



## Analysis of *Amblyomma* surveillance data in the Caribbean: Lessons for future control programmes

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### ABSTRACT

*Amblyomma variegatum*, the Tropical Bont Tick (TBT), is the principal vector of heartwater and is associated with dermatophilosis, major causes of losses in animal production and mortality in Caribbean livestock. From 1995 to 2007, the Caribbean *Amblyomma* Programme (CAP) supported treatment and surveillance activities in 11 islands of the Eastern Caribbean with an initial objective of eradicating TBT. In addition to control activities, surveillance data were collected between 1997 and 2006 in a unique regional database. We report the analysis of the surveillance data from four islands (Nevis, St Kitts, St Lucia, and Barbados) where control and surveillance followed the initial protocol and where enough data were collected. We describe the evolution of TBT infestation levels and the efforts carried out throughout the surveillance period. Logistic regression identified factors associated with herds found infested with TBT. Overall, treatment programmes were associated with a decrease in proportion of TBT-infested farms. High surveillance efforts were carried out throughout the 1997–2007 period for all island of interest, but inadequate level of surveillance was observed in several quarters especially for St Kitts. Third quarter of the year, as indication of adult TBT seasonality on livestock, was significantly associated with the risk of detecting TBT in Nevis and St Kitts livestock farms. Also, presence of cattle in Nevis farms was shown associated with an increasing probability of farms being declared TBT-infested. Outcomes of these analyses provide basis for recommendations to improve future national and regional control and surveillance activities. This analysis demonstrates the usefulness of long term and adequate surveillance data for control programmes and identification of factors associated with risk of having infested herds.

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## 1. Introduction

Tropical Bont Tick (TBT), *Amblyomma variegatum*, is a major constraint to ruminants breeding in Africa and the Caribbean: first, bites induce attachment lesions and direct losses by blood spoliation. Second, TBT favor the development of the acute form of dermatophilosis, a skin

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disease caused by the bacteria *Dermatophilus congolensis* (Martinez et al., 1992). Finally, TBT is the vector of *Ehrlichia ruminantium*, an intracellular bacteria, causal agent of the ruminant's fatal disease heartwater. In the Caribbean, dermatophilosis has been responsible of direct and indirect losses in livestock population (e.g., a loss of 75% of the cattle population in Nevis has been recorded in the 1990s, Hadrill et al., 1990). Heartwater is currently present in the islands of Guadeloupe, Marie-Galante and Antigua, and was estimated to cause annual losses of 10–20% for national livestock herds (Barré et al., 1996).

It is believed that TBT was first imported into the Caribbean by livestock coming from West Africa to the island of Guadeloupe around the 19th century (Uilenberg et al., 1984). Spatial distribution of TBT was confined to three to four islands until the late 1960s when it began to spread rapidly. By the end of the 1980s, 18 Caribbean islands had become infested (Barré et al., 1987; Fig. 1). The recent increased TBT spread is believed to be partly associated with the establishment of cattle egrets (*Bubulcus ibis*), ground feeding birds that live in close contact with livestock (Uilenberg, 1990; Corn et al., 1993). The ability of cattle egrets to carry immature TBT along their movements within the Caribbean region emphasizes the

threat of introducing TBT and associated diseases into the American mainland (Barré et al., 1987). Costs of TBT introduction for American animal industry have been estimated to be worth than US\$ 760 millions (Gersabeck, 1994).

A programme aiming to eradicate the TBT from the English Lesser Antilles was launched in 1994: the Caribbean *Amblyomma* Programme (CAP). Nine islands participated to the eradication activities: Anguilla, Antigua and Barbuda, Barbados, Dominica, Montserrat, Nevis, St Kitts, St Lucia and Saint Maarten (Pegram et al., 1998). To reach the objective of TBT eradication, CAP was organised in two overlapping stages. First, a treatment phase was implemented, during which all domestic ruminants were supposed to be treated by their owner every 2 weeks with Bayticol, a pour-on acaricide of the flumethrin family. It was hypothesized that 2–3 years of compulsory blanket treatment were required to control all adult TBT that may remain in the environment. Second, active surveillance programme was implemented to (1) inform on the end date of the treatment phase (a 6-month period with no detection of TBT was required to end the treatment phase), and (2) show TBT-freedom (another 6-month period with no detection of TBT was required to apply for provisional

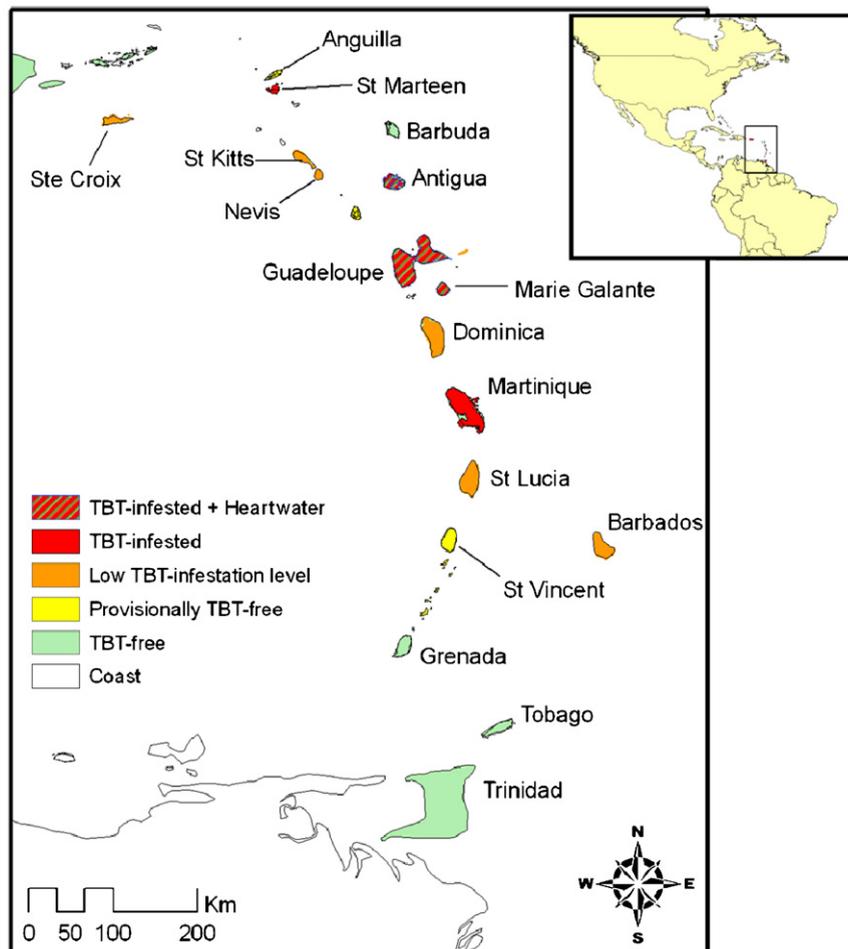


Fig. 1. Current Tropical Bont Tick infestation and heartwater national status within the Lesser Antilles.

TBT-freedom). Six islands out of nine were declared provisionally free of ticks: St Lucia and St Kitts in 2001; Montserrat and Anguilla in 2002; Dominica and Barbados in 2003. TBT-freedom status was removed for St Kitts in 2004. Antigua and Barbuda, Nevis and Saint Maarten still remain with the “TBT-infested” status (Pegram and Eddy, 2002). CAP programme ended in 2008 at this situation.

The presence of TBT in several islands and the presence of cattle egret as a possible factor for TBT spread highlight the need for an in-depth analysis of the data obtained during the course of the CAP. The objectives of the present study were to: (1) understand the reasons of successes and failures of the eradication programme for the different islands involved in CAP, and (2) identify factors associated with presence of TBT which could be potentially targeted to improve surveillance or control programmes in this region. To achieve these objectives, we focused the analysis on islands that followed the eradication protocol and collected sufficient surveillance data for several years: Nevis, St Kitts, Barbados and St Lucia.

## 2. Materials and methods

### 2.1. Data collection

Infestation data were collected and recorded during the second phase of the programme when absence of tick had to be demonstrated to stop blanket treatment and declare provisional freedom status (CAP, 1999).

The objective of the surveillance phase was to detect farms that remained infested using a two-degree random sampling: first, farms were randomly selected each quarter among all farms. Second, randomly selected animals were immobilized and examined to detect presence of adult TBT. At each visit, number and species of animals present in farm, number and species of examined animals, and number of male, female and engorged female TBT were recorded in TickINFO (Pegram et al., 2007), an ACCESS database with a simple interface for data capture. Data recorded in previous databases were later transferred to TickINFO.

### 2.2. Descriptive analyses

As the surveillance was designed to detect infested farms, we chose the farm as the epidemiological unit to assess the evolution of infestation in the four islands. A visit was defined as a farm in which animal were examined. A farm was considered infested when at least one animal showed TBT infestation. The eligible popula-

tion is all herds present in each island of interest. The study population is all herds that were visited during the course of surveillance programme. We used the proportion of infested farms among visited farms as an estimate of prevalence for each quarter-year, year, quarter and species. Estimates of total number of herds and total number of animals in each island were extracted from the reports of activities sent annually by every island to the CAP regional coordination unit.

### 2.3. Statistical analysis

A logistic regression model was developed for St Kitts, St Lucia and Nevis to quantify the effect of putative explanatory factors on the probability of TBT infestation in farms. No model could be fitted on Barbados data, as insufficient infested farms were detected compared to the number of farm-visits. For this analysis, outcome  $Y_{ij}$  was the report of at least one animal with TBT infestation from the  $i$ th farm, during the  $j$ th visit. Influence of year, quarter, and presence of cattle, presence of goat, and presence of sheep in the visited farm were all introduced in the model at once and remained in the model to account for mutual confounding. For all models, we tested the influence of the sampling fraction in farms, the  $\log_{10}$ -transformed animal population size or the  $\log_{10}$ -transformed animal sample size on the odds of declaring a farm TBT-infested. These latter variables were retained in the models if they confounded other variables or if they significantly improved model fit at an alpha level of less than 0.05. Interaction between explanatory variable were successively tested and kept in models if remained significantly associated. We extended the fixed-effects model to include random effect terms to account for correlation arising from repetitively visiting the same farms throughout the surveillance period.

Regression analyses were performed using a generalized linear model with multivariable normal random effect terms using maximum Laplace approximation methods (Pinheiro and Bates, 2000) implemented in the LME4 package (Bates et al., 2008) in R Version 2.7.2 (R Development Core Team, 2008).

## 3. Results

### 3.1. Surveillance data

Six to ten years of surveillance were recorded in TickINFO, depending on the islands studied (Table 1). Two

**Table 1**

Caribbean Amblyomma Programme (CAP) surveillance data. Surveillance period, total number of visits, and average numbers of farm-visited and animal examined per quarter (and their 95% confidence intervals) throughout the TBT surveillance period stratified by island of interest. Estimates of number of herds and animals present in each island of interest are also provided for indication.

Islands	Herds <sup>a</sup>	N <sup>a</sup>	Period	No. quarters	No. visits	Mean visits (95% CI) <sup>b</sup>	Mean animals (95% CI) <sup>c</sup>
Barbados	683	56,096	1999–2006	30	6155	182 (155–209)	3075 (2649–3500)
St Kitts	763	14,798	1997–2006	38	4397	113 (94–132)	564 (440–687)
St Lucia	6938	29,261	2000–2006	28	7901	278 (225–330)	4675 (3383–5966)
Nevis	551	29,244	2001–2006	23	5728	250 (94–132)	5357 (4011–6702)

<sup>a</sup> Estimated total number of herds and animals provided by the CAP nation reports during the period of surveillance.

<sup>b</sup> Average numbers of farm-visited per quarter throughout the TBT surveillance period.

<sup>c</sup> Average numbers of animal examined per quarter throughout the TBT surveillance period.

surveillance strategies have been taken in the four islands of interest. On one hand, in Barbados, St Kitts and Nevis, inspections were done in farms selected at random. In these islands, surveillance operators and managers respectively examined 6%, 4% and 18% of livestock population quarterly. On the other hand, a buffer strategy was implemented in St Lucia, where compulsory inspection were carried out in farms historically known to be TBT-infested and their surroundings, in which 95.4% (95% CI: 95.0–95.8%) of animals present were examined. We estimated that 16% of the St Lucia livestock population was examined for TBT throughout the surveillance period.

High level of surveillance was carried out in both Barbados and Nevis (Table 1) where an average of 27% and 45% of farms were visited per quarter, respectively. In Barbados, intensity of surveillance was strengthened during 6 months preceding the declaration of provisional freedom: the number of visits rose to 363 and 282, in the two successive quarters starting from the third quarter of 2002. Although being certified TBT-free, level of surveillance remained constantly at a high level, averaging to 191 visits per quarters (95% CI: 157–226) from the first quarter of 2003 onward. Nevis surveillance efforts were constant for the 6 years of surveillance, with number of visits per quarter ranging from 200 to 400, but dropped drastically at the end of 2006 where only two visits were recorded for the third quarter of 2006.

In St Kitts, surveillance operators and managers visited an average of 15% of farms in each quarter (Table 1). However, a twofold decrease in surveillance was observed from the fourth quarter of 2001 to the end of 2002. During this period, the number of visits per quarter was reduced from 150 to less than 100, corresponding to a drop of 300 quarterly examined animals from the initial 600. Following this period of low surveillance level, number of visits widely fluctuated: two peaks of surveillance was observed in the two last quarters of 2003 and in the second quarter of 2005, with periods of low level surveillance in between (i.e. surveillance level bottomed down to 50 visits per quarter).

Across the four islands of interest, 0.4–1.7% of the farm-visits recorded in TickINFO showed inconsistencies as a number of animals examined greater than the number of animal present. These records remained in the database to provide sufficient level of TBT infestation for analysis, and to allow the detection of persistent (or re-emerging) TBT infestation in livestock.

### 3.2. Descriptive analysis

Throughout the whole surveillance period, 60, 164, 221 and 335 adult TBT were found in Barbados, St Lucia, St Kitts and Nevis, respectively. Of these adult TBT, 24–33% were females, from which 13–21% were engorged. The average number of TBT collected on infested animals was 5.56 (95% CI: 1.35–9.78), 3.23 (95% CI: 2.39–4.08), 4.75 (95% CI: 3.10–6.40) and 4.28 (95% CI: 2.90–5.67) in Barbados, St Kitts, St Lucia and Nevis, respectively.

Similar pattern of variation for the proportion of TBT-infested farms per quarter-year were observed in Barbados

and St Kitts (Fig. 2). This pattern consisted in: (1) a decreasing trend from 1999 to the end of 2001 for Barbados and from 1997 to the second quarter of 2000 for St Kitts, (2) a period during which no farms were detected TBT-infested for several quarters (six for Barbados, and seven for St Kitts), and (3) a reappearance of TBT in visited farms. In Barbados, TBT reappearance consisted in two infested farms in two non-continuous quarters whereas a progressive increase in the proportion of TBT-infested farms was observed in St Kitts which reached a peak in the second quarter of 2006.

In St Lucia, a low level of farm infestation was detected during the 2000–2002 period, varying from 0% to 1%. An increasing trend followed throughout the year 2003 and three peaks were recorded afterward: one in the first quarter of 2005, another in the first quarter of 2006, and the last in third quarter of 2006 (Fig. 2).

In Nevis, two periods may be discerned regarding the variation of the proportion of TBT-infested farms (Fig. 2): (1) from the beginning of 2001 to the end of 2004, 2–4% of the visited farms were recorded TBT-infested, with three peaks of farm infestation occurring during each third quarter, and (2) from the first quarter of 2004 to the second quarter of 2006, proportion of TBT-infested farm decreased to a low level, with no TBT detected during six non-successive quarters.

In St Kitts and Nevis, a high proportion of farm-visit was declared TBT-infested in the third quarter, compared to the rest of the year (Fig. 3). For St Lucia, proportion of TBT-infested farm-visits was greater in the first and third quarter of the year than for the rest of the year. It is worth noting that no TBT was ever detected in Barbados during any first quarter of the 7 years and a half of surveillance.

For Barbados, St Kitts and Nevis, greater proportion of TBT-infested farms were recorded for farms having at least one cattle than for all farms having at least one small ruminant (Fig. 3).

### 3.3. Risk factors analysis

The logistic regression demonstrated the significance of the peaks and outbreaks described for St Kitts, St Lucia and Nevis in the analysis of the variation of the proportion of infested farms (Table 2). In St Lucia, the odds of declaring a farm TBT-infested increased in 2003 and in 2006 by a factor 11.9 (95% CI: 4.1–34.6) and 14.0 (95% CI: 4.8–41.1), respectively, compared to the period 2000–2002. In St Kitts, no significant difference was found between the odds of visiting infested farms in 1997 and that of 2006 ( $P > 0.5$ ), while lower odds for farm infestation were found for the period 1999–2004 ( $OR < 0.1$ ,  $P < 0.01$ ). In Nevis, farms that were visited in the 2004–2006 period were between 11 and 25 times less likely ( $P \leq 0.01$ ) to be declare TBT-infested than farms visited in the 2001–2003 period.

According to mixed-effects logistic regression model, the presence of cattle increased by a factor 22.1 (95% CI: 4.1–119,  $P < 0.001$ ) the odds of finding at least one TBT in the visited farms in Nevis. The influence of species was not significant in St Lucia and St Kitts (Table 2).

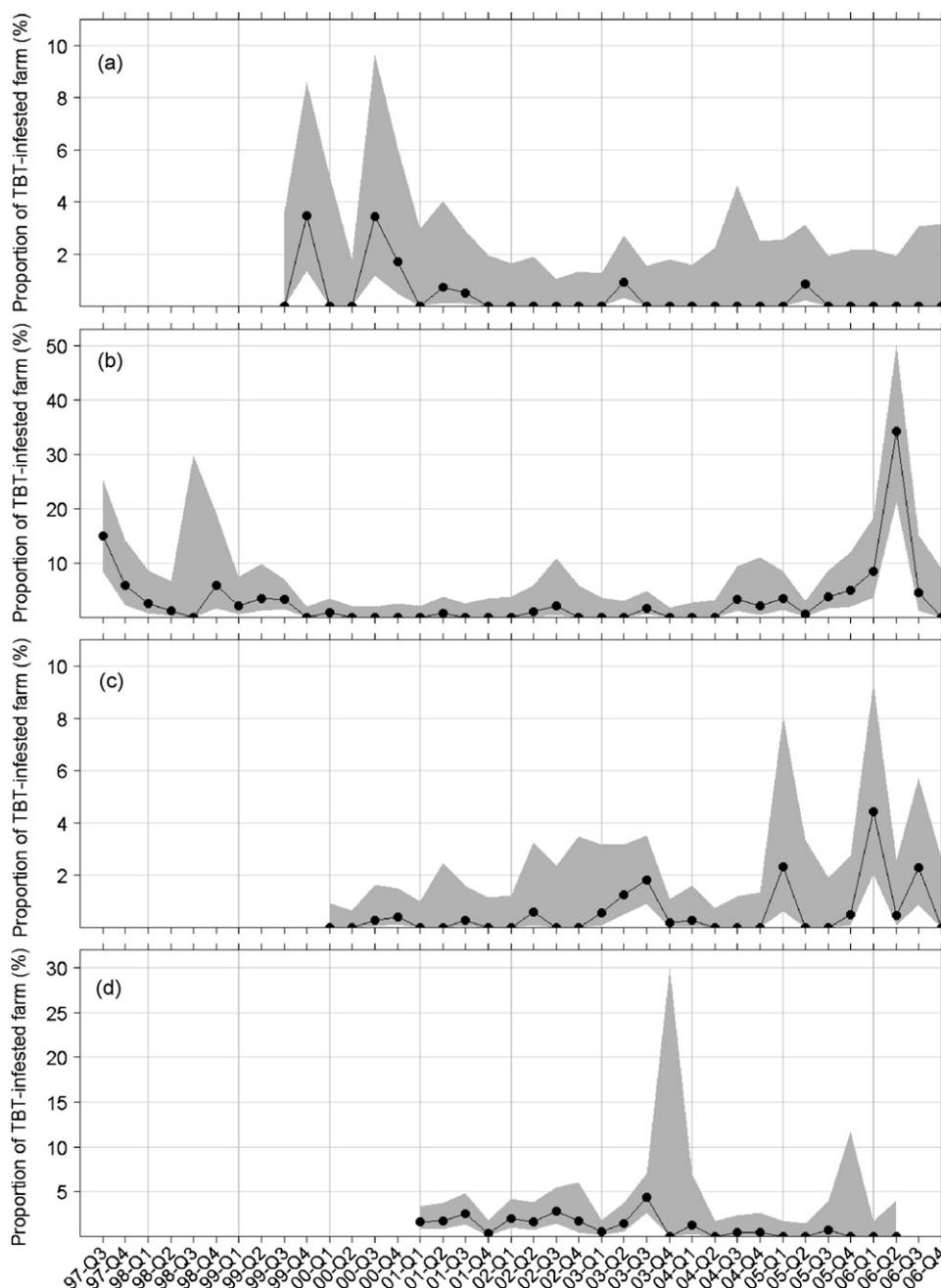


Fig. 2. Evolution of the proportion of infested farms. Line plots showing the evolution of the proportion of farms (%) visited during the CAP surveillance activities that showed at least one animal infested with TBT throughout the surveillance period: (a) Barbados, (b) St Kitts, (c) St Lucia, and (d) Nevis. Shaded areas represent the 95% confidence interval envelop.

Farms that were visited during the third quarter of the surveillance year were at greater odds of being declared TBT-infested in St Kitts and in Nevis, than during the other quarters (Table 2). In St Lucia, farms that were visited in the fourth quarter were significantly at lesser odds (OR = 0.26, 95% CI: 0.09–0.80,  $P = 0.02$ ) of being declared TBT-infested than farms visited in the third quarter.

The size of the herd significantly increased the probability of infestation in St Lucia: the odds of finding

at least one TBT in a visited farm increased by a factor 3.1 (95% CI: 1.6–5.9,  $P < 0.001$ ) with each unit increases of  $\log_{10}$  herd size.

Finally, the mixed-effects logistic regression models computed for over all farm-visits present in St Kitts, St Lucia, and Nevis showed a significant farm effect. For farm-visit in St Kitts, and Nevis, variances of the random effect 'farm' were 75.6 (SD = 8.70), and 38.8 (SD = 6.23), respectively. No farm effect was detected by the fitted mixed-

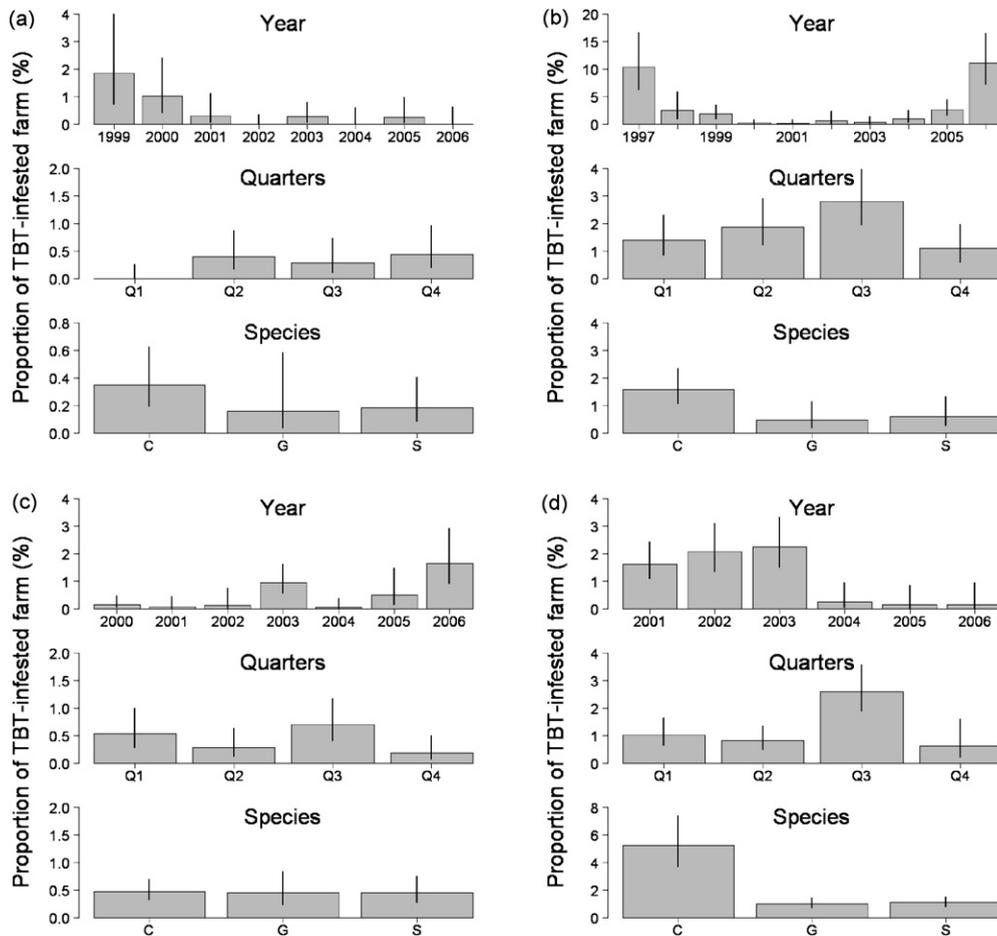


Fig. 3. Analysis of the Caribbean Amblyomma Programme (CAP) surveillance data. Barplots showing the proportion of farms (%) visited during the CAP surveillance activities that showed at least one animal infested with TBT as a function of the year and quarter of visits, and species of animal examined: (a) Barbados, (b) St Kitts, (c) St Lucia, and (d) Nevis. Segments represent the 95% confidence intervals.

effects logistic model in St Lucia (variance =  $2.18 \times 10^{-12}$ , SD =  $1.48 \times 10^{-6}$ ).

All models explain more than 10% of the observed variability of data:  $R^2$  for St Kitts, St Lucia and Nevis were respectively 0.182, 0.121 and 0.103.

#### 4. Discussion

This study provides the first descriptive analysis of TBT surveillance data after the end of the “Caribbean Amblyomma Programme”. When compared to other Caribbean islands and Africa; Barbados, St Kitts, St Lucia and Nevis showed a low level of farm and animal TBT infestation. For example, in 2005, a study of randomly sampled farm in Marie-Galante reported a farm TBT infestation prevalence of 73.8% (Molia et al., 2008), twice the highest quarterly proportion of TBT-infested farm for the most infested island in our study. When regarding at the number of TBT present on animals, ruminants in Caribbean were eight to nine times less infested than in Africa: an average of three to five TBT were collected on infested animals in the four islands of interest, while 39–44 TBT were found in average on TBT-positive animals in

traditional cattle herds in the South of Burkina Faso (Stachurski, 2000). Two hypotheses may explain the lower infestation level in the English Lesser Antilles. Firstly, in the four islands, the surveillance data has started at least 2 years after the extensive treatments were implemented in the islands. Thus explaining the low infestation level observed in the surveillance data. Secondly, the TBT introduction mechanism may have been responsible for the discrepancy between the infestation levels observed in the Caribbean and in Africa. In Guadeloupe, large numbers of TBT were probably introduced with cattle imported from Africa. In other Caribbean islands by contrast, TBT may have been introduced by cattle egrets (hosting mainly immature TBT) and immigration of livestock from other infested islands (Uilenberg et al., 1984). The few TBT individuals introduced may have been less likely to settle and spread widely. Furthermore, in Guadeloupe TBT introduction occurred more than 100 years ago, while the first TBT were reported in 1985 in Barbados. Longer period of time may be necessary in suitable environmental conditions to allow the establishment of a settled population which was not the case in the English speaking islands of the Caribbean. Tick genetic

**Table 2**

Risk factors for diagnosing at least one animal infested with TBT in farms. Odds ratio and their confidence intervals provided by mixed-effects logistic regression model of factors influencing the risk of TBT infestation on farms. All models were adjusted for the confounding effects of the year of the farm-visit.

Island	Variables	N visits <sup>a</sup>	N TBT <sup>b</sup>	OR (95% CI)	P
St Kitts	Quarter	4201	76		
	Q1	1069	15	0.22 (0.06–0.80)	0.022
	Q2	1058	20	0.15 (0.04–0.58) <sup>c</sup>	0.006
	Q3	1083	30	Ref.	
	Q4	991	11	0.17 (0.05–0.62)	0.007
	Presence of				
	Cattle	1984	46	0.72 (0.10–5.35)	0.748
Sheep	1453	14	0.14 (0.01–1.67)	0.119	
Goat	1473	13	0.34 (0.03–3.91)	0.384	
St Lucia	Quarter	5472	16		
	Q1	1830	10	1.07 (0.46–2.46)	0.882
	Q2	2048	6	0.39 (0.15–1.02)	0.056
	Q3	1983	14	Ref.	
	Q4	2040	4	0.26 (0.09–0.80)	0.019
	Presence of				
	Cattle	5450	26	Ref.	
Sheep	3287	15	0.84 (0.33–2.15)	0.712	
Goat	2191	10	0.67 (0.27–1.67)	0.391	
log <sub>10</sub> size			3.11 (1.6–5.94)	<0.001	
Nevis	Quarter	5156	72		
	Q1	1657	17	0.23 (0.10–0.52)	<0.001
	Q2	1481	15	0.29 (0.13–0.68)	0.004
	Q3	1355	36	Ref.	
	Q4	663	4	0.12 (0.03–0.48)	0.003
	Presence of				
	Cattle	531	29	22.1 (4.10–119)	<0.001
Sheep	3044	36	1.46 (0.32–6.66)	0.628	
Goat	3038	33	1.02 (0.29–3.57)	0.974	

Q1–Q4: first to fourth quarter; OR: odds ratio; CI: confidence intervals; P: Wald's test P-value. Proportion of variance explained by the computed models for St Kitts, St Lucia and Nevis were  $R^2 = 0.18$ ,  $R^2 = 0.12$ , and  $R^2 = 0.10$ , respectively.

<sup>a</sup> Number of farm-visits at risk.

<sup>b</sup> Number of farm-visits that had at least one animal infested with TBT.

<sup>c</sup> Interpretation: farms in St Kitts that were visited during the second quarter of the year was less at risk of finding at least one animal infested with TBT by a factor 0.15 (95% CI: 0.04–0.58), compared to farms visited during the third quarter of the year.

population studies may be useful to assess the validity of this hypothesis.

The proportion of TBT-infested farms progressively decreased from the start of the surveillance period in Barbados, St Kitts and Nevis (Fig. 2). However, records of TBT remained in farms, despite several years of treatment against TBT prior to the study period (2 years for Barbados and St Kitts, 6 years for St Lucia and Nevis). Surveillance activities allowed national TBT control managers to adapt their initial treatment schedule as a function of the degree of persistence of TBT infestation in their country. While the initial strategy for TBT eradication consisted to apply a blanket treatment for 2–3 years, this strategy was extended in the four islands of interest (Pegram et al., 2002, 2007). This change in the initial treatment strategy was extremely beneficial with the proportion of TBT-infested farms dropping to a low level in Nevis since 2004, and reaching an undetectable level for several quarters in Barbados and St Kitts.

Intensity of surveillance activities was variable throughout the study period and between islands. Intense and constant efforts of surveillance were maintained in Barbados, St Lucia and Nevis, involving a large sample of farms that was visited in each quarter with a large

proportion of animals examined. Although this level of surveillance has the potential to provide accurate and precise estimates of the proportion of TBT-infested farms in this islands, this is true only for Barbados and Nevis in which a relatively large sample of farms were selected at random rather than conveniently sampled such as in St Lucia (Pegram and Eddy, 2002). Because St Lucia surveillance activities did not cover homogeneously the entire island, focusing only on the Northern and the Southern parishes where TBT was known to be established, surveillance data may not be a good representation of the TBT infestation level at the country-level nor for the regions that were surveyed. Also, it is believed that the surveillance strategy implemented in St Lucia was potentially inadequate to detect within brief delays any residual or emerging TBT population in non-surveyed districts. This may have favored 2003 outbreak. In St Kitts, a low level of surveillance activities, involving small and probably insufficient inspection efforts, was carried out and may have led to the premature declaration of provisional freedom in November 2001. This is a plausible explanation to the reappearance (or observation) of numerous foci of TBT when surveillance was enhanced 2 years later. For comparison's sake, surveillance activities

implemented in Barbados permitted a consistent declaration of TBT-freedom: level of surveillance was even increased during the two quarters preceding the freedom certification in February 2003. In addition, surveillance efforts were not relaxed soon after the TBT-freedom certification but remained at a high level. As a consequence only two isolated cases of TBT-infested animals were finally detected 2 years later and rapidly managed.

In addition to allow the assessment of surveillance activities and the evolution of farm infestation according to time, surveillance data provided enough information to evaluate and quantify associations between several putative explanatory factors and the presence of TBT in farms.

Visiting farms during third quarters significantly increased the probability of detecting TBT in St Kitts and Nevis (Fig. 3 and Table 2). Similarly, the third quarter was significantly at greater risk than the fourth one in St Lucia. This may indicate presence of seasonal temporal pattern in the presence of TBT on host in these Caribbean islands. Seasonality of TBT infestation has been well documented for TBT-infested countries in Africa where temperature and humidity fluctuate significantly between dry and rainy season. Large number of TBT adults have been consistently recorded on host during the hot and rainy seasons while no (or very few) TBT may be recorded during the dry and cold season (Pegram et al., 1986; Kaiser et al., 1988; Kabore et al., 1998; Stachurski, 2000). In the Caribbean, and more precisely in Guadeloupe, no significant seasonality of TBT infestation may be distinguished but a continuous presence of TBT adult due to continuous suitable environmental conditions for sustaining a TBT life cycle (Barré, 1989). Because islands of the Caribbean show disparity in environmental conditions, seasonal effects due to changes in temperature and relative humidity is a plausible explanation for farms being at greater risk to be detected TBT-infested during the third quarter, compared to the rest of the year. In addition to temperature and humidity, latitude and day length may also influence seasonality, especially in the southern islands of Barbados and St Lucia. From these results, cost-effective strategy for TBT surveillance and control activities may be design in St Kitts and Nevis with an application of treatments during the hot rainy season to prevent peaks of nymphs and adult on host.

Although there are 31-times less cattle than small ruminants in Nevis (CAP, 2000), cattle presence in a farm increased by a factor 22 the risk of detecting TBT. Our finding concurs with the description of cattle as preferential adult TBT host (Barré, 1989), but is in contrast with TBT surveillance manager's thought that small ruminants were responsible for maintaining TBT population (Pegram, pers. comm.). According to them, as catching and treating properly almost 20,000 free-roaming small ruminants every 2 weeks was not feasible, small ruminants constituted a stray untreated hosts population, more likely to meet and spread residual TBT. Their assumption may have been true to some extent and especially for immature TBT not targeted by CAP surveillance, but the great majority of adult TBT were feeding on cattle even if they were fewer than small ruminants, tied up or fenced and

easy to treat. For future eradication programme in Nevis, control and surveillance activities, should focus on cattle,

Important farm effects were detected in the mixed-effects logistic regression models for TBT infestation in farms of St Kitts and Nevis (Table 2). These results indicate that factors specific to farms, and unaccounted for by the fixed-effects, may contribute to their level of TBT infestation. These unknown factors could, for example, be related to farm husbandry practices or quality of TBT inspection, or factors operating at individual animal as opposed to those operating at farm-level, and which were not included in the analysis. Similarly, a large proportion of variability was not explained by each model (Table 2). This finding indicates that additional factors that have the potential to either positively or adversely affect the detection of TBT in farms were not captured in the models. Although this is a common and acknowledged problem for the use of surveillance data, this suggests that more detailed records regarding husbandry practices, treatment compliance, and environment parameters are required to improve the characterization of inspected farms and, consequently, the power of future analyses using TBT surveillance data in CAP countries. We stress that it is required that data collection strategy during surveillance be planned considering the analysis in view. This would help for regular and frequent data analysis, which would allow identifying influencing factors in real time, adapting actions strategy, and detecting gaps in data collection.

In conclusion, this analysis of CAP data represented a unique opportunity to evaluate in four Caribbean islands the changes of TBT infestation level throughout a 6–10-year period, using a huge total number of 22,730 farm-visits and 346,117 animal examinations. This analysis was facilitated by the use of a regional database, TickINFO, which allowed recording and analyzing surveillance data of good quality for several countries. The CAP surveillance strategy as initially defined, and applied in Barbados and Nevis allowed a consistent assessment of the level of TBT infestation in real time which facilitated changes in strategies within brief delays that improved the treatment phase efficiency. Barbados may be considered as an example of surveillance strategy to prove the absence of TBT in a national herd. CAP surveillance data analysis also pointed out in several islands the role of seasonality and animal species in the level of tick infestation. These results demonstrate the usefulness of long term and adequate surveillance data for control programmes and identification of factors associated with risk of having infested herds.

#### Conflict of interest

None declared.

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