ticks?
- Is there a rickettsemia in Creole cattle, allowing the infection of *A. variegatum*?

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