STUDIES ON THE EPIDEMIOLOGY AND POTENTIAL EXTENT OF CATTLE TICK INFESTATIONS IN THE TICK FREE AREA OF QUEENSLAND.

BY
R.J. GLANVILLE
VETERINARY OFFICER
VETERINARY SERVICES BRANCH
YEERONGPILLY

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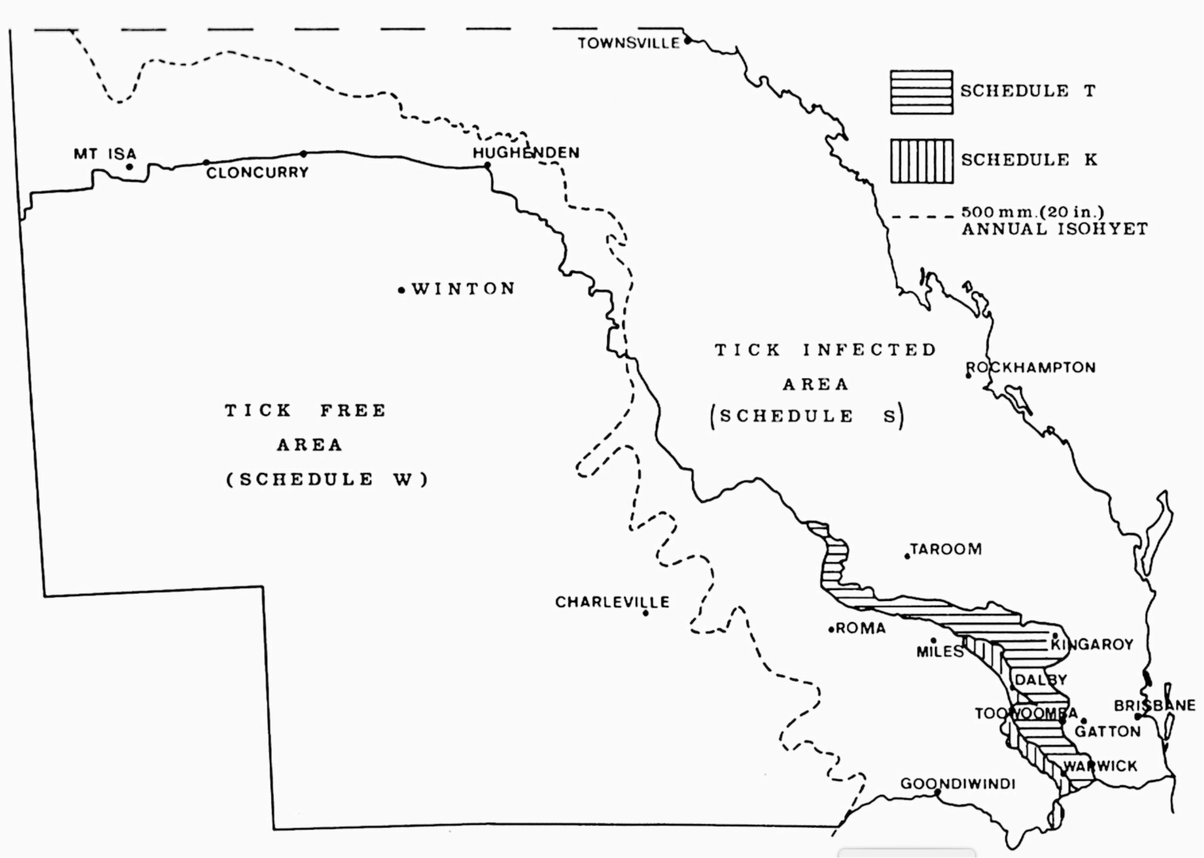
1. INTRODUCTION

Since its introduction into Queensland in about 1891, the cattle tick, *Boophilus microplus* has become endemic over a wide area of the state. However, human intervention and climatic factors have limited the spread of the tick, so that approximately 35% of the states' cattle population now live in the tick free area, which for administrative purposes is called schedule "W" (see figure 1). The tick infected area is referred to as schedule "S" and there are two buffer areas in the southern part of the state (schedules "T" & "K") that, for the purposes of this discussion, will be regarded as part of the tick free area.

Figure 1. Map of Queensland Showing Tick Infested and Tick Free Areas



All cattle movements from Queensland into New South Wales are required to travel via the tick free area, so maintenance of its tick free status is regarded as important by the Queensland beef cattle industry. There is also an element of fear that the tick may spread further and cause production losses. A large proportion of Veterinary Services Branch time and funds are therefore allocated to maintenance of the tick free area. Despite our efforts, incursions of ticks into the area have always been a problem and the number of these incursions has increased dramatically since the mid 1970's with two areas in particular presenting serious problems. These are:

(1) South of the S-W line in North West Queensland.

This is an area 50-70 km. wide south of the S-W line between Cloncurry and Hughenden and is now known as the Maxwelton special area. Prior to 1975 there were approximately 11 tick infested properties in this area but by 1980 this had increased to 88 known infested properties.

(2) Eastern Darling Downs.

As in the north, the number of properties quarantined for ticks has risen sharply since about 1974 (see table 1). The area south of Toowoomba is the worst affected, with many properties in virtual permanent quarantine.

The potential for cattle tick survival in these areas, and the tick free area generally, has been the subject of much discussion over the years but little scientific data has been available, so I was appointed in 1981 to collect and evaluate the required information. The aims of the study were to predict:

a. Where the cattle tick would survive without control and at what level.
b. The ease of control of infestations.
c. The potential rate of reinfestation.

To do this, studies were undertaken in 3 areas:

1. Analysis of past and present tick outbreaks.
2. Tick survival studies using tick plots.
3. Computer modelling. Two computer models were used; one I designed to assist with the evaluation of tick plot results and a CSIRO model which evaluated climatic data.

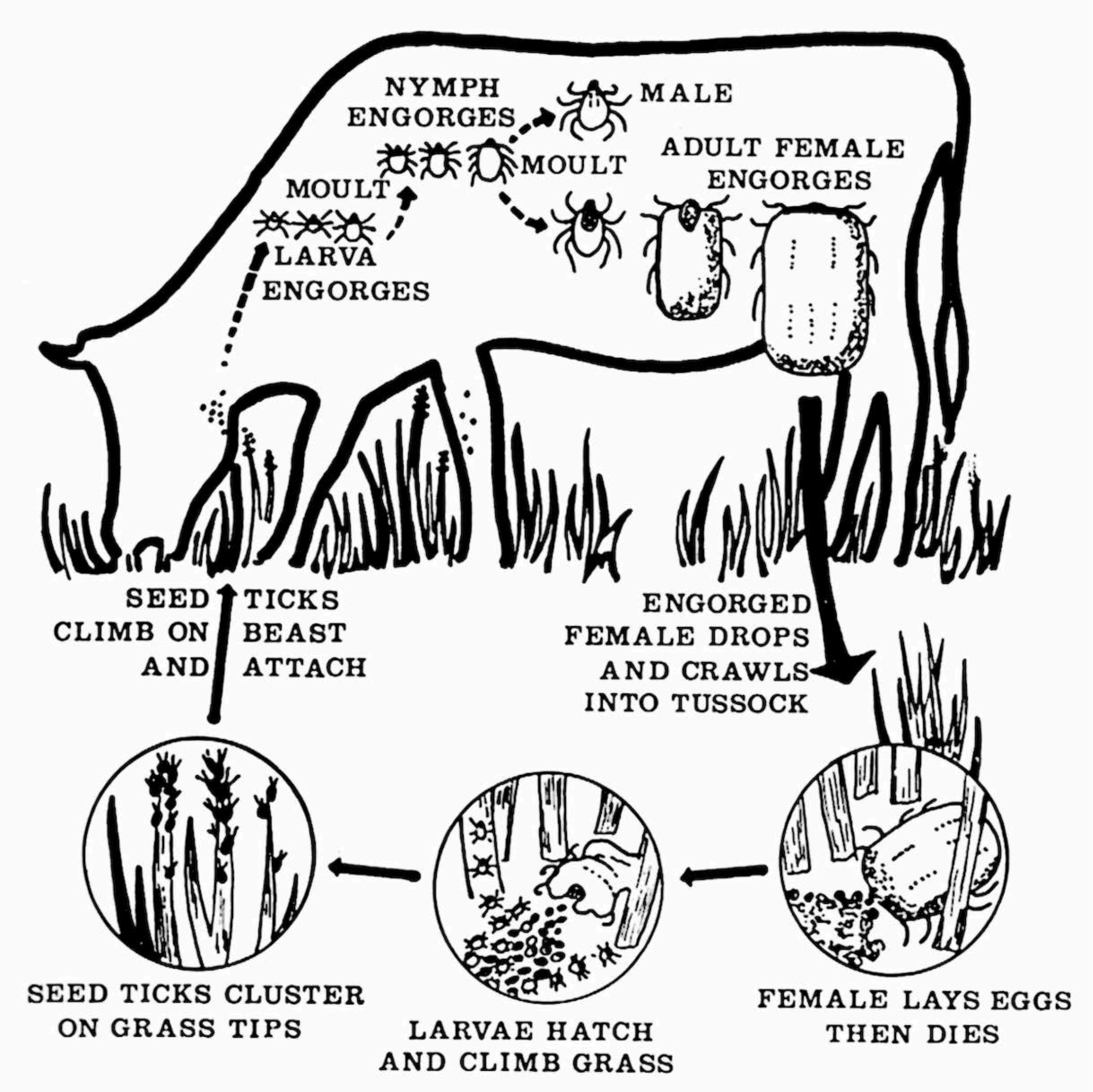
TABLE 1. Number of Southern Queensland Properties Quarantined for Ticks during the years 1968 to 1983.

	Year (19..)															
Stock District	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83
Toowoomba	27	18	33	19	24	25	88	72	161	188	199	171	171	114	96	101
Warwick	23	12	3	3	7	5	24	46	40	38	19	24	21	24	32	35
Kingaroy	15	3	9	18	24	33	63	98	90	145	47	49	45	42	47	74
Dalby	1	0	0	0	1	12	22	12	10	3	1	0	0	0	0	1
Roma	2	1	1	0	0	0	0	0	3	3	3	7		4	4	4
Wandoan	0	1	1	1	2	3	8	16	14	14	12	12		7	7	14
Total	**68**	**35**	**47**	**41**	**58**	**78**	**205**	**244**	**318**	**391**	**281**	**263**	**237**	**191**	**186**	**229**

2. LIFE CYCLE OF THE CATTLE TICK

The cattle tick, *Boophilus microplus* (Canestrini) is a one-host tick which completes its three parasitic stages on the one bovine host (Seddon 1967). Figure 2 shows a simplified version of the life cycle of the cattle tick.

Figure. Life Cycle of the Cattle Tick



Engorged female ticks fall to the ground and lay masses of up to 3,000 eggs in sheltered positions in the pasture (Hitchcock 1955a; Seddon 1967). They normally commence laying within one week of detaching from the host, but may wait for up to a month in cold weather. The eggs hatch from 3 to 17 weeks later depending on the ambient temperature. Temperature and moisture availability determine the percentage hatch (Hitchcock 1955a, Snowball 1957). After hatching, larvae become very active and climb vertical objects in their vicinity to await the passing of cattle or other animals. Light of moderate intensity stimulates the upward movement of larvae and they are particularly active in the early morning. When an animal approaches, larvae wave their front legs in the air and if the animal comes near enough, they grasp hair and skin (Seddon 1967). Cattle exhibit some larval avoidance behaviour, especially when larval densities are high (Sutherst pers. com.).

Larval survival times are dependent on ambient temperature, moisture, prehatch conditions and pasture type. Larvae may survive for as little as 1-2 days under hot, dry conditions or as long as 5 months when conditions are cool and moist. They will live longer on lush pasture than when it is sparse and dry and some plants possess larvicidal properties (e.g. Fitzroy stylo, *Stylosanthes scabra*). Larvae hatching from eggs with long prehatch periods (e.g. laid in the Autumn and hatched in the Spring) have shorter survival times (Sutherst pers. com.).

The parasitic phase of the life cycle lasts about 3 weeks with a range of 18 to 35 days for female ticks, while adult males may stay on the host for up to 70 days (Hitchcock 1955b). The parasitic larval stage lasts from 5 to 13 days and the nymphal stage 7 to 11 days. Climate has little effect on the duration of the parasitic phase but there is a diurnal rhythm in the fall of engorged ticks from the host, with most falling between 6 and 10 a.m. (Wharton and Utech 1970).

The number of attaching larvae that reach maturity varies from 0.5 to 50 percent depending on:

（1） The breed of cattle. *Bos indicus* type cattle are generally more tick resistant than *Bos taurus* cattle (Utech, Wharton and Kerr 1978).

（2） Innate immunity of the individual animal. There is a natural variation within each breed, some animals being far more resistant than others (Utech, Seifert and Wharton 1978).

（3） Immunity acquired from previous exposure to ticks e.g. *Bos indicus* cattle are no more resistant than *Bos taurus* cattle prior to exposure to ticks (Sutherst, Wagland and Roberts 1978).

（4） Season. Cattle are least resistant in the autumn and winter and most resistant in the spring (Sutherst et al. 1983).

（5） Physiological State. eg. Pregnancy and poor nutrition can reduce tick resistance.

(6) Number of Larvae attaching. In cattle previously exposed to ticks, there is a density dependent relationship between the number of attaching larvae and the number of females that mature, such that the proportion of females maturing is smaller when large numbers of larvae attach to the host (Sutherst et al. 1973; Sutherst, Utech, Kerr and Wharton 1979).

Most ticks are lost within 24 hours of attachment (Wagland 1979), both through mechanical means such as licking by the host and through immunological means (Snowball 1956; Wagland 1978; Willadsen et al. 1978).

In southern Queensland, ticks normally cease producing viable eggs in March/April as temperatures fall. As temperatures rise again in the spring, ticks are able to recommence reproduction and four or five generations of ticks can be produced before winter. Each generation is generally larger than the one before, so that tick numbers on cattle are normally greatest between March and June (3rd - 5th generations) (Sutherst, Wharton, Cook, Sutherland and Bourne 1979).

Parthenogenisis is possible, but the viability of eggs laid by unmated females is very low and only female progeny are produced. Each generation is weaker than the one before (Stone 1963).

3. FACTORS AFFECTING THE DISTRIBUTION OF THE CATTLE TICK

For the cattle tick to become established in an area, it must be introduced and it must then be able to survive in the area.

3.1 METHODS OF TICK DISPERSAL

The cattle tick may be introduced into or spread within an area by the following means.

1. Cattle

Cattle are the definitive host of *Boophilus microplus* and are therefore, by far. the most important method of spread of the tick. A large number of tick outbreaks can be directly attributed to cattle movements. These may take the form of straying stock, illegal movements, accidental escape of travelling stock from vehicles. or inefficient treatment of stock moving from infected to clean areas. The risk from cattle movements may be reduced by more stringent supervision of cattle movements, development of direct marketing to abattoirs, and at to the straying stock problem in certain areas. Room for improvement in this area is limited however, so cattle will continue to be the major carrier of new infestations.

2. Sheep

Although B. microplus can mature on sheep and heavy infestations have been reported, sheep are generally more resistant than cattle to infestation with the cattle tick (Wilkinson 1970). Few sheep are found in the endemic tick areas of Queensland, so they probably play little, if any part in the spread of the cattle tick. On the contrary, sheep areas are more likely to act as natural barriers to tick infestation because of the low cattle density in these areas. It is thought that a reduction in sheep numbers (and concurrent increase in cattle numbers) has been partly responsible for the recent spread of the tick in north-west Queensland.

3. Horses

As with sheep, horses are generally more resistant to tick infestation than cattle. Although heavy infestations are occasionally seen on horses at pasture, horses at work and periodically groomed seldom become heavily infected (Seddon 1967). Travelling horses, even when they miss being treated, therefore probably seldom introduce engorged females into clean areas. However, Lewis (1968) showed that horses can act as mechanical spreaders of tick larvae for 24 hours after being in contact with infected pastures.

4. Wildlife

Deer appear to be the only wildlife species in Queensland capable of acting as the definitive host of the cattle tick (Seddon 1967; Mackerras et al. 1961). Their presence in tick infected areas adjacent to the eastern Darling Downs means that they are a potential source of infection for the area the importance of this is uncertain.

Lewis (1968) demonstrated that birds can carry larvae up to half a mile and it is likely that they could carry them much further. The importance of birds in the spread of ticks is uncertain, but they could be important.

Other forms of wildlife are not likely to transport tick larvae over large distances mechanically, but could transport the tick between adjacent properties.

5. Vehicles and Man

Mackerras et al. (1961) reported that tick larvae and adults can be carried quite large distances on clothing, trucks and other goods. However, they considered that this was not an important cause of tick outbreaks in New South Wales. Uncleansed cattle trucks are constantly travelling from tick infected to tick free areas of Queensland and it is not difficult to find live, engorged ticks on them, so they are an obvious potential source of infestations. This could explain the occurrence of single tick infestations on house cows that have regular access to cattle yards. Transport of larvae on hay, especially during droughts, is also possible.

6. Wind

Lewis (1968) showed that larvae can move up to 30 metres and possibly as far as 60 metres with wind assistance, but it is not known how much further than this they could be carried. If larvae were carried long distances, the dilution effect would probably minimise the chances of larvae being picked up by a suitable host and subsequently developing to maturity. However, this could explain the occurrence of some single tick, single animal infestations detected in herds in otherwise "clean" country. It is probable that wind commonly assists with spread between adjacent properties.

7. Water

Sutherst (1971) showed that adult *B. microplus* can survive immersed in water for at least 2 days, while eggs and larvae may survive for 14 days or more. Although larvae washed down from watersheds during heavy rains have been suggested as the cause of some tick outbreaks in New South Wales, Mackerras et al. (1961) did not consider this to be the most likely cause. Transport by water is unlikely to be a major cause of outbreaks in Queensland as watersheds in the tick infected area generally flow away from the tick free areas. However, it could play a role in local spread in same areas.

3.2 FACTORS AFFECTING TICK SURVIVAL

Tick survival in an area depends on the presence of a host, climate, and other environmental factors affecting the free-living stages. Temperature and moisture are the most important climatic factors.

1. Presence of a Host

The presence of a. host is generally not a limiting factor in the survival of the cattle tick in Queensland, as cattle are present throughout most of the State. Low cattle densities in marginal areas will tend to work against tick survival however and there is some evidence that the presence of sheep (and low numbers of cattle) in the North-West marginal area may have helped keep the area free of ticks prior to 1974.

2. Moisture

Hitchcock (1955a) showed that, under laboratory conditions, the survival of both eggs and larvae of *B. microplus* is affected by the temperature and relative humidity at which they are kept. Eggs will not hatch when kept at less than approximately 75% constant relative humidity and at less than 80% the hatch is very poor. Larval survival is also reduced with relative humidity. For example, at a constant temperature of 15°C, larvae will survive for approximately 200 days at 90% R.H., 90 days at 70% R.H., and 13 days at 50% relative humidity. In addition, Harley (1966), Wilkinson (1953) and Wilkinson and Wilson (1959) showed that larvae can imbibe moisture in the form of dew and plant juices thus prolonging survival, especially under conditions of low relative humidity.

The availability of moisture in ego and larval microhabitats is difficult to estimate from normal meteorological records, thus making correlation of moisture availability with tick distribution difficult. The development of a moisture index by Sutherst and his co-workers (Sutherst and Dallwitz 1979; Maywald et al. 1980) will eventually solve these problems. Mackerras et al. (1961) and Wilkinson (1970) examined the distribution of ticks in Queensland in relation to the 20 inch rainfall isohyet (see figure 1). They concluded that moisture availability probably limits the distribution of ticks in northern Queensland, but not in southern Queensland. The isohyet lies adjacent to or to the east of the tick line in northern Queensland, but far to the west of it in southern Queensland. They felt that temperature was probably the limiting factor in southern Queensland.

3. Temperature.

In southern Queensland, establishment of the cattle tick in an area depends mostly on its ability to overwinter. which largely temperature dependent. Although there are some gaps in the laboratory data, it seems that oviposition falls rapidly below about 15.6°C. (Hitchcock 1955a; Snowball 1957). Development of eggs also ceases below this temperature unless the relative humidity is very high. Larvae on the other hand, can survive for prolonged periods at low temperatures, provided the relative humidity is not too low. Hitchcock (1955a) showed that, under laboratory conditions, larvae can survive for up to 170 days at 15°C and 80 percent R.H., and 200 days at 90 percent R.H. In the field, Snowball (1957) showed that larvae hatching in the Autumn in southern Queensland can survive for approximately 3-4 months. The survival of this Autumn hatch of larvae is important for the survival of tick populations over winter. These larvae are produced from ticks dropped in about March, which are normally the last generation of ticks to produce viable eggs. Some of these larvae survive until August/September when it is warm enough for ticks to produce viable eggs again.

On further examination of Snowballs' data, Mackerras et al. (1961) showed that the total survival time of all non-parasitic stages produced by ticks dropped in March ranged from 3 3/4 to 5 1/2 months, with a mean of 5 months. They therefore concluded that ticks would have little chance of surviving the winter if the interval between the time when the mean monthly temperature falls below approximately 20°C in the Autumn and rises above approximately

15°C in the Spring, was more than about 5 months. Table 2 shows the mean monthly temperatures for a number of southern Queensland towns in infested, marginal, and clean areas. The number of months between the two limits suggested by Mackerras et al. (1961), and the average annual rainfall are also shown. The location of these towns is shown in Figure 1. The five month winter break theory does not seem to hold when this data is examined. For example, Goondiwindi, Roma and Miles all have a period of only four months too cool for tick development, yet they are well within the tick free area and east of the 20 inch isohyet considered important by Mackerras et al. (1961) and Wilkinson (1970). Contrary to the conclusions of these workers, this would suggest that either ticks are capable of living much further west than they do at present or that other factors also play a part in tick survival in southern Queensland localities, especially west of the Great Dividing Range.

TABLE 2. Mean Monthly temperatures, number of months too cool for tick reproduction and rainfall for southern Queensland towns in Tick Infected, Marginal and Free areas (Bureau of Meteorology 1975).

	Month (mean monthly temperature degreees C)												**Months too Cool**	**Rainfall (mm)**
Tick Infected	*Jan*	Feb	Mar	Apr	May	Jun	Jly	Aug	Sep	Oct	Nov	Dec		
Brisbane	24.9	24.9	23.7	21.7	18.5	16.4	15.1	16.5	18.7	21.1	23	24.2	3	1146
Gatton	25.4	24.4	23.1	20.3	17	14.2	13.1	14.9	17	20.4	22.6	24.7	4	912
Taroom	26.6	26.6	24.6	21.3	16.6	13.9	12.8	14.5	18.2	22.3	24.9	26.2	4	685
Tick Marginal														
Toowoomba	21.7	21.6	20.2	17.7	13.8	11.5	10.2	11.8	14.5	17.6	19.8	21.3	6	955
Dalby	25.1	24.8	22.9	19.9	15.2	12.7	11.4	13	16.2	20.1	22.8	24.4	5	673
Warwick	23.4	22.7	21.3	18.1	14.1	11.6	10.2	11.8	14.4	18.4	20.4	22.5	6	702
Kingaroy	23.2	23	21.3	18.5	14.6	12.2	10.9	12.4	15.4	18.8	21.3	22.7	6	777
Tick Free														
Miles	25.9	25.6	23.7	20.1	15.3	12.5	11	13.3	16.4	21.1	23.8	25.1	4	661
Roma	27.3	27.2	24.9	21.3	16.3	13.5	12.3	14.3	17.9	22.2	25.1	26.6	4	593
Goondiwindi	26.7	24.8	22.9	19.9	15.2	12.7	11.4	13	16.2	20.1	22.8	24.4	4	614

The five month survival period was estimated under fairly moist conditions in Brisbane. Under somewhat drier conditions west of the range, it is likely that the survival period would be considerably less. In north-west Queensland, conditions are too cool for tick reproduction for only about 2 months of the year (Bureau of Meteorology, 1975), so it is reasonable to assume that moisture is the limiting factor here.

4. Other Environmental Factors

Wilkinson (1970) investigated certain geographical areas which, although seemingly climatically suitable, were reported to have anomalously fewer ticks than surrounding districts. He referred to these as RTS (reputed tick scarcity) areas and identified a number of factors under two basic headings that could possibly explain their existence.

(1) Factors affecting temperature and humidity in the micro-climate inhabited by non-parasitic stages of the tick.

Sheltered places in which a high humidity is maintained are essential for survival of eggs and larvae, especially in marginal areas. Local physical factors that effect this micro-habitat will, therefore, affect tick survival. Type of ground cover will affect both the temperature and moisture content of soil. Mackerras et. al. (1961) cited the instance of dry sclerophyll forest in the Richmond area of NSW which suffers very little from tick infestations. In northern Australia, lack of ground cover as well as causing moisture loss, will result in lethally high soil temperatures (Wilkinson 1970).

Soil type, and in particular its moisture holding capacity, will also affect the favourability of microclimates. Wilkinson (1970) considered that dry sandy soils and other less moisture retentive soils probably account for the existence of some RTS areas. For example, in the Georgetown area, egg development occurs only in the alluvium of major rivers and lagoons. Slope and aspect can also affect soil temperatures and tick distribution (Wilkinson 1967).

(2) Predation of eggs, larvae and adults.

Wilkinson (1970) cited a number of instances where predation by ants could account for the existence of RTS areas. These areas had large populations of ants which were seen to attack experimentally exposed engorged females ticks. The two main species reported were

Pheidole sp. and *Aphaenogaster sp*. Lycosid spiders have also been reported to take ticks and a number of birds have been known to feed on engorged females. However, there are no known instances of them limiting tick survival. Some pasture plant species also possess larvicidal properties, the most notable being *Stylosantheses scabra* (Sutherst et al. 1982).

In summary, although factors such as host availability, predators and certain physical factors affecting favourability of microclimates may affect the survival of the cattle tick on a local basis, its distribution in Queensland is probably mostly determined by climatic factors. Temperature and moisture are the two most important climatic variables but the combination of these necessary for tick survival requires more detailed study than just looking at gross climatic data. Computer programs that integrate all the relevant variables are being developed by CSIRO. The results of one of these are presented in section 6. (Utech et. al. 1983, Maywald et. al. 1980).

4. ANALYSIS OF PAST AND PRESENT TICK OUTBREAKS

4.1 EARLY HISTORY

The following information was obtained from Col Joyners' Thesis, Seddon (1967) and early reports from the Chief Inspector of Stock (CIS).

Infestations were reported on the Darling Downs at Miles in 1904 and also at Jondaryan, Wallangara and Toowoomba. The cattle tick then spread over a large area including the Warwick and Inglewood districts. Deaths from tick fever were reported at Stanthorpe and areas west to Goondiwindi.

Plunge dips were established at Millmerran in 1906, Tummaville (1913), Felton (1910), Cambooya (1912), Clifton (1912) and Pittsworth(1916). The Eastern Downs Tick Board was established in 1911 with the aim of preventing tick introduction to the Downs and eradicating infestations already present. Clearing dips operated at the Toll Bar, Ravensbourne, Toowoomba, Geham, Merritt's Creek, Cabarlah and Ballard.

In 1914 the Board attempted the enforcement of regular dipping of stock within 10 miles of its eastern boundary. This was called the Helidon cleansing area and was later extended in 1917. It involved an area 22 miles by 15 miles bound by the eastern railway line, Flagstone and Stockyard creeks and the Great Dividing Range. The South Burnett and Miles - Chinchilla cleansing areas was also formed at this time.

According to Seddon, ticks were again prevalent and spread over a large area of the southern Darling Downs in 1916-17 and at regular intervals since. The furthest west in southern Queensland that ticks have been found was at Coomrith, approximately 80 miles north-west of Goondiwindi, where they were taken by travelling cattle in 1941.

The March 1923 CIS report talks of outbreaks at Clifton, Pratten, Dalby, Pittsworth, Yeulba(Yuleba), Macalister and Bowenville. In the same year, 4201 holdings and 162,650 head of stock were inspected in the Helidon cleansing area. Of these, 499 properties were infested. In 1924, ticks were found at Pittsworth, Cecil Plains and Dalby.

The Miles - Chinchilla cleansing area included all the country between Macalister and Dulacca, from the western railway line, north to the Great Dividing Range. Infestations in the area were light and patchy and eradication was completed by about 1923.

Ticks were prevalent in the Kingaroy area prior to the commencement of eradication in the 1920's (South Burnett cleansing area). Eradication was successful to the extent that the country east of the Dividing Range, to the towns of Kingaroy and Nanango, south to the Cooyar Range and north to the Wondai -Chinchilla road was later recognised as tick free. Reinfestations have occurred periodically however, the most serious being that which occurred in the mid 1970's.

Ticks have also been reported at Winton, Aramac, Boulia, McKinlay, Longreach and Isisford in the West and North West. The March 1923 CIS report talks of extensive outbreaks in the Winton, Blackall and Isisford districts in 1922. Holdings on both sides of the Barcoo river at Blackall were found infested. These infestations were generally short lived, but some did persist for longer periods (e.g. at Aramac in the early 1920's). Disused cattle dips can be found in many of these areas if you look hard enough.

4.2 DISTRIBUTION OF RECENT TICK INFESTATIONS ON THE DARLING DOWNS

Figures 3, 4 & 5 show the distribution of previously quarantined properties on the Darling Downs. These maps were compiled using records kept at local stock offices. The records are more complete in some areas than others, (e.g. there was a fairly extensive outbreak in the Milmerran district in the mid 1960's but we have no record of what properties were involved) but they do give a fairly clear picture of the extent of tick infestations on the Downs over the last 20-30 years.

The maps are colour coded according to the total length of time properties have been in quarantine over the study period. Orange is used for properties quarantined for less than 5 years, green for 5-10 years, blue for 10-15 years and pink for greater than 15 years. For example, if a property had been in quarantine twice, once for 3 years and once for 4 years, these would be added together and the appropriate colour would be green. This system was used, rather than just coding according to the number of times a property had been quarantined, as some properties, especially those close to the Dividing Range, may have only been quarantined once but the quarantine lasted for a long time or was virtually permanent.

Figure 3. Distribution of Previous Cattle Tick Quarantines on the Eastern Darling Downs.

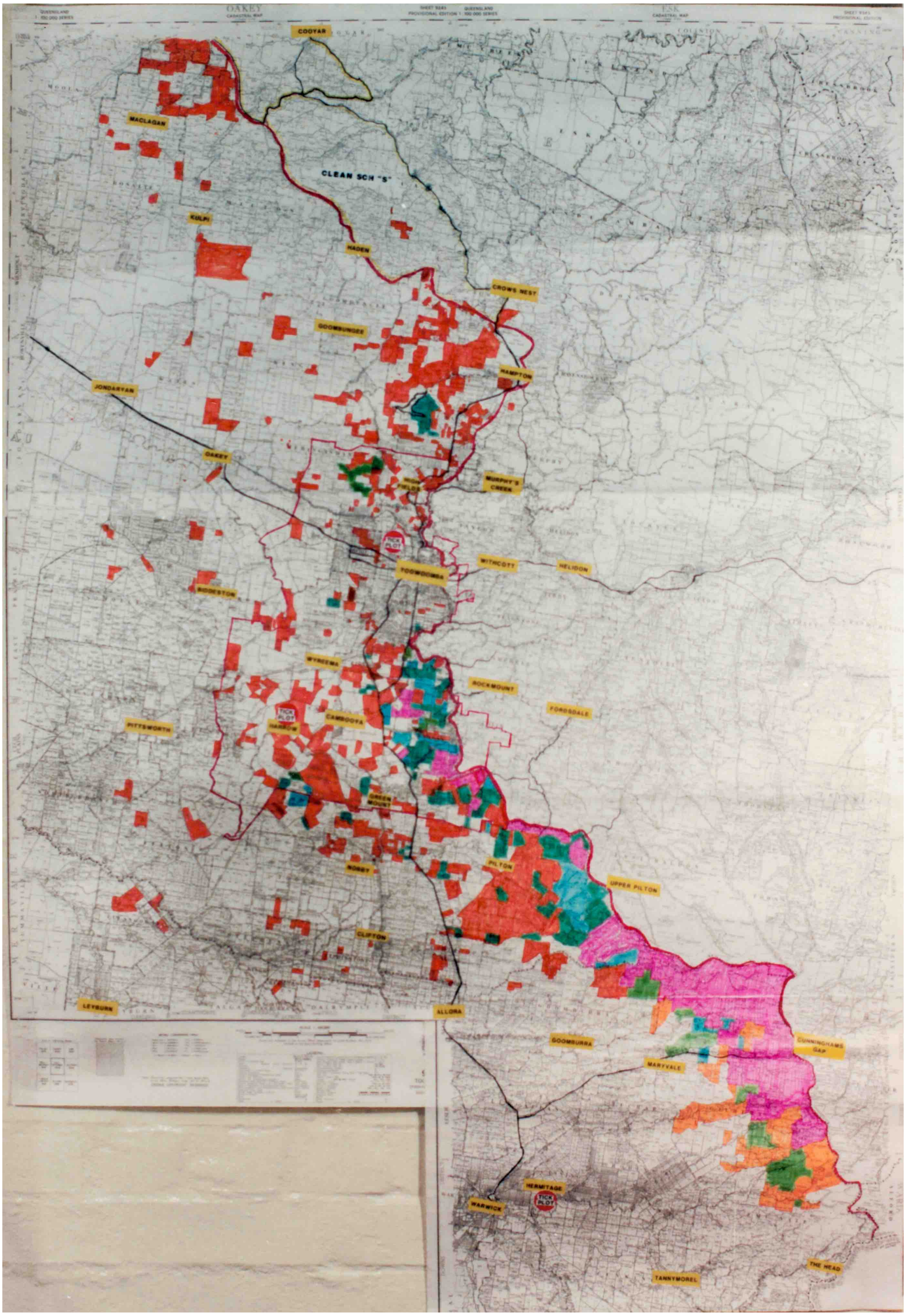


Figure 3 shows the distribution of tick quarantines in the area from the New South Wales border to Cooyar.

In the Warwick stock district (NSW border to Clifton), there have been extensive, long standing tick quarantines close to the Great Dividing Range, especially in the Maryvale area. There have also been isolated, short term quarantines further to the west but these are not indicated on the map because of problems with records.

From Clifton to Toowoomba, the area between the New England Highway and the Great Dividing Range has experienced extensive tick infestations and many have been long standing. The properties not coloured in on the map are largely agricultural concerns. There would be few, if any, cattle herds in the area that have not been cattle tick infested at some time.

West of the Highway, the occurrence of infestations has also been widespread, but they have been much more scattered and the infestations have generally been only short lived. It is likely that many more infestations have passed unnoticed in the area as the method of detection of infestations is quite haphazard. Detected infestations are generally very light and are often brought under control with minimal treatment.

Between Toowoomba and Crows Nest, the situation is similar to that West of the Highway, South of Toowoomba. Infestations have occurred throughout the area, but most have only been short lived. A probable explanation of why ticks are so much more prevalent in "T" adjacent to the tick line south of Toowoomba, when compared with the country north of Toowoomba, can be obtained by examining the adjacent "S" country. South of Toowoomba in "S" cattle numbers are fairly high and ticks are prevalent, whereas north of Toowoomba, there are tracts of forest country along the range which tend to act as a buffer between the infected and clean country. This buffer has weak points, but the density of ticks adjacent to "T" is certainly less north of Toowoomba than south.

North of Crows Nest, the incidence of tick infestations has been very low and this is probably because of protection given by the adjacent "clean S" area. This is an area that has enjoyed tick free status for many years and for local administration purposes is regarded as part of the tick free area. Why this area remains relatively uninfested is unclear. Cattle are cleared into the area, but general tick control within the area is not stringent. Infestations do appear in the area from time to time, but numbers are generally not great despite what appears to be a suitable environment. The country to the east supports large numbers of cattle and ticks are prevalent. Whatever the reason for its tick free status, the area certainly appears to protect the country to the west of it from tick infestations.

Figure 4. Distribution of Previous Cattle Tick Quarantines in the Kingaroy Stock District

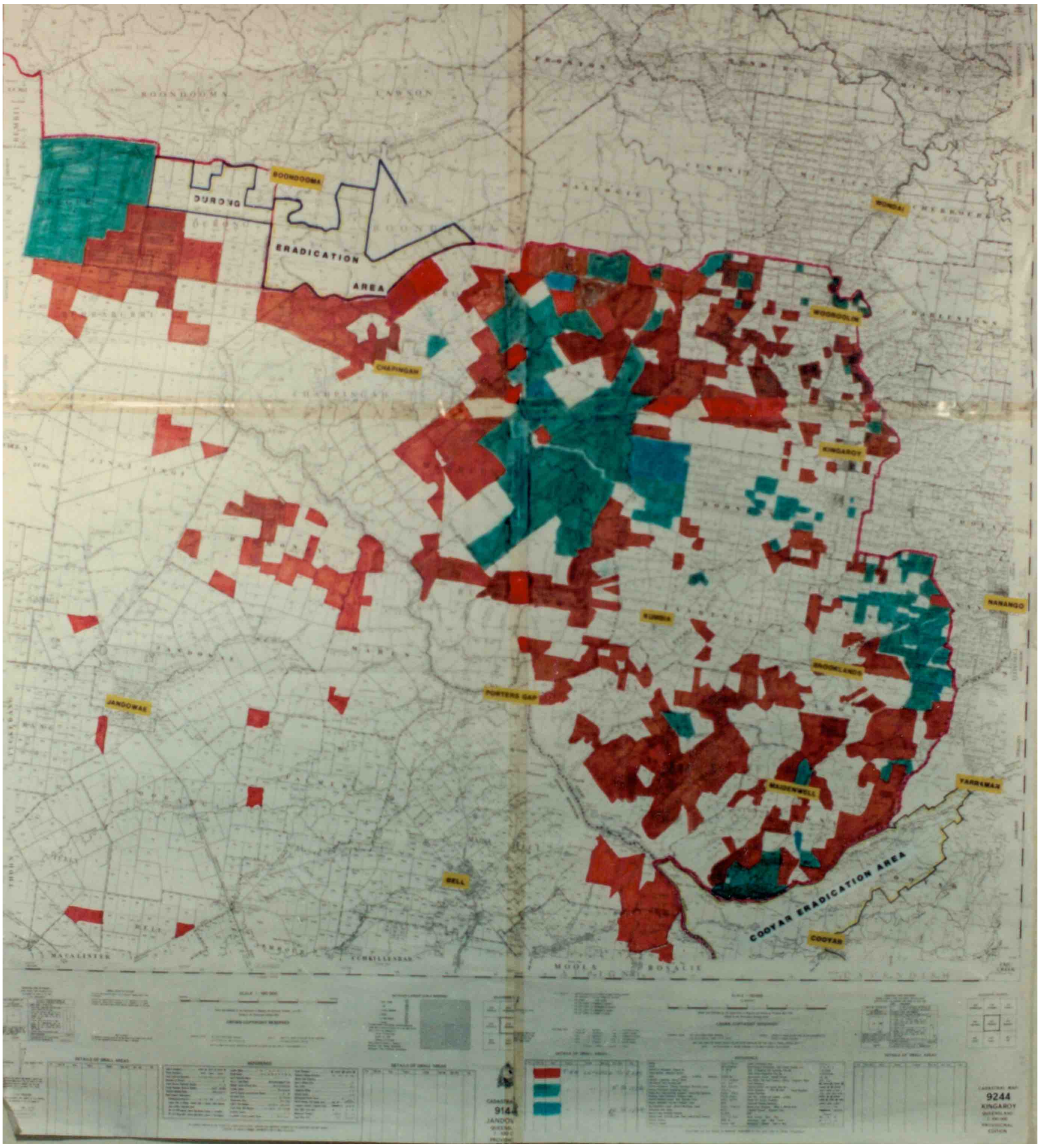
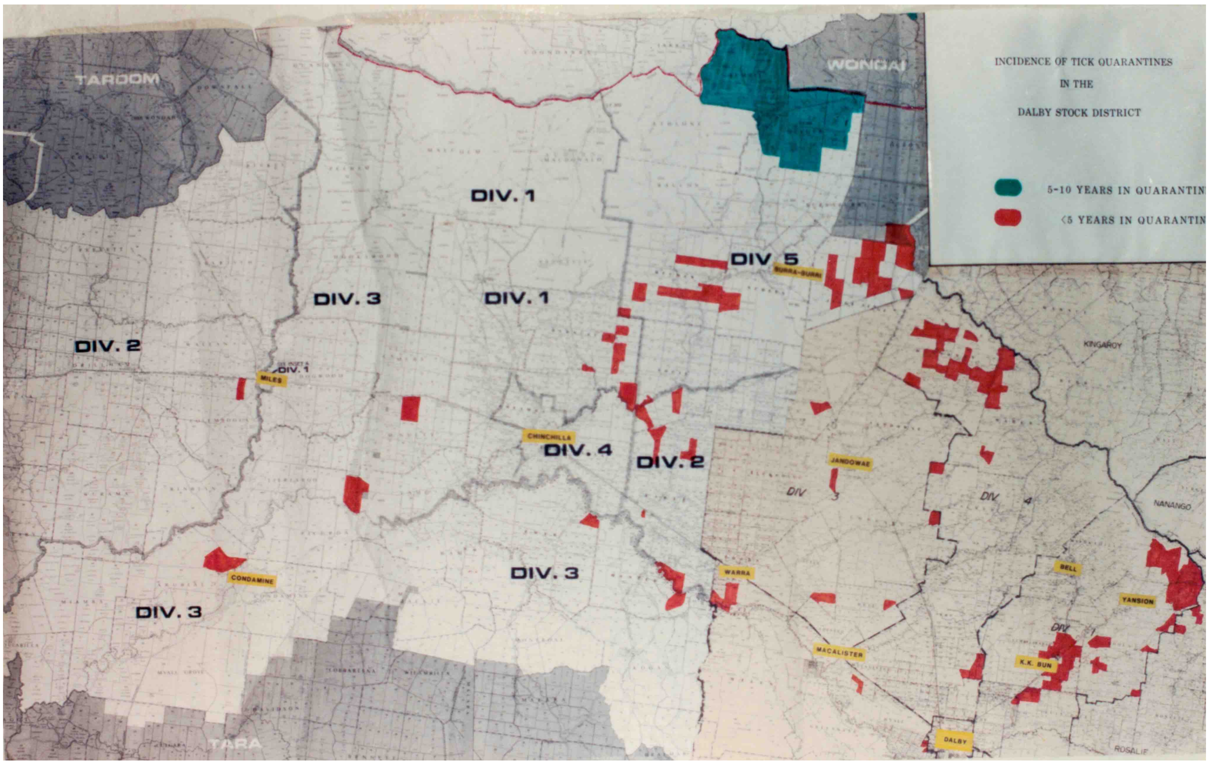


Figure 4 shows the distribution of tick quarantines in the Kingaroy stock district. This area is unique in South East Queensland in that it is the only area where the tick line extends to the east of the Great Dividing Range. Over the last 20 years, tick infestations have been widespread over the entire area east of the range except for some relatively clean areas to the south west of Kingaroy that are mainly used for agriculture. Infestations have mostly been short lived, especially to the south, which is protected to a certain extent by the Cooyar Eradication Area. This is an area that adjoins the Crows Nest 'clean S' area and has also enjoyed clean S status for many years. There have been several outbreaks in the past, but until the current major outbreak which commenced in the mid 1970's, they had always been eradicated. This latest outbreak has still not been successfully eradicated, mainly because of changed producer attitudes.

On the northern side of the Kingaroy stock district is the Durong Eradication area which came into being in 1979. This is an area with a small cattle population and considerable areas under cultivation. Despite this, progress has been slow. Both eradication schemes are voluntary and were instigated by producer pressure.

Figure 5. Distribution of Previous Cattle Tick Quarantines in the Dalby Stock District.



Previous tick infestations in the Dalby stock district can be seen in Figure 5. There have been isolated infestations throughout the area, but they have most been very light and only short lived. A large number, especially those furthest from the tick line, have been traced to travelling stock. The area is protected to the east by the Kingaroy stock district and to the north by State Forest.

4.3 DETAILED TOOWOOMBA STUDY

4.3.1 METHODOLOGY

Records of herd inspections for past cattle tick quarantines were compiled by Stock Inspectors at the Toowoomba stock office. Details of all herd inspections are recorded at this office, but to simplify analysis, only inspections where a property was placed under or released from quarantine were included in the study. Inspections of properties examined for ticks, but never placed under quarantine were also recorded.

For each property inspection, the following details were recorded:

- Registered property number,
- date,
- level of tick infestation (including presence of tick fever),
- enterprise type (beef, dairy or mixed),
- distance from the Great Dividing Range (closest point),
- whether the property was east or west of the New England Highway,
- quarantine status (quarantined, released or checked negative) and
- for properties not under quarantine, whether they were first or second removed from an infested property.

Records from 234 properties were used in the study. They were all within the Toowoomba stock district and came from the Shires of Cambooya (160), Jondaryan (33), Toowoomba (22), Crows Nest (9), Rosalie (7) and Clifton (3). The records were taken in computer compatible form and were analysed using programs from the SPSS statistical package (Nie et al. 1975). Separate computer programs were also written to perform certain transformations on the data, such as listing each property with the number of times it had been placed under quarantine and the length of each quarantine period.

Daily weather records for Toowoomba were obtained from the Bureau of Meteorology, including:

- daily maximum and minimum temperatures,
- air pressure,
- rainfall,
- 9 am and 3 pm dry bulb and wet bulb temperatures and
- wind direction and speed.

Dry bulb temperatures and air pressure were used to calculate 9 am and 3 pm relative humidity. The SPSS statistical package was used to obtain for each year mean values for each of the weather indices. Means were obtained for three seasons of the year, namely; winter (April to August), early summer (September to December) and late summer (January to March). The length of the winter break (number of weeks with mean temperature below 15.6°C) was also calculated. The summer period corresponds with the normal time when reproduction is possible for the cattle tick, whereas April to August is the normal overwintering period. With the wind data, indices were calculated for the period, October to March when larvae are normally present in large numbers on pasture. The indices used were: the percentage of days when wind was blowing from the direction of tick infested country (North-East to South-East), average wind speed for these days and the number of days when the wind from this direction was greater than 20 and 25 knots.

Stepwise multiple regression techniques were used to relate the number of tick quarantines and releases from quarantine each season with the various weather indices. The GLIM statistical package (Baker and Nelder 1978) was used for this. Lag effects were looked for by relating tick quarantines with meteorological indices for the previous year. The number of properties in quarantine at the beginning of each season was also included in the study as these properties could act as sources of infection for new tick infestations.

4.3.2 RESULTS

Of the 234 properties in the study, 123 were dairy farms, 107 ran beef cattle, 3 had both beef and dairy cattle and one ran horses and beef cattle. One hundred and ninety three (193) of these properties had a history of tick infestation while the other 41 were first or second removed properties that had been checked negative for ticks. Thirty were first removed and 11 were second removed.

The properties were situated up to 24 km west of the Great Dividing Range with an average of 7.2 km for previously infected properties. Checked negative properties were, on average, situated significantly further west than the infected properties with a mean of 9.5 km (see figure 6 and table 3). There was no significant difference between first and second removed properties. Seventy one properties were situated east of the New England Highway (64 infected) and 163 west of the highway (129 infected).

Figure 6. Distance from the Great Dividing Range of Properties with a History of Infection and First and Second Removed Properties checked negative for Cattle Ticks.

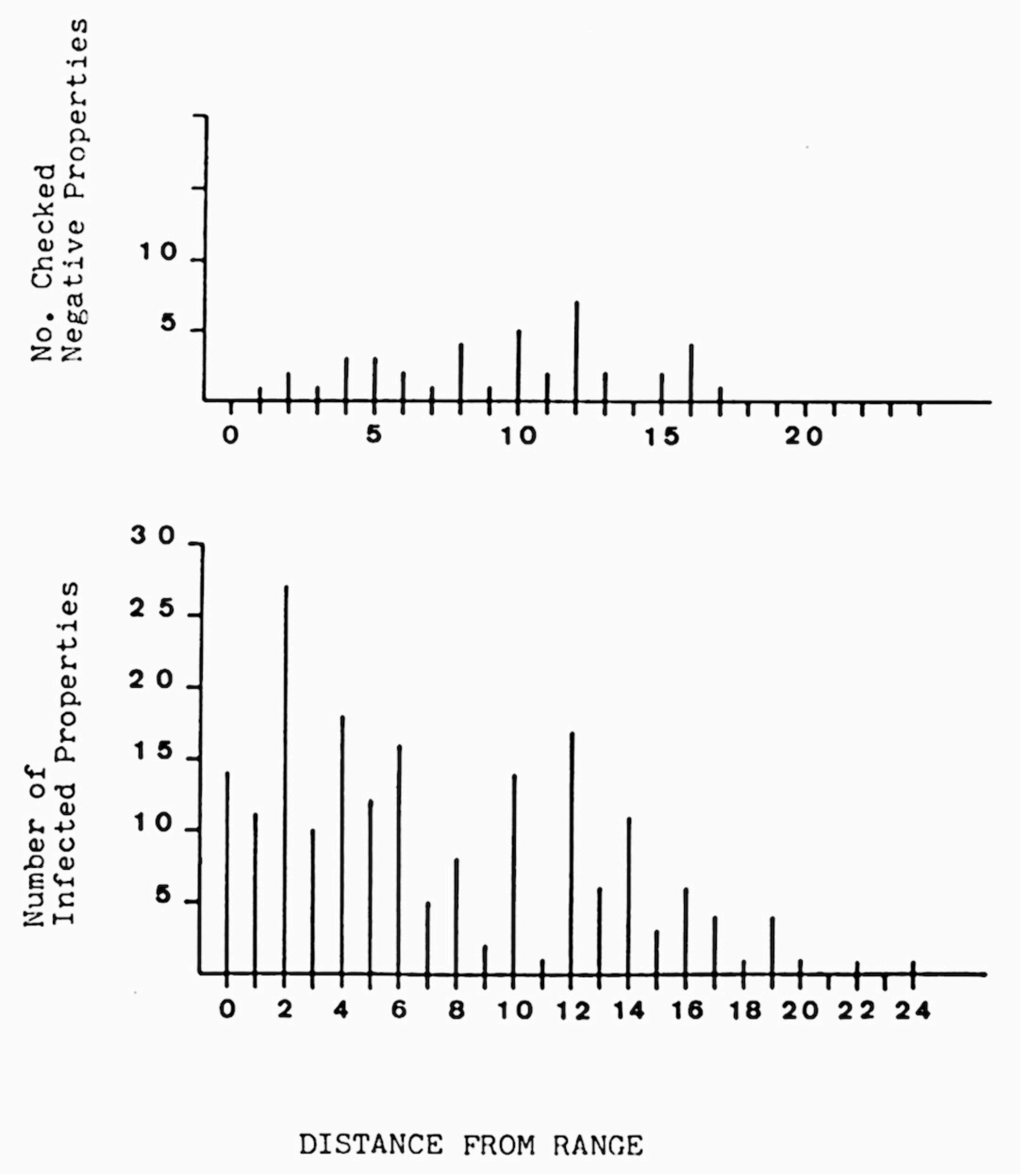


Table 3. Distance from the Great Dividing Range (Km) for:

(A) Properties with a history of infection,
(B) Checked negative properties

Group	Mean	S	N	t	P
Infected	7.2	5.6	193	2.412	0.017
Not Infected	9.5	4.4	41		

Figure 7. Number of Properties Quarantine and Released from Quarantine during each Month of the Year.

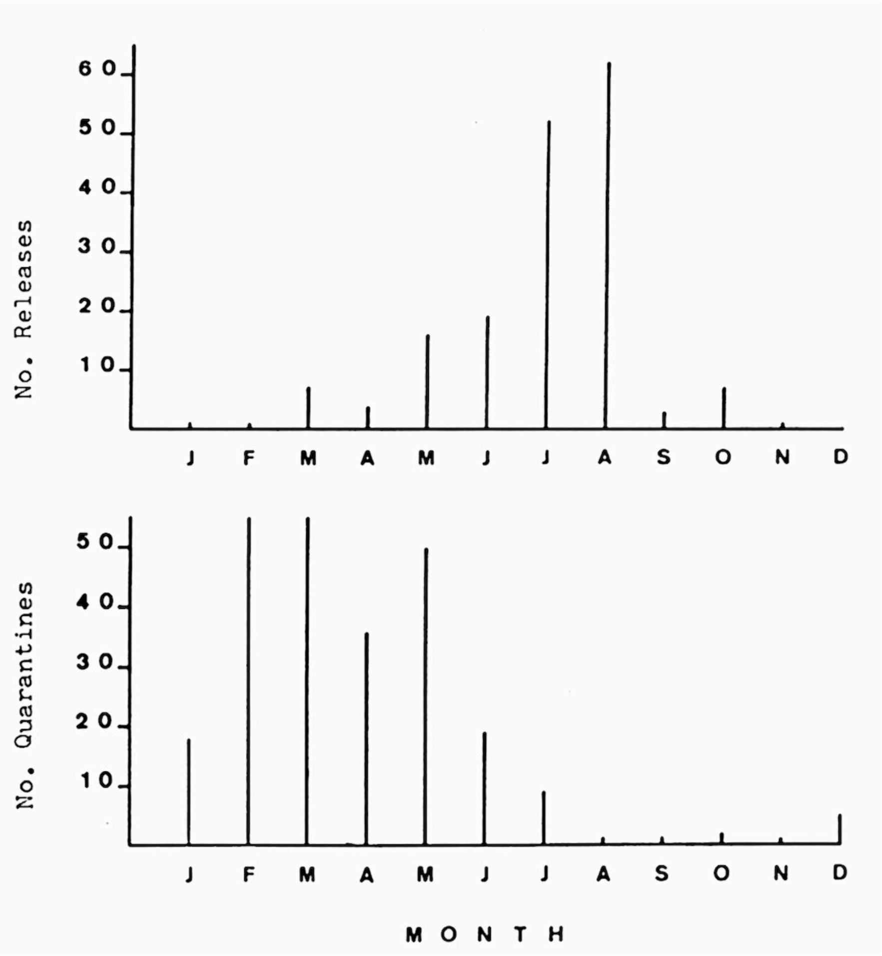


Figure 7 shows the distribution by month when properties were placed under quarantine and released from quarantine. Nearly all properties were placed under quarantine between January and July, with February to May being the most common months. Most properties were released from quarantine between May and August.

Table 4. Level of Tick Infestation seen at each Quarantine Inspection.

Level of tick infestation	**Number of quarantines**	**%**
Tick fever only	23	9.2
Odd (very small numbers)	132	52.6
Light	76	30.3
Heavy	20	8.0
Total	**251**	

Table 4 shows the level of tick infestation seen at the time each property was placed under quarantine. The level of infestation was normally very light, although some (8%) heavy infestations were seen. On the majority of properties (53%), only the odd tick was seen, although more ticks could have been present as inspections often cease once one tick has been found. Light infestations were seen on about 30% of properties and cases of tick fever accounted for about 9% of quarantines. On many of the latter properties no ticks were found. I will discuss this phenomenon later.

Table 5. Presence of Tick Fever in Relation to Distance from Great Dividing Range.

	Distance from Range							
	0-2 km		3-6 km		7-12 km		13-24 km	
	N	%	N	%	N	%	N	%
Tick Fever	2	2.6	4	5.6	15	25.4	2	4.5
No Tick Fever	74	97.4	68	94.4	44	74.6	42	95.5
Total	76		72		59		44	
$X^2 = 21.36$					$P = 8.9 \times 10^{-5}$			

Table 6. Level of Tick Infestation in Relation to whether a Property Lies East or West of the New England Highway.

	East of Highway		West of Highway	
Level of Infestation	N	%	N	%
Tick Fever*	2	2.0	21	13.7
Odd**	54	55.1	78	51.0
Light	39	39.8	37	24.2
Heavy	3	3.1	17	11.1
Total	98		153	
X2 = 16.0			P = 0.0011	
* Seen with or without ticks ** Very small numbers seen, often 1 or 2				

Tables 5 and 6 compare the presence or absence of tick fever with the distance from the Great Dividing Range and whether the property is east or west of the New England Highway. The incidence of tick fever increases significantly both west of the highway and as distance from the range increases. These two are of course interrelated.

Table 7. Duration of Quarantine Period.

Duration of Quarantine Period	Number of Properties	%
6 to 12 months	7	2.8
13 to 18 months	72	28.6
19 to 24 months	10	4.0
25 to 30 months	29	11.5
31 to 36 months	15	6.0
37 to 48 months	27	10.7
Greater than 48 months	14	5.6
Still in quarantine	78	31.0
Total	252	100.0
Mean (not including those still in quarantine) = 27.4 months		

Table 7 shows the length of time properties were in quarantine. The quarantine period was quite variable, with the shortest period being 6 months, the longest 89 months and the average about 27 months. Thirty one percent of properties were still in quarantine at the time of compilation of the data. These properties had been in quarantine for an average of about 4 Years. The length of the quarantine period was not greatly affected by distance from the Great Dividing Range, except that significantly more of the properties still in quarantine were situated close to the range (see Table 8). About 65% of quarantines lasted for longer than 2 years, which suggests that the level of control is not particularly good and infestations are persisting for more than one season. Reports from local stock inspectors that many owners in the area take a very blasé attitude to tick control supports this.

Table 8. Length of Quarantine Period in Relation to Distance from Great Dividing Range.

	Distance from Range							
	0-2 km		3-6 km		7-12 km		13-24 km	
Length of quarantine period (months)	N	%	N	%	N	%	N	%
6 – 18	24	31.6	24	32.9	23	39.0	8	18.2
19 - 36	4	5.3	18	24.7	16	27.1	16	36.4
> 36	12	15.8	14	19.2	7	11.9	8	18.2
Still in Q	36	47.4	17	23.3	13	22.0	12	27.3
Total	76		73		59			
X^2 = 25.5				P = 0.0025				

Of the properties with a history of infestation, 145 had been placed under quarantine once, 37 twice and 11 three times. Properties quarantined more than once were, on average, situated significantly closer to the Great Dividing Range than those that had been quarantined only once (Table 9, figure 8). The same trend is seen in Table 10 which shows that properties west of the New England

Highway are quarantined less often than those to the east. Although not significant, there was also a trend for dairy herds to be quarantined more often than beef herds (Table 11). There was no difference in the length of the quarantine period, however.

Table 9. Distance from the Great Dividing Range for:
(A) Properties Quarantined Once
(B) Properties Quarantined more the Once.

Group	Mean	s	n	t	p
A	7.7	5.6	145	2.06	0.041
B	5.8	5.0	48		

Figure 8. Distance from the Great Dividing Range of Properties Quarantined once and more than once.

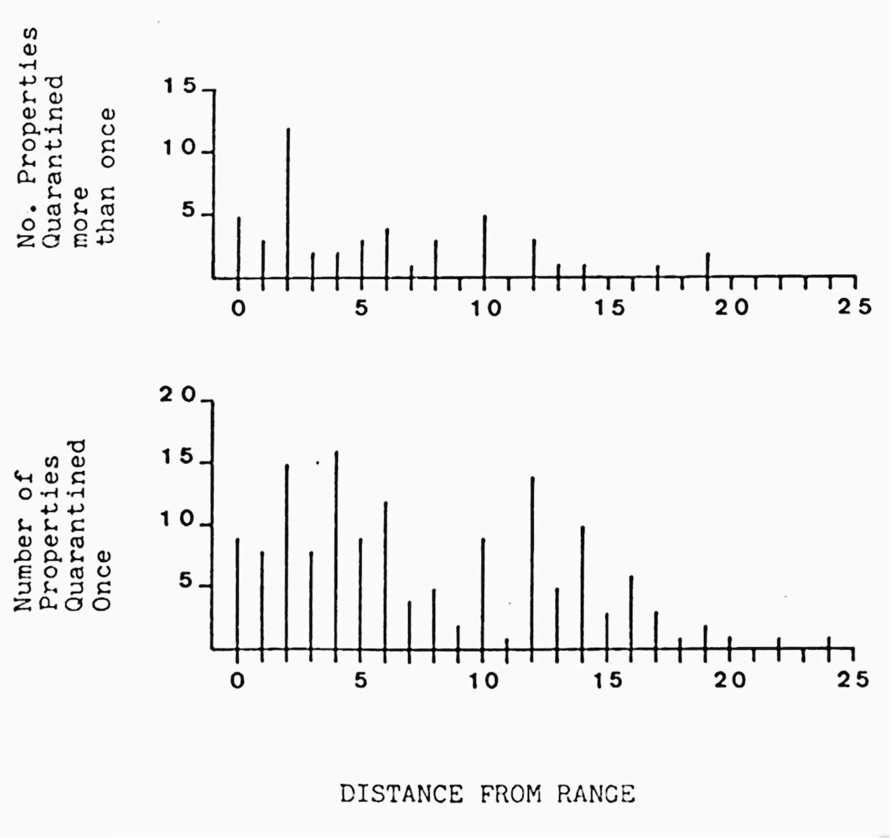


Table 10. Number of Times in Quarantine in Relation to Whether a Property is Situated East or West of the New England Highway.

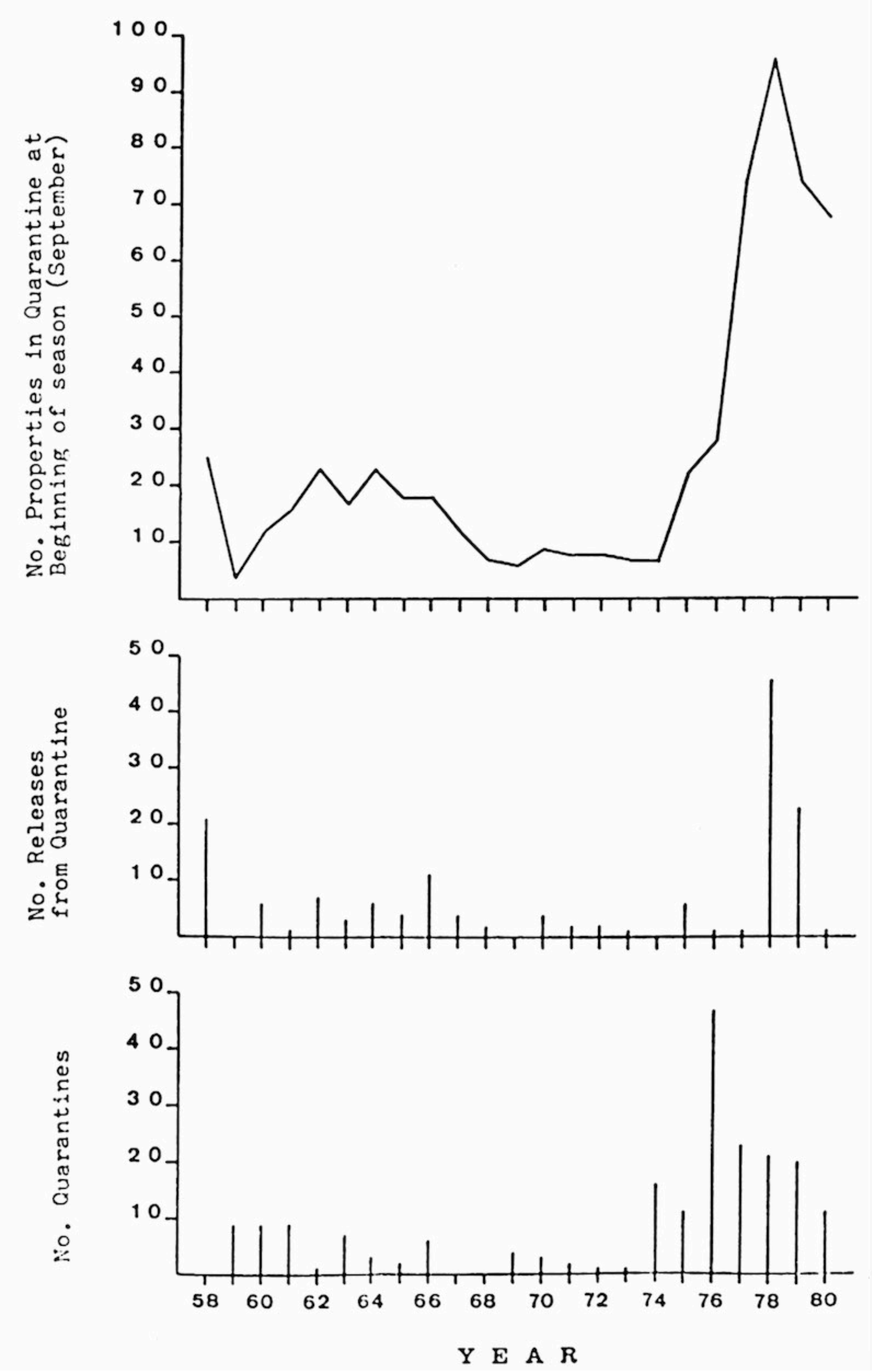
	East of Highway		West of Highway	
Number of times in quarantine	N	%	N	%
Once	38	59.4	107	82.9
More than once (2 or 3)	26	40.6	22	17.1
Total	64		129	
X^2 = 11.49			P = 0.0007	

Table 11. Enterprise Type by Number of Times in Quarantine.

	Enterprise			
	Beef		Dairy	
Number of times in quarantine	N	%	N	%
Once	71	82.6	72	69.9
More than once (2 or 3)	15	17.4	31	30.1
Total	86		103	
X^2 = 3.42			P = 0.064	

Figure 9 shows the number of new quarantines and releases from quarantine for each tick season (September to August) and the number of properties in quarantine at the beginning of the season (September). As was discussed earlier, there was a large increase in the number of new tick quarantines and total number of quarantined properties in 1974 which has continued to the present time.

Figure 9. Number of New Quarantines and Releases from Quarantine for each tick season and number of Properties in Quarantine at the beginning of each Tick Season (September).



4.3.3 CORRELATION WITH METEOROLOGICAL DATA

Figures 10 and 11 show the number of new tick quarantines each season and the corresponding mean daily summer rainfall, percentage days during the tick season with the wind velocity coming from the infected area greater than 20 and 25 knots, mean summer temperature, mean temperature for the previous winter and the number of weeks during the previous winter with the temperature below 15.6°C. The use of early and late summer means for temperature and rainfall did not significantly improve the ability to predict tick quarantines. Mean daily relative humidity was also examined, but it was highly correlated with rainfall which was a better predictor of tick quarantines. Relative humidity was also missing from the Meteorological Bureau data for a number of years. It was, therefore, excluded from the final analysis.

On close examination of the data, it became evident that most years followed a similar pattern, except for 1976 which had by far the highest number of tick quarantines (47), the highest summer rainfall, but one of the lowest mean summer temperatures. For most other years, the number of tick quarantines was positively correlated with the mean summer temperature. By excluding the 1976 data from the calculations, a quite different picture emerged. For this reason, the results of the multiple regression exercise both including and excluding the 1976 data will be reported.

Table 12 (a) shows the results of the multiple regression exercise including the 1976 data. The number of new quarantines each season was significantly correlated with the number of properties in quarantine at the beginning of the season, summer rainfall and summer rainfall for the previous season. Correlations with summer temperature, winter temperature, winter rainfall, length of winter break or wind were not significant. Figure 12 (a) compares the number of quarantines predicted by the regression equation with the observed number of new quarantines each year. The fit is reasonable for years with large numbers of quarantines, but not as good for the other years.

Figure 10. Number of New Tick Quarantines, Mean Summer Temperature, Mean Temperature for Previous Winter and Number of Weeks below 15.60C during Previous Winter for Years 1958 to 1980.

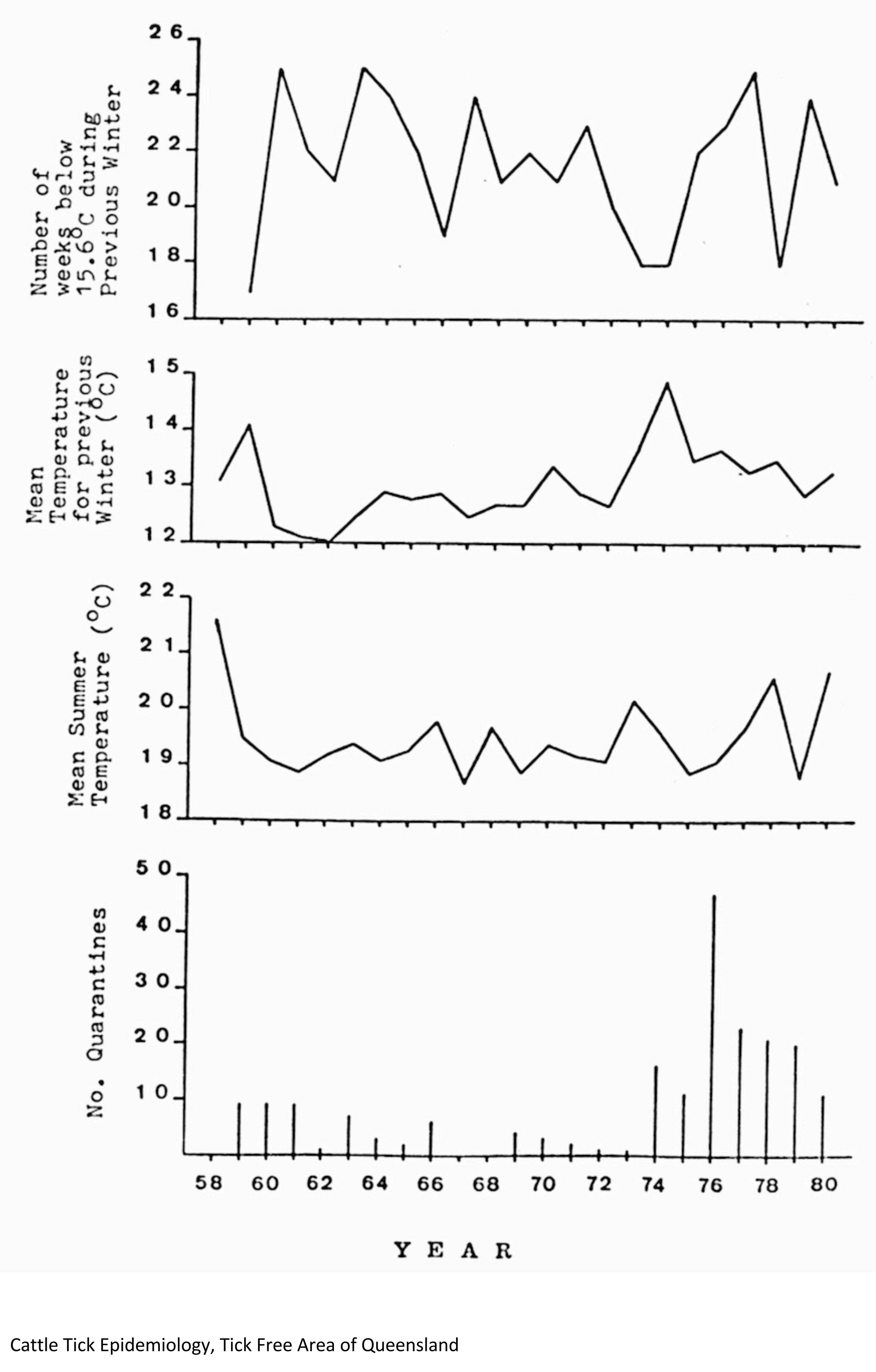


Figure 11. Number of New Tick Quarantines, Mean Daily Summer Rainfall and Percentage Days with Wind Speed Greater than 20 and 25 knots from the Direction of the Tick Infested Areas for the Years 1958 to 1980.

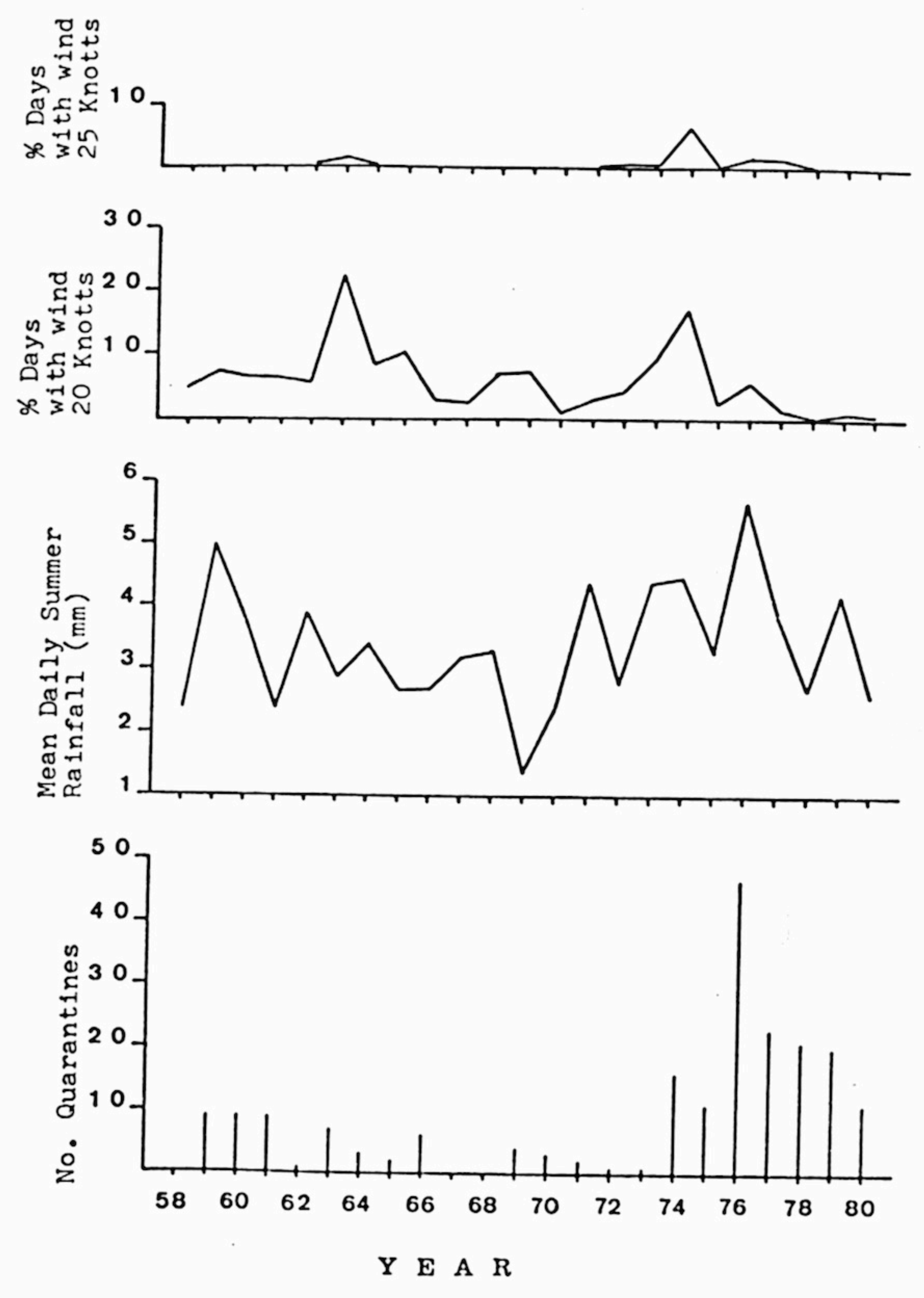


Table 12. Multiple Regression of Number of New Tick Quarantines per Year against Meteorological Data.

A. Including 1976 data.

Fitted model = $30.19 + 0.2143 \times BY - 27.98 \times SR + 4.695 \times SR^2 + 2.903 \times PSR$

Where BY = number of properties in Quarantine at beginning of season
SR = mean daily summer rainfall
PSR = mean daily summer rainfall for previous year

Analysis of Variance					
Source of Variation	d.f.	s.s.	m.s.	F	P
Regression	4	2117.4	529.4	22.3	1.4×10^{-6}
Deviations	17	403.6	23.7		
Total	21	2521.0	$R^2 = 0.84$		

Component Analysis				
Source of Variation	Estimate	S.E.	t	P
BY	0.2143	0.04245	5.05	9.9×10^{-5}
SR	-27.98	6.128	4.57	2.7×10^{-4}
SR^2	4.695	0.8436	5.57	3.4×10^{-5}
PSR	2.903	1.123	2.59	0.019

B. Omitting 1976 data.

Fitted model = $-74.16 + 0.1873 \times BY + 1.803 \times PSR + 3.608 \times PST + 1.23 \times W$

Where PST = mean daily temperature for previous year
W = percent days with wind speed greater than 25 knots from ticky areas

Analysis of Variance					
Source of Variation	d.f.	s.s.	m.s.	F	P
Regression	4	911.9	228.0	29.2	3.6×10^{-7}
Deviations	16	125.1	7.82		
Total	20	1037.0	$R^2 = 0.88$		

Component Analysis				
Source of Variation	Estimate	S.E.	t	P
BY	0.1873	0.02524	7.42	1.5×10^{-6}
PSR	1.803	0.7118	2.53	0.022
PST	3.608	0.9779	3.69	0.002
W	1.23	0.4897	2.51	0.025

Table 12 (b) contains the results of the same regression exercise when the 1976 data was excluded from the calculations. In this case, the significant variables were the number of properties in quarantine at the beginning of the season, summer rainfall and temperature for the previous season and the number of days with the wind speed from the direction of the tick infested area greater than 25 knots. Although the incidence of new quarantines was also correlated with rainfall and temperature for the same season, their inclusion in the full regression equation did not significantly improve the ability to predict new tick quarantines. Figure 12 (b) shows the number of new quarantines each year predicted by the regression exercise. The predictions for years with small numbers of quarantines are better than when the 1976 data was included in the analysis.

The number of releases from quarantine each season was not correlated with any of the meteorological indices, but was significantly correlated with the number of properties in quarantine at the beginning of the season (Table 13). Figure 13 compares the number of releases from quarantine each season with the number predicted by the regression equation. Except for a few instances, the fit is reasonable.

Table 13. Regression of Number of Releases from Quarantine per Season against Total Number of Properties in Quarantine at the Beginning of the Season

Fitted model = -0.4472 + 0.3242xBY
Where BY = number of properties in quarantine at beginning of season

Source of Variation	d.f.	s.s.	m.s.	F	P
Regression	1	1405	1405	30.09	$1.4x10^{-5}$
Deviations	24	1074	46.7		
Total	21	2479	R^2 = 0.57		

Figure 12. Comparison of Observed Number of Tick Quarantines with Predictions using Weather Data.

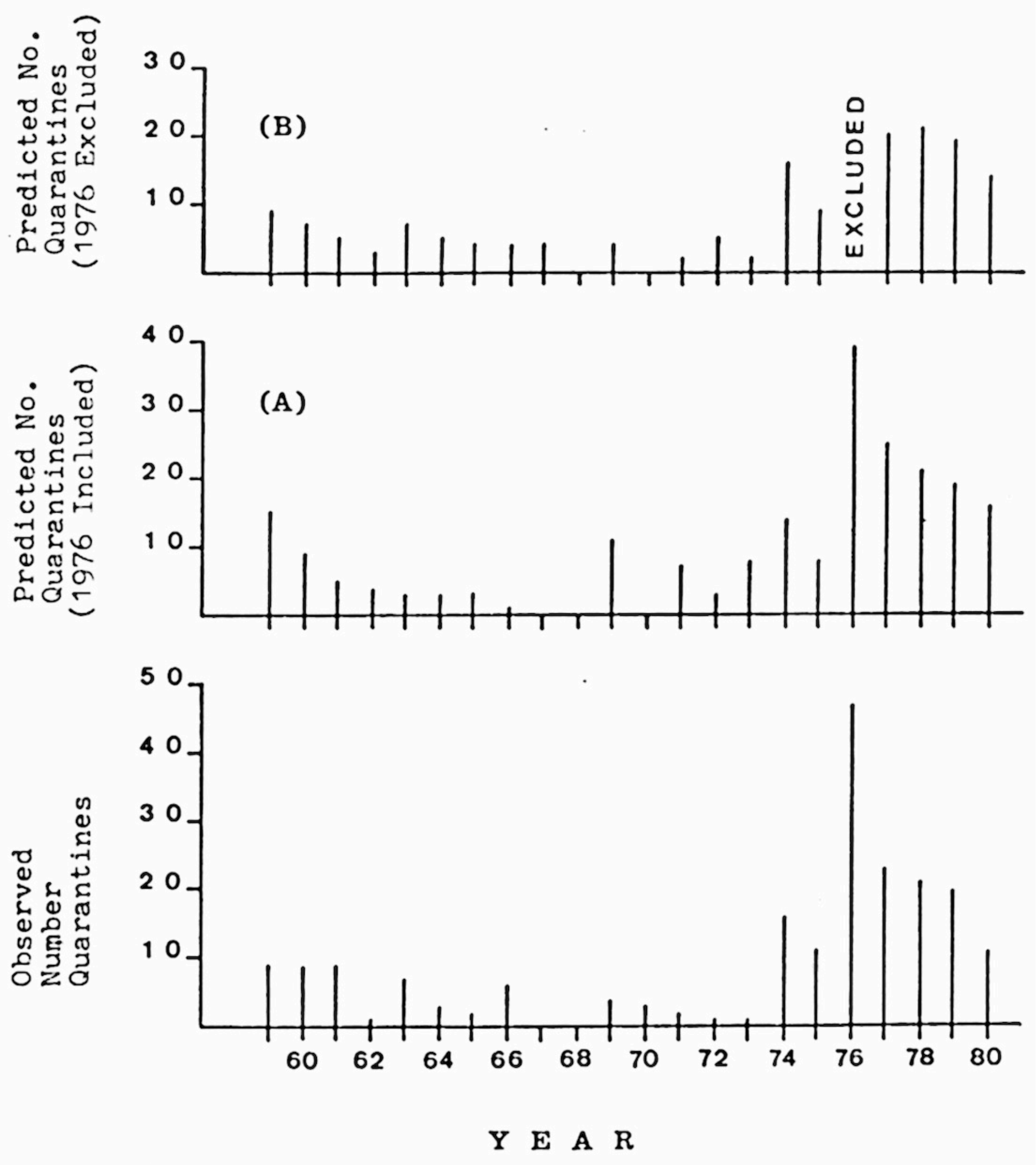
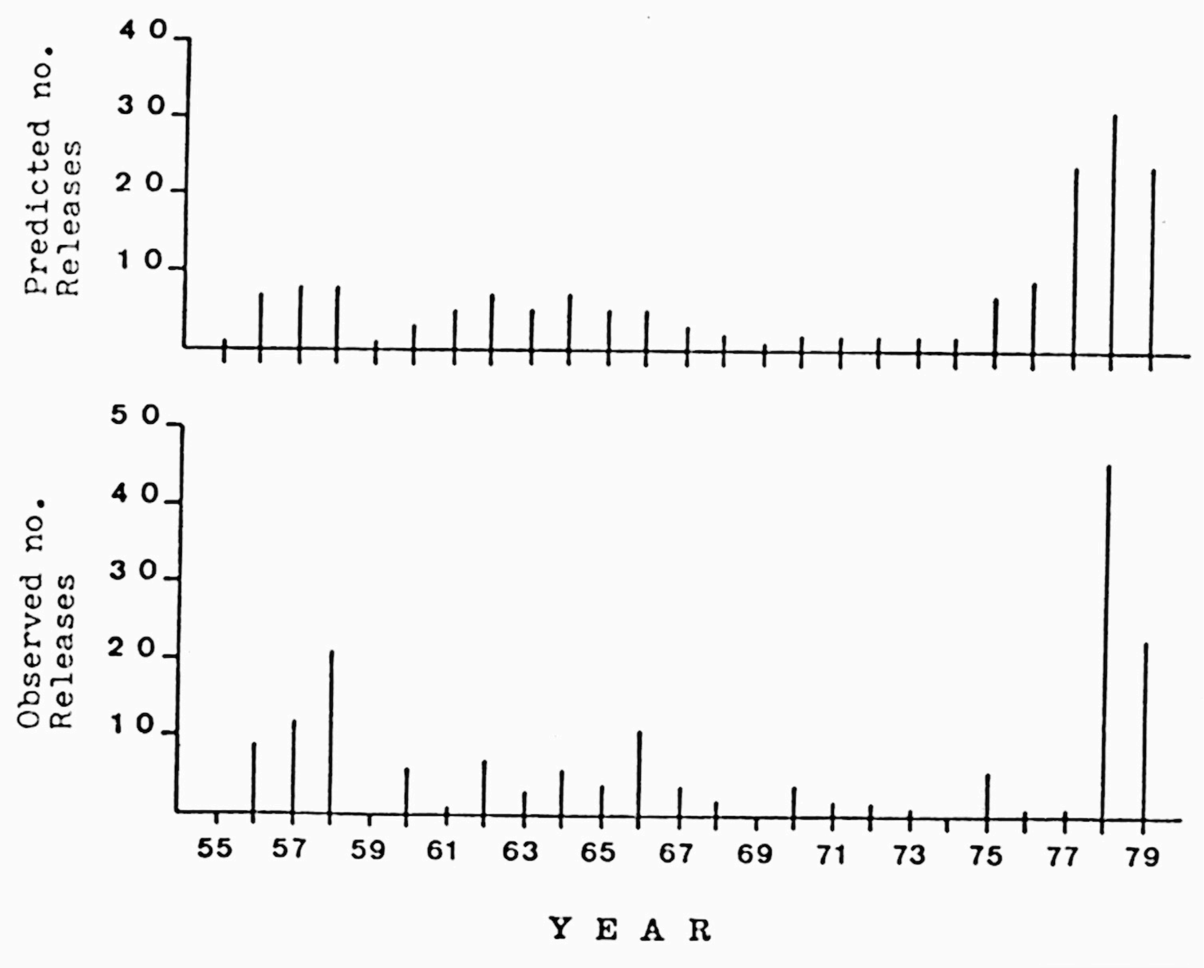


Figure 13. Comparison of Observed Number of Releases from Quarantine per Season with Number Predicted from the Number of Properties in Quarantine at the Beginning of the Season.



4.3.4 DISCUSSION

The main objective of this exercise was to look for evidence of whether the cattle tick is able to exist permanently on the eastern Darling Downs, or whether the tick must be continually re-introduced into the area for new outbreaks to occur. The evidence suggests that at least the area close to the Great Dividing Range should be regarded as an endemic area, but the margins of this endemic area still need to be defined.

The New England Highway was included in the analysis as it is one of the possible boundaries of a new infected area. Although a large number of previously infected properties are situated west of the highway, they were less frequently infested than those to the east. The much higher incidence of tick fever west of the highway also suggests that cattle in this area have much less contact with ticks than cattle to the east as herd immunity against tick fever is inversely proportional to the level of tick infestation in a herd (Joyner and Donnelly 1979).

The distribution of tick quarantines by month follows closely the normal pattern of tick infestation seen on cattle in South-East Queensland. However, this is only of limited value in deciding whether or not the area is capable of permanently supporting tick populations. Tick quarantines in the favourable tick months could result from:

a) An upsurge in tick numbers on properties where ticks were already present in low numbers, resulting in a more easily recognised infestation.

b) Introduction or spread of ticks from the tick infested area when tick numbers are highest.

c) Spread of ticks from adjacent infected properties during the favourable tick months. This is supported by the finding that the incidence of new quarantines was correlated with the number of properties already in quarantine at the beginning of each season.

The high correlation between meteorological data and tick quarantines was surprising considering the number of other factors that could be involved. These include:

a) Variations in inspection, detection and eradication procedures.

b) Introductions by animal or mechanical means.

c) Variations in tick microclimates that may not be predicted by raw meteorological data e.g. soil temperature influenced by aspect and ground cover.

d) Carry over of infestations from previous years.

e) Variations in weather patterns throughout the area.

f) Local effects, e.g. ticks introduced suddenly into a small area more favourable than surrounding areas. Infection of a large number of small adjacent farms may artificially inflate the observed number of quarantines rather than if a smaller number of large farms had been infected.

Contrary to the conclusion of Mackerras et al. (1961) and Wilkinson (1970) that low temperatures limit the distribution of the cattle tick in southern Queensland, the results of this study suggested that, at least in the study area, both temperature and moisture may be important. As discussed earlier, temperature will determine whether the tick population survives from one season to the next, but the size and visibility of infestations are probably determined by the favourability of the growing season i.e. rainfall over the Spring - Autumn period. The results also suggest that wind may play a role, although its association with tick quarantines, especially in 1974, may have been incidental.

The very high incidence of quarantines in 1976 remains anomalous. That year had the highest rainfall of all years in the study, but had quite a low average temperature. The high number of quarantines could possibly be accounted for by one or more of the other factors affecting tick quarantines discussed above. It is interesting to note from Table 1 that Toowoomba was the only stock district in southern Queensland to record such a high incidence of tick quarantines in 1976.

The lag effect seen in the association between meteorological data and tick quarantines could have two possible explanations:

1) Properties are becoming infected one year and are not being detected until the following year.

2) There is a cumulative effect of successive good seasons, e.g. if two good seasons follow each other, tick populations may become established in the first season and then multiply further in the second season.

Examination of meteorological data around the time of the large upsurge in quarantines in 1974 is particularly revealing. The summers of 1973 and 1974 were both favourable for ticks and the winters preceding both these years were relatively warm. Although winter temperature was positively correlated with summer temperature and did not show significance in the multiple regression exercise, it is still quite likely that a warm winter could contribute to the build up of tick populations in the following season. The favourable conditions over these two years may have allowed tick numbers to build up, resulting in the upsurge of quarantines in 1974.

Another contributing factor may have been the beef crash at around this time. As beef prices fell, so did management standards and farmers had less incentive to control cattle ticks. The tick may have been easier to introduce through straying stock and once introduced, control measures may have been less rigorously implemented. The continuing high incidence of tick quarantines in succeeding years probably resulted from the larger pool of infected properties to act as foci of infection, in conjunction with producer apathy and the occurrence of further favourable seasons for ticks, especially in 1976 and 1977.

The distribution by month of releases from quarantine is consistent with the normal procedure for dealing with quarantined properties. The procedure as outlined by Pembroke (personal communication) has been as follows:

> *Where the infestation is detected early in the year, as is the norm, the owner is advised to carry out treatments until winter (about June). In the following summer, the owner is advised to carry out at least three treatments commencing about November or December. Three or four herd inspections are then carried out between February and July before removal of quarantine restrictions. Considering the number of factors involved, it is not surprising that the number of releases from quarantine per season was not weather related.*

Dairy herds are much more closely observed than beef herds, which probably explains the higher frequency of quarantines seen in dairy farms.

In summary, it was found that the incidence of new tick quarantines was significantly correlated with the number of properties in quarantine at the beginning of the year and seasonal weather conditions, rainfall being the most important, i.e. spread from existing infestations was probably important and this was more likely to happen in good seasons.

4.4 MAXWELTON SPECIAL AREA

By 1981 there were approximately 78 properties quarantined for cattle ticks in the McKinlay, Richmond and Flinders shires. Ticks spread south into this area during the mid 1970's because of an increase in cattle numbers in the area (and concurrent reduction in sheep numbers), combined with a number of good seasons conducive to tick survival and the lack of an effective stock barrier between the tick infected and clean areas. There are numerous natural water channels in the area running from south to north which flood during the wet, washing out fences and thus allowing cattle to stray south. The Department is currently constructing a flood proof fence between Cloncurry and Hughenden to overcome this problem.

Eradication programs so far appear to be meeting with some success, mainly through the help of very dry conditions prevailing over the last couple of seasons. Of 40 properties inspected in 1984, 33 were found to be clean. Infestations have mainly been very light and the impression of local Stock Inspectors is that there are now very few ticks left in the area (especially the western end) and those that are present are mainly confined to straddle properties or properties with some moist areas. It now looks likely that the majority of properties will be tick free by the end of 1985.

4.5 OTHER AREAS

There are currently 17 properties quarantined for ticks in the Roma division. These are nearly all situated adjacent to and South of the tick line in the Taroom shire and are, on the whole, not a problem. Movements off these properties are normally controlled whether they are quarantined or not.

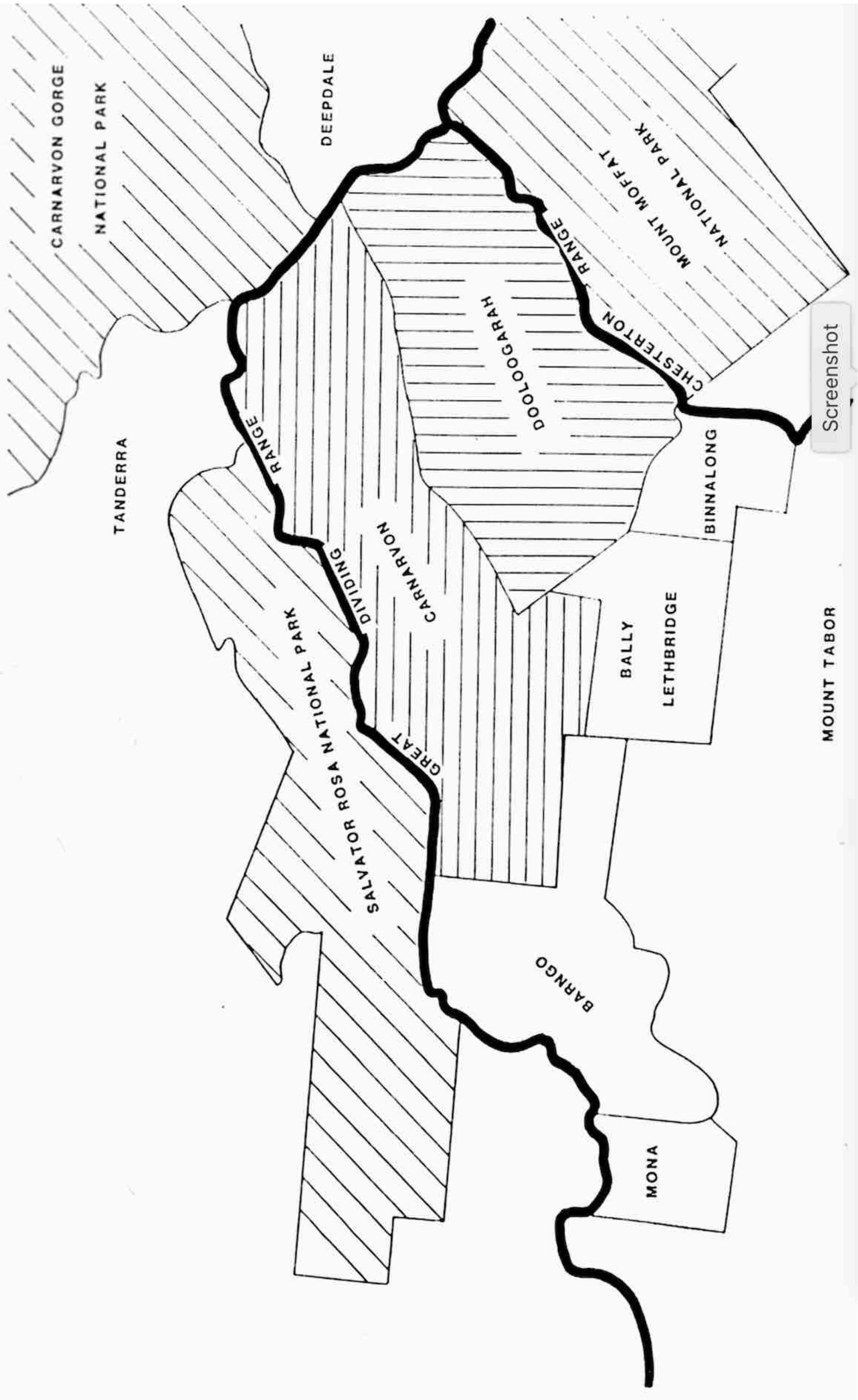
There are two tick infested properties in the Western division, Carnarvon and Dooloogarah on the southern side of the Carnarvon Ranges in the Murweh shire (Upper Warrego Special Area - see figure 14). Because of the inaccessibility and distance from Charleville of these properties, clearing of cattle from them (and their neighbours) causes a disproportionate amount of work. Over the last few years, the level of infestation on these properties has been very low. Carnarvon did have a heavy infestation in 1984 but the property was partially destocked and then restocked since.

There are basically two types of country on these properties: sandy forest country which is largely inhospitable to ticks and lower lying, black soil country where ticks are probably surviving. The country is difficult to muster, but I feel that ticks could be eradicated with a program that combined paddock rotation (making use of paddocks of cultivation) and treatment programs. Although rainfall and moisture availability are good (many springs in the area), the winter is very harsh on these properties, so the spring generation of ticks could be expected to be very small. A less than ideal program may be sufficient to eradicate them. The recent advent of an efficient pour-on acaricide with long treatment intervals has prompted an attempt to eradicate ticks during the summer of 1985/86.

In the past, reinfestation from the north has been a problem, but the surrounding country is now mostly National Park, so this should no longer be a problem, as long as they are kept free of stock. Fencing and general management is also being improved.

From the Upper Warrego Special Area north to Hughenden, incursions of ticks into schedule "W" have not been a problem except for the odd outbreak caused by travelling stock. These have always been quickly brought under control.

Figure 14. Upper Warrego Special Area.



4.6 PERSISTANCE OF INFESTATIONS

There have been numerous instances of single tick infestations being found on the Darling Downs, which are almost invariably controlled, even with little or no treatment. The occurrence of single cases of tick fever with no ticks being found is also common. Two of these cases were studied in detail during 1983/84.

The first involved a single case of tick fever (*Babesia bigemina*) in March, 1983 at Brown's farm at Yangan, east of Warwick. Quarantine was applied and a number of herd treatments and inspections were carried out during 1983. In January, 1984 another animal died from tick fever, this time *B. bovis*. No further herd treatments were carried out, but fortnightly herd inspections were performed until July. Again, no cattle ticks were found. There is a possible link between these cattle and another case of tick fever at Bony Mt. to the north west of Warwick and a case of illegal introduction of "S" cattle by K. McCahon at about the same time. The Bony Mt. case of tick fever (again no ticks found) occurred in February 1983 and Brown of Yangan had brought cattle from another property in the Bony Mt. area at about the same time. Illegal introductions by McCahon had occurred in November 1982 and it is suspected that some of these cattle went to the Bony Mt. area. The "long paddock" was being extensively used at the time, so this could explain the February/March 1983 cases of tick fever, but not the 1984 case. Whatever their origin, it appears there were ticks present in very low numbers on these properties during 1983/84, but they did not persist.

The second case was in the Kaimkillenbun area north east of Dalby. Mr. Skerman of "Ripley Park" found a single tick on his cattle on 10/12/83. Three weekly inspections were carried out until June 1984 with no further ticks being found. Neighbouring properties were also inspected with no ticks being found except one tick on Luffs' property, "Dunbar" in February. No further ticks were found on this property and no treatments were carried out on either property during the entire period.

These two cases are fairly typical of the "one tick" phenomenon, which is quite common on the Darling Downs and also in the marginal areas of New South Wales. A common theory is that these are very light "smouldering" infestations that just become apparent from time to time. However, I doubt that this is normally the case. Available evidence suggests that these infestations do not normally persist and the laws of chance are also against a tick population surviving at such low levels (that is, a lack of a critical mass of individuals to sustain the population). There are two other possible explanations for the occurrence of single tick infestations:

(1) Timing of Inspections.

In all tick infestations there are times of the year when there are few or no ticks on the cattle. At these times the tick population is mostly in its non parasitic phase (i.e. eggs or larvae on pasture). With light infestations, there will be more of these times when there are few ticks on cattle. If inspections are done at these times, "single tick" infestations are likely. However, heavier infestations will be seen at other times.

(2) Introduction of Ticks from other Areas

There are many possible methods of tick dispersal (see section 3.1), introduction of infested cattle being the best documented. Two other methods could explain a large number of single tick (and possibly some more extensive) infestations. These are wind dispersal of larvae and introduction of engorged female ticks on cattle trucks. Work by Ivor Lewis of the NSW Dept. of Agriculture showed that larvae can be carried short distances by wind, but it is impossible to demonstrate over longer distances. However, Rob Sutherst of CSIRO is firmly of the opinion that larvae are regularly picked up by up-draughts below the Range and then "rained" down upon the Downs. The dilution factor would be considerable, so that single tick infestations (if any) would be the most likely outcome.

It is not difficult to find live, engorged female ticks on the floors of cattle trucks travelling across the tick line, so it is obvious that these are a potential source of infestations. It is not unknown in single tick infestations for the tick to be found on the house cow which often has regular access to areas around cattle yards where ticks from trucks could be dropped.

Just as common as single tick infestations on the Downs are infestations where numbers are heavier and it is obvious that regeneration is taking place. There have also been cases where control has been poor and very heavy infestations ("hanging off them like grapes") have resulted. These have occurred mainly in the Toowoomba area but cases have also been seen at Warwick and

Dalby. These heavy, persistent infestations are seen in the same areas as the single tick infestations that often seem to die out by themselves. I feel that the only basic difference between these two situations is the size and/or "luck" of the initial infestation. If the initial infestation is very small, the laws of chance are against it and the population normally just dies out because of (a) lack of available males to fertilise females and (b) very low larval densities on the pasture. Introductions during the winter have an even lower chance of survival and this is the time that introductions are most likely because of high tick numbers in the infected area.

If the odds against the tick are beaten and one or more females are fertilised, some of their progeny may find a host allowing the cycle to continue. The often-seen phenomenon where no ticks will be found on a whole herd except one beast which carries a significant infestation is likely in this situation. Once past this first generation, the population is much more likely to survive, as the second generation will normally be much larger. As with most populations, a threshold population size probably exists below which the population will not survive. The threshold level will depend on climatic suitability and the density of the host population.

I doubt that parthenogenesis will produce persistent low level infestations as, although the phenomenon does occur (Stone 1963), only very small numbers of viable larvae are produced and each subsequent generation is weaker than the one before. Only female larvae are produced, so introduction of male larvae would be needed for the population to develop further. Persistent dispersal into an area and/or spread from neighbouring infestations are more likely to account for the regular occurrence of single tick infestations.

Persistence of heavier infestations suggests that ticks are quite capable of surviving permanently on the eastern Downs if given the chance. Three examples will highlight this.

Case 1 involves the herd of Mr. F. Bebbington of "Mt. View", Ramsay, which is situated just east of the New England Highway about 10 Km. south of Toowoomba. Mr. Bebbington’s herd was quarantined in the 1950's and again about 10 years ago. The property is still in quarantine and ticks have been found by Departmental officers on numerous occasions. Mr. Bebbington himself admits that the infestation has been very heavy at times and he was having extreme difficulty in controlling the infestation until he switched to Barricade in 1984. The property is situated on a low hill and local Stock

Inspectors have noticed that the more persistent infestations are often associated with stony hills or ridges where ground temperatures are normally warmer than the surrounding low lying areas. I will discuss later how this affects winter survival.

Case 2 occurred on the property of C. Jones, Hopelands, which is situated on the south bank of the Condamine river south east of Chinchilla. A very heavy infestation was first observed on 16/5/63, following an earlier introduction of infested stock. Treatments were commenced immediately and this initial infestation was cleaned up. One of the paddocks in which the cattle had been grazing was closed up at this time for agricultural purposes. In late November, Jones' cattle broke into the paddock and 14 days later were found to have a light to medium infestation of nymphal ticks. A portion of this paddock contained a well covered, timbered area and it was obvious that the progeny of the ticks present in the Autumn had been able to survive the winter in this area.

Case 3 involved the property of Mr. Lees at Yarrabah, Inglewood. Infested stock were illegally introduced to this property in November,1982 but the movement was not traced until May,1983. When inspected, a light but significant infestation was found. For ticks to be found at this time, they would have had to cycle twice since November. Normally this would not have seemed an unusual occurrence but, at the time, the property was experiencing a severe drought. When inspected in May, the property was only lightly stocked and was very dry with very little feed available. Despite these extremely adverse conditions, the population was able to survive, probably along the banks of a creek that ran through the property. This suggests that heavy infestations would probably build up during a good season. Obviously, it is unknown whether the population would have survived the winter.

4.7 TICK DISPERSAL

From the evidence given to date, it can be concluded that new tick infestations on the Downs arise from two sources, namely long-distance dissemination from the tick infested area and local dissemination from already existing infestations. The latter can be fairly easily explained by methods such as straying stock and mechanical spread which may involve machinery, other animals, wind and possibly water.

Apart from the proven method of travelling stock, long distance dissemination is very difficult to study. The evidence discussed earlier on the distribution of quarantines in relation to the adjacent “S" country certainly suggests that dissemination from these areas is important. It appears that if you have a high population of ticks adjacent to a clean area, an overflow situation is likely to occur.

As discussed in section 3.1, dissemination could occur through:

a) Travelling stock (either illegal movements or straying stock). It is interesting to note that in the problem area between Toowoomba and Clifton, there are six roads traversing the tick line, whereas there are only two between Toowoomba and Crows Nest.

b) Wind borne larvae. The topography south of Toowoomba appears as though it would favour this method of dissemination more than that to the north of Toowoomba. Also looking at topography, wind direction and cattle densities, it is unlikely that this method would be important in the more northern areas.

c) Stock trucks.

d) Deer could be important as they are the only wildlife species in Queensland capable of acting as definitive hosts of the cattle tick and they are present in tick infested areas adjacent to the Darling Downs.

e) Other mechanical methods of spread:- other wildlife, vehicles, hay. Watersheds generally flow away from the tick free area, so transport by water is unlikely to be responsible for outbreaks (except possibly local spread).

The theory of larval dissemination via wind or mechanical means (e.g. birds) is supported by experiences in areas of NSW adjacent to the Numinbah valley. Since tick populations have been controlled in this valley, outbreaks in the adjacent NSW areas have been reduced dramatically. Cattle movements between the two areas do not occur, so logically dissemination must have been occurring either wind or the very plentiful bird life in the area.

It is interesting to note that the overflow situation, apart from the special case of the Maxwelton special area, only occurs to any great extent in the more intensive southern portion of the state. This is probably because the more extensive production systems tend to act against the possible methods of dissemination. Dissemination through cattle movements would be the exception to this rule e.g. Maxwelton Special Area.

Whatever the method, an overflow situation is likely when an infested population of cattle resides next to an uninfested one. The overflow will be more extensive when tick and cattle population densities are high and when there is little or no buffer between the two areas. Once ticks have been dispersed into the adjacent clean area, climatic influences (and human intervention) will determine whether the population is able to become established. This will be discussed in the next two sections.

5. TICK PLOT STUDIES

5.1 METHODOLOGY

Tick plots were established at Toowoomba and Hermitage Research Station, Warwick in March 1981, Hughenden in mid 1981, Winton and Toorak Research Station, Julia Creek in December 1981 and "Harrow", west of Cambooya in August 1982.

The Toowoomba plot was situated in a paddock with a north easterly aspect behind the DPI offices. It was well grassed with a mixture of native and introduced grasses (mainly Kikuyu) growing on red soil.

The Hermitage tick plot was originally sited on a flat piece of ground near the banks of a small creek on the southern boundary of the Research Station. This site was subject to flooding, so in December 1981 it was moved to a higher site with a slight south westerly slope. In June 1982, a cylinder of larvae was discovered broken open, presumably by a bird and the plot was moved into a large wire mesh cage that had previously been used for pasture studies. This site had a southerly aspect and was protected on its northern side by high stands of Pampas grass. All three sites had a generally sparse covering of native and introduced grasses on black soil.

The Harrow plot was on a stony ridge with a north easterly aspect and a good covering of native grasses.

Two plots were used at Toorak Research Station. One was on open Downs country while the other was situated along a ditch adjacent to a bore drain. This ditch was normally filled with water from the bore drain although this seldom occurred during the drought of 1983. We wanted to site the plot actually on a bore drain but this was not possible because of the regular delving of the bore drains on the property.

The Winton plot was originally situated on open Downs country outside of town, but was later moved to a site behind the DPI office where an attempt was made to create an artificial bore drain.

The Hughenden plot was first situated on a site adjacent to a bore drain (but receiving little water from it) on the property, "Dunluce". It was later moved to a site high on the banks of the Flinders river near the town. This site was well grassed with some shade from a tree and a lot of dead vegetable matter covering the ground.

Each tick plot comprised two parts:

a) <u>Larval production Studies</u>.

A technique based on that of Sutherst, Wharton and Utech (1979) was used. Ten to fifteen engorged female ticks were exposed in the tick plots each month (fortnightly at more critical times of the year). Each tick was enclosed in a polyamide mesh bag which was placed in a stainless steel mesh cylinder corked at one end. This was then placed under or in a grass tussock so that direct sunlight could not fall on it. Weekly observations were made to determine the time of commencement of lay and time of hatch of larvae. When hatching had ceased, the contents of each cylinder was transferred to alcohol so that the number of larvae and unhatched eggs could be counted. This was done using an aliquot technique developed by myself.

The results of the larval production studies are provided in two ways on the results charts (see figures 15,16,17,32). At the bottom of the chart is a graph which shows the number of eggs laid and the number of larvae hatched according to the date of exposure of the engorged ticks. This illustrates which times of the year are suitable for tick propagation, but does not show at what times hatching actually takes place e.g. eggs laid in March may hatch in May whereas eggs laid in April may hatch much later in September or October. This information is given in the centre section of the chart which contains a series of horizontal lines. The beginning of each line represents the date of exposure of the engorged ticks, the end of the line shows the date eggs commenced hatching and above this is a vertical bar showing the size of the hatch. If no hatching occurred, the horizontal line becomes broken and if there was no lay, there will just be a dot at the exposure date.

b) <u>Larval Survival Studies.</u>

To study larval survival, a new technique was developed with the help of Dr. Rob Sutherst of CSIRO where larvae hatched in the laboratory were exposed in the field enclosed in cylinders or packets made from polyamide mesh. Previously used methods (Sutherst, Wharton & Utech 1978), where larvae were released on small squares of grass surrounded by mown areas, were unacceptable because of the risk of escape to surrounding tick free areas. The cylinders measured approximately 15 x 4 cm and each contained around 5,000 larvae. Twenty of these were placed in the tick plots each month and destructively sampled at intervals thereafter to determine the percentage that remained alive at each point. I developed a new technique to separate live and dead larvae so that this could be done.

The cylinders were positioned so that the top of each was about level with the top of the grass sward which was kept trimmed for the purpose. Studies at the Animal Research Institute, Yeerongpilly compared survival in the cylinders with survival of larvae free on grass and showed that larvae in cylinders generally survive about 20% longer than those on grass. This advantage was even greater during wet weather as rain tended to wash away free larvae whereas larvae in cylinders were kept in place. Whether larvae washed away are able to re-ascend grass elsewhere or become trapped in mud and die is up to speculation. Another major discrepancy occurs with larval survival in the spring, as larvae hatched from eggs with long incubation periods do not live as long as larvae hatched in the laboratory. However, these discrepancies are taken into account in the analyses, so the results do provide a good guide to larval survival in the field.

The top section of the results chart shows the results of the larval survival studies. These are given in the form of survival curves which generally are sigmoid in shape. The top of the curve represents 100% larvae alive at the date of exposure and the bottom represents the point when the last larvae died. The results from Harrow are given in a straight line form as we did not have the resources to expose enough cylinders here to obtain quantitative results. Instead, only 5 cylinders were exposed each month and qualitative observations were made each week as to the approximate number of remaining live larvae (this was possible as live larvae tended to stay at the top of the cylinders while dead larvae dropped to the bottom). The results from Toorak are also given as straight lines as survival times were generally too short to obtain meaningful intermediate survival rates.

5.2 COMPUTER MODEL FOR ASSESSMENT OF TICK PLOT DATA

It can be very difficult to fully assimilate all the data obtained from tick plots. To overcome this problem a computer model was constructed which integrates the data from the tick plots and presents it in a more easily understood form i.e. predictions of numbers of larvae on pasture and ticks on cattle subsequent to any specified initial infestation. At the beginning of each simulation, the operator must specify an initial infestation of engorged ticks dropping from cattle or larvae hatching in the pasture, and the model then uses data from a tick plot to predict the size and timing of subsequent generations of ticks.

Data from different tick plot sites can be used to drive the model so that propagation and survival at different sites can be compared. Any combination of three different control methods can also be specified (dipping, resistant cattle and pasture rotation) and an economic appraisal can be made of any control strategy. This can be used to determine the most efficient control strategy in a particular area.

A more detailed description of the model and its operation is given in the appendix, including validation of model predictions against field observations.

In sections 5.3.4 and 5.3.5, model predictions will be used to assess winter survival and summer growth potential. In section 6.1 it is used to assess the efficiency of different control strategies.

5.3 EASTERN DOWNS TICK PLOT RESULTS

5.3.1 Toowoomba

Figure 15 shows the Toowoomba tick plot results. Looking at larval production first, the most striking feature is the break in larval production during the winter months. Over the study period, no ticks exposed in May or June produced progeny, although some eggs were normally laid.

Both April and July are marginal in that ticks exposed in those months may or may not produce progeny and the numbers they do produce are generally low. In 1982,1983 and 1984 ticks were exposed during the first week and in about the middle of April. In 1982, eggs from both exposures hatched, one at the end of August and the other at the end of October. In 1983, neither exposure produced any larvae and in 1984, the early April exposure produced larvae in August, but-no larvae hatched from the mid April exposure.

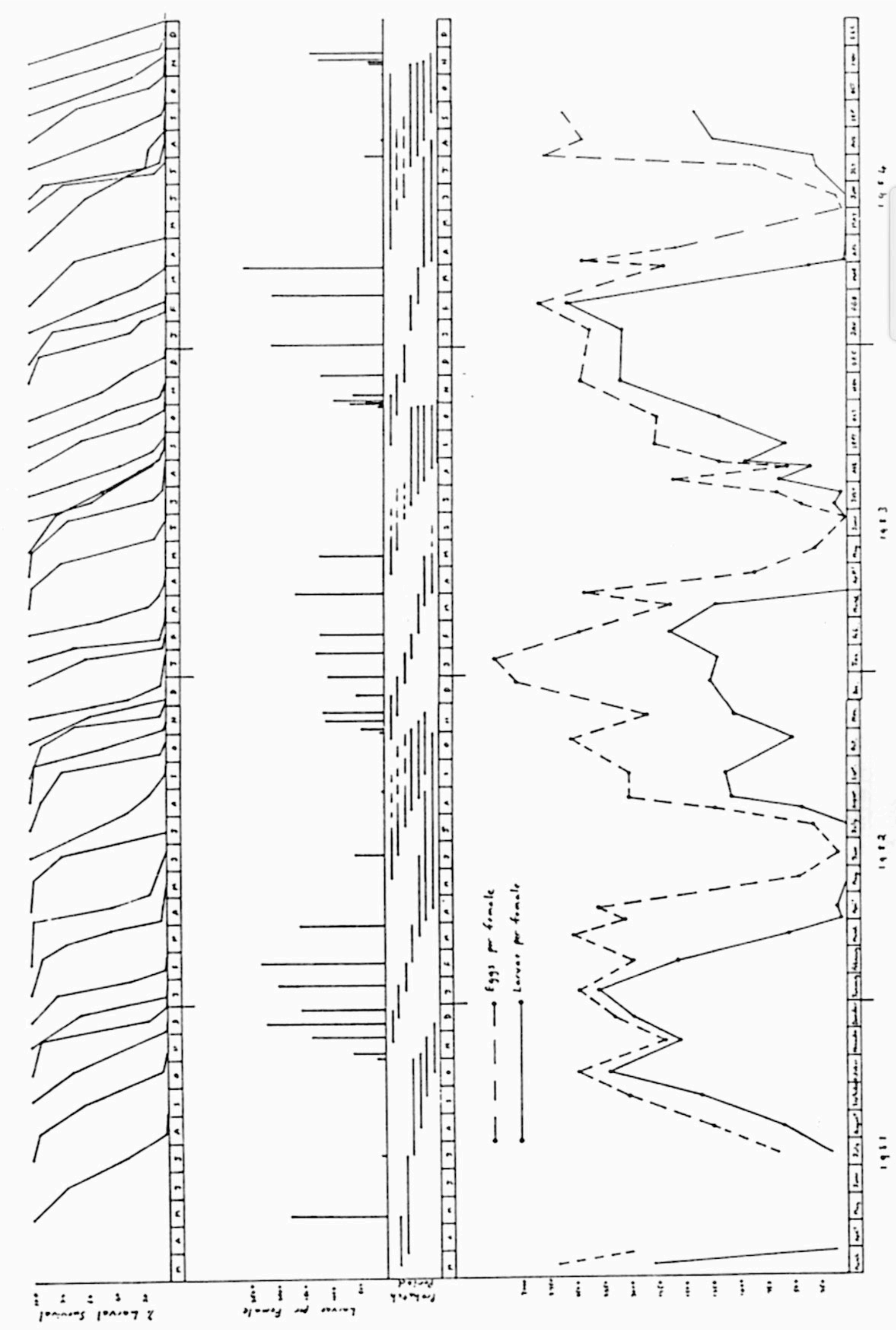
Ticks exposed in July produced progeny in 3 out of 4 years. These larvae hatched at the end of October or the beginning of November as did larvae from the August and September exposures. This is called the spring rise and its importance in relation to control strategies is outlined in section 6.1.

Ticks exposed from August through to March all produced large numbers of larvae during the three summer periods of the study. In fact, the summers of 81/82 and 83/84 were extremely conducive to tick propagation. Temperatures were warm, but not too hot and pasture moisture levels were high. If unchecked, heavy build ups would be expected. A drought was experienced during the summer of 82/83 and although hatchings were down, around 50% of eggs still hatched. This is about the worst you could expect for tick propagation at the Toowoomba site.

The larval survival studies showed that Toowoomba is also very favourable for larval survival. Moisture levels are generally high and temperatures are mild. As opposed to the situation with larval production where egg development ceases at low temperatures, larvae survived for long periods during the cold winter months. For larvae exposed between April and August, the minimum longevity recorded was about 3 months, while the longest was 4.5 months. Larvae exposed during the summer months generally survived for between 1.5 and 3 months depending on ambient temperature and moisture levels (high temperature and/or dry conditions reduce larval survival times).

See sections 5.3.4 and 5.3.5 for an assessment of winter survival and summer growth potential.

Figure 15. Tick Plot Results, Toowoomba



5.3.2 Hermitage

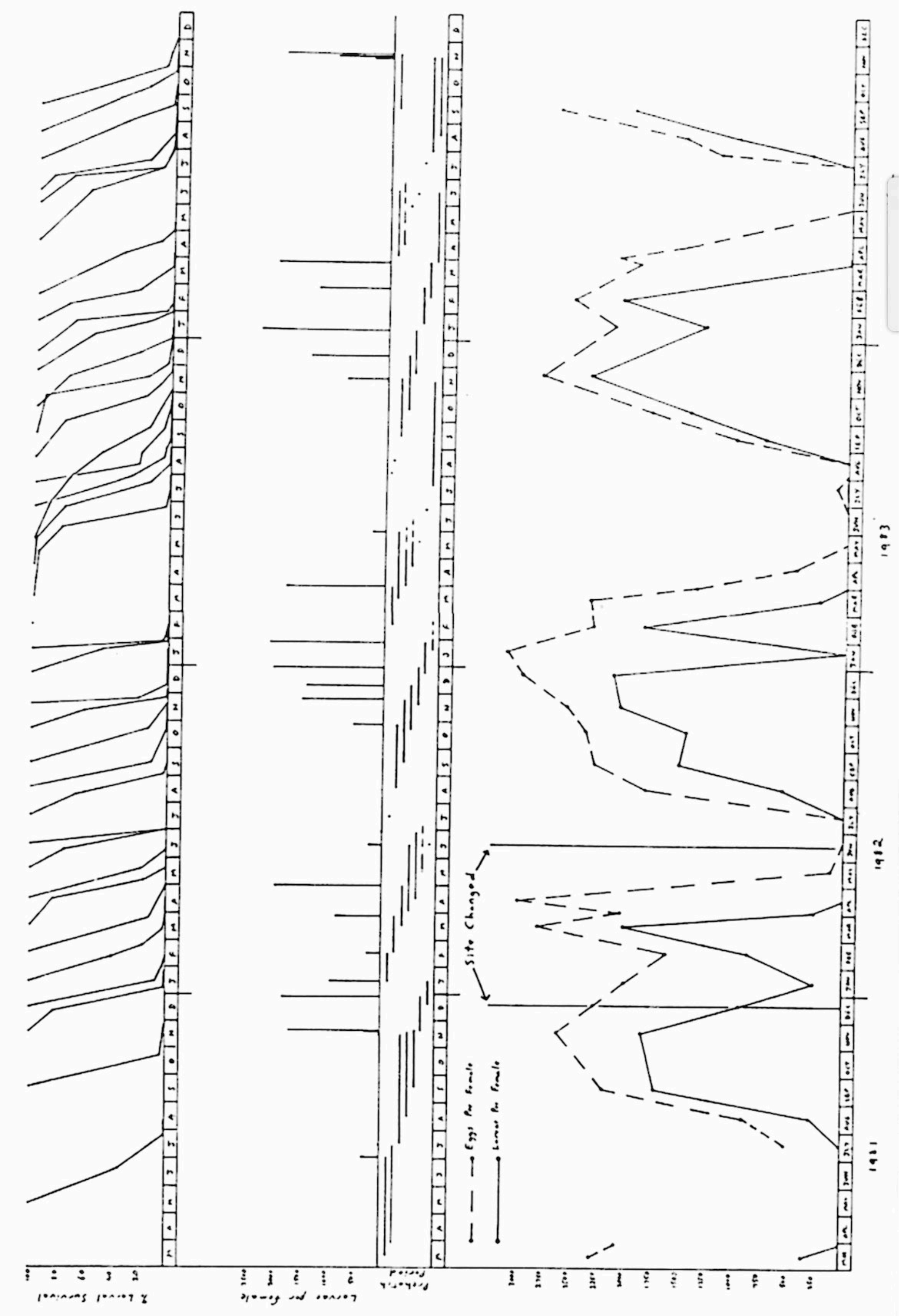
Interpretation of the Hermitage results is complicated by the site changes that had been necessary (Figure 16). My assessment of the three sites would be that the first two were roughly equivalent except that the second was slightly drier, whereas the third site was considerably colder, especially during the winter. This was because the pampas grass along its northern border provided shade from the morning sun. Pasture moisture levels were better in the third site however, so summer propagation was better than in the first two sites.

Comparing the results with those from Toowoomba, it can be seen that April and July are even more marginal. Very few, if any, larvae were produced by exposures in these months. Even the August exposure failed to produce viable larvae in 1983. These differences are probably due more to the southerly aspect of the Hermitage sites rather than gross climatic differences. Examination of long-term weather data reveals that during the winter, Hermitage has slightly warmer days, but colder nights than Toowoomba. According to CSIRO research, daily maximum temperature is a better indicator of the potential for tick propagation than minimum temperature.

Summer propagation was generally good, despite the drier climate at Hermitage. The black soil at Hermitage dried out quicker than the red soil at Toowoomba and this is reflected in the relatively poor hatches over the December - February period in 1981/82, January 1982 (where no eggs hatched because of extremely dry conditions) and January 1984.

Larval survival times were normally less than at Toowoomba at the first two sites, but the third site which was much cooler, produced survival times roughly equivalent to those at Toowoomba, i.e. the more sheltered sites that are less suitable for tick propagation during the winter are more suitable for larval survival.

Figure 16. Tick Plot Results, Hermitage Research Station, Warwick



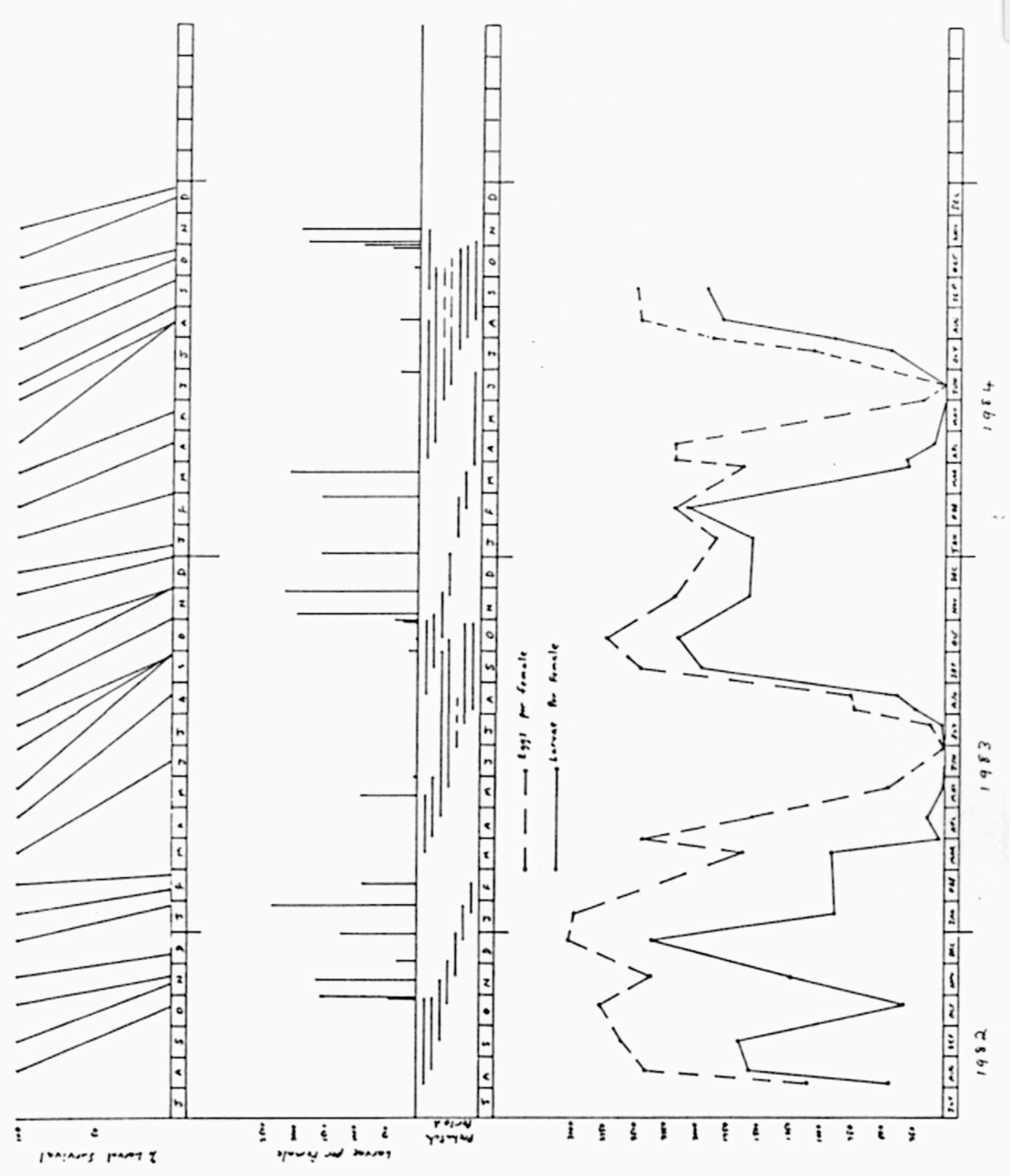
5.3.3 Harrow

This site was chosen as it is on the western side of the problem area for tick infestations south of Toowoomba and its position on the north easterly side of a stony ridge reflects the type of country stock inspectors say is often difficult to clean up.

The results (Figure 17) confirm these observations as tick propagation was better than at Toowoomba during the marginal months of the year. For example, in 1983 no ticks exposed in April or May at Toowoomba produced progeny, whereas at Harrow exposures in April produced small but significant numbers of larvae and the May exposure also produced a very small hatch. The July and August hatches of 1983 were smaller than at Toowoomba but were still significant while the April 1984 hatches were much larger. Larval production during the summer was on a par with that at Toowoomba i.e. it was very good, even during the drought of 1982/83.

Because of the warmer but slightly drier climate, larval survival times were about half those at Toowoomba during the summer, but this trend was not as evident during the winter when larvae at Toowoomba lived for only about two weeks longer than those at Harrow.

Figure 17. Tick Plot Results, "Harrow", Cambooya



5.3.4 Assessment of Potential for Winter Survival

Figures 18-23 show stylized summaries of larval production and survival at Toowoomba, Hermitage, Harrow, Nanango, Maryborough and Taroom. The latter three charts were compiled from previous tick plot studies done at these centres. The rectangular boxes represent the egg stage of the life cycle. The left hand side of the box represents the exposure date of engorged female, ticks, the right side corresponds with the hatching date and the height of the box is proportional to the number of eggs laid.

The black triangles represent the larval stage of the life cycle. The height of the left hand side of the triangle shows the number of larvae hatched while the length of the triangle represents their maximum survival time. An unshaded triangle means that no larvae hatched. The charts represent what would happen in an average year at each site. Obviously, differences will occur from year to year e.g. in months where very small hatches are shown, this normally indicates that larval production may or may not occur depending on the particular season.

The. Taroom chart indicates no tick propagation occurring during January. This will not always be so, but the tick plot results indicated that there was normally a short period during the summer when it was too hot and/or dry for tick propagation and this normally occurred in January.

FIGURE 18 EGG HATCHING AND LARVAL SURVIVAL FOR CATTLE TICKS AT TOOWOOMBA

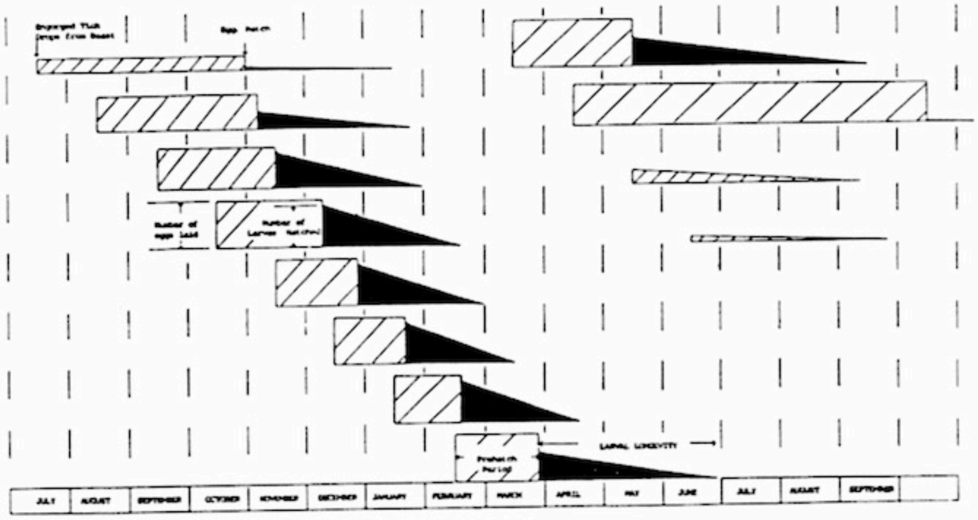


FIGURE 19 EGG HATCHING AND LARVAL SURVIVAL FOR CATTLE TICKS AT HERMITAGE, WARWICK

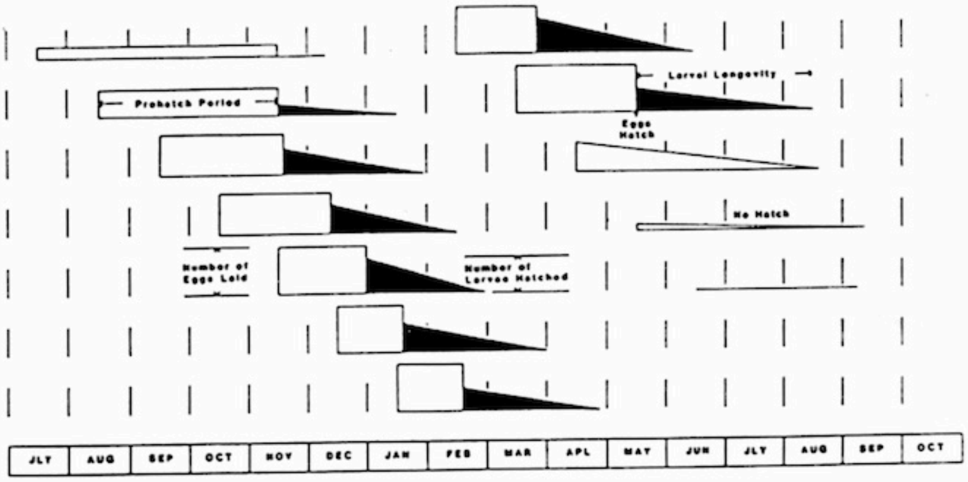


FIGURE 20 EGG HATCHING AND LARVAL SURVIVAL FOR CATTLE TICKS AT HARROW, CAMBOOYA.

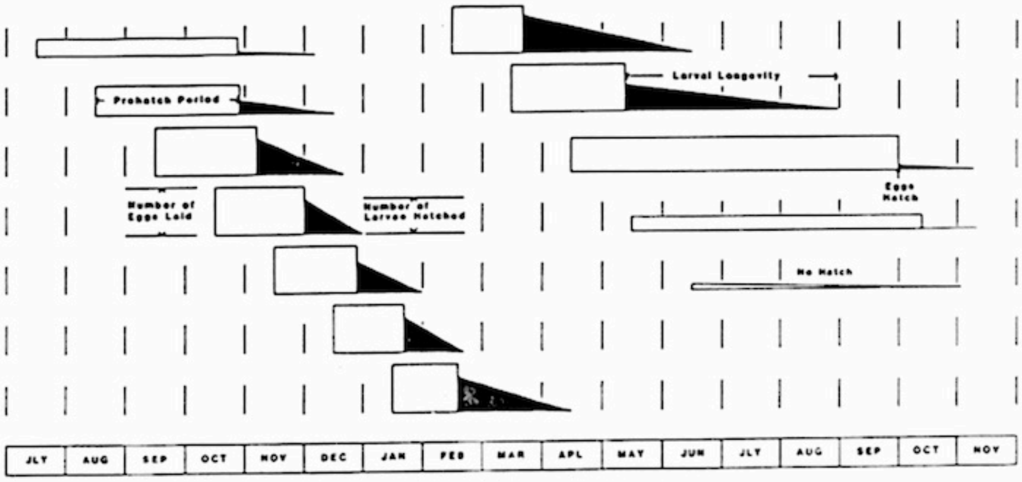


FIGURE 21 EGG HATCHING AND LARVAL SURVIVAL FOR CATTLE TICKS AT NANANGO

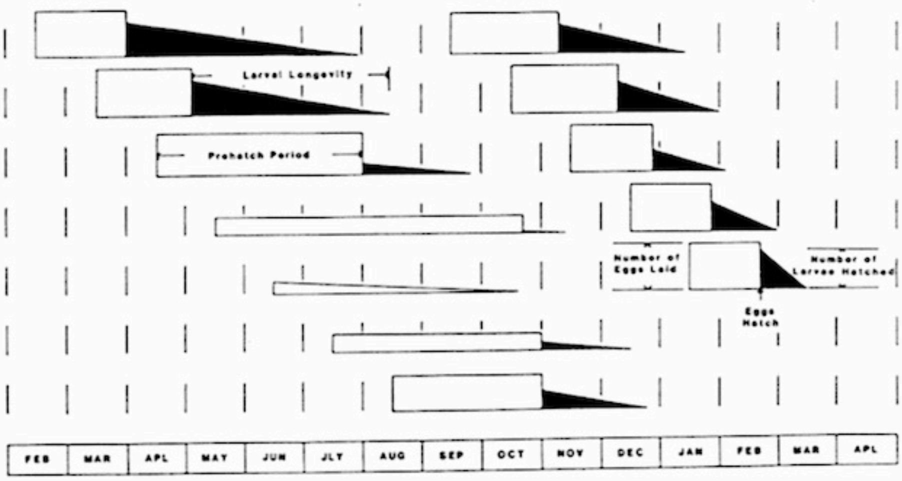


FIGURE 22 EGG HATCHING AND LARVAL SURVIVAL FOR CATTLE TICKS AT GRAHAM'S CREEK MARYBOROUGH

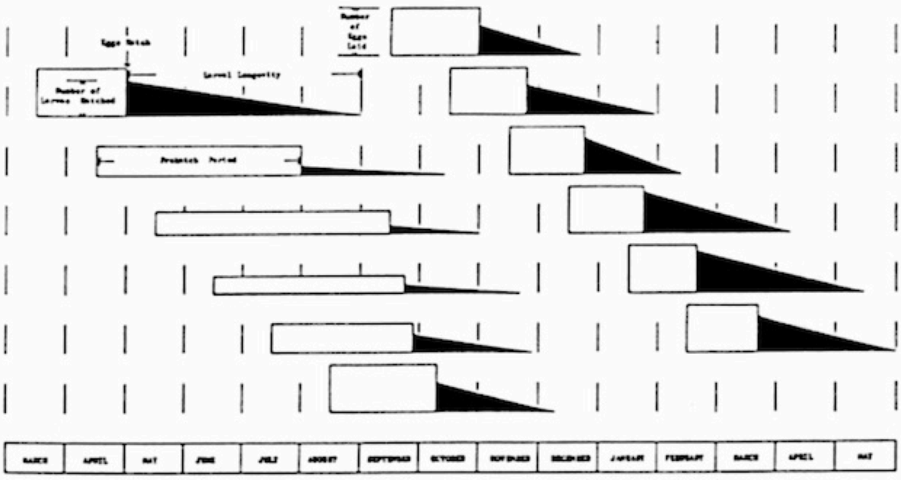
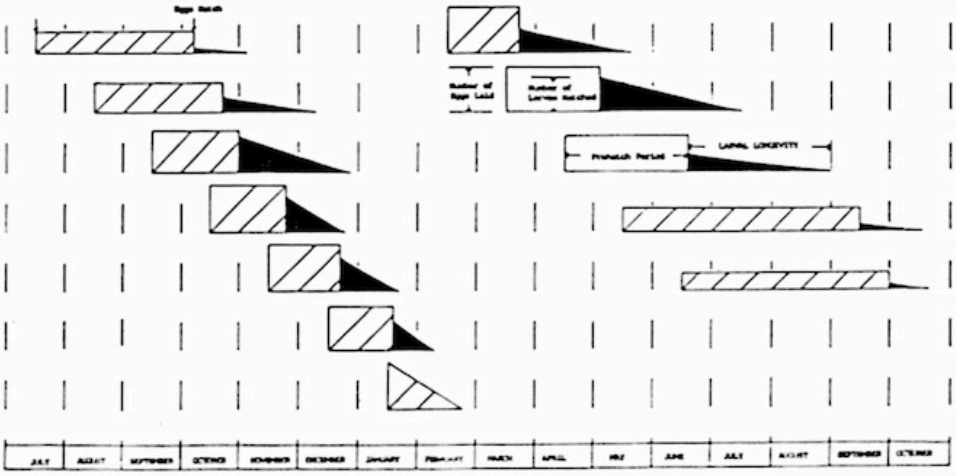


FIGURE 23 EGG HATCHING AND LARVAL SURVIVAL FOR CATTLE TICKS AT TAROOM



As noted earlier, at all Darling Downs sites (and Nanango) there is a period during the winter when no tick propagation occurs. There are two possible ways that a tick population may survive the winter under these conditions:

(1) Eggs laid in late March or April may remain dormant throughout the winter and hatch in the spring. These larvae then attach to a host and continue the life cycle. The question may be asked: why don't the cold winter conditions that prevent eggs laid in May and June from hatching, also prove fatal for these eggs? For eggs to survive prolonged cold periods, they must develop to a fairly advanced stage under relatively warm conditions before the cold sets in. If conditions are cold during the first few weeks after eggs are laid, then they rarely ever hatch.

(2) Eggs laid during March hatch around May and if some of the larvae survive until tick propagation commences again in the spring, the life cycle can continue.

The former method is a feature of more stable climates for tick survival. If a population relies on the second method to survive the winter, any event that drastically affects larval survival will put the population at risk.

From the charts it can be seen that both methods of winter survival normally occur at Maryborough, Taroom, Nanango and Harrow. At Maryborough and Taroom, propagation normally continues throughout the winter, although there are often short periods when propagation ceases. Propagation during the winter is only slightly worse at Harrow than at Nanango, which is regarded as a quite stable climate for ticks. Winter propagation is slightly worse again at Toowoomba as overwintering of eggs often occurs at low levels but is not reliable. However, winter larval survival is very good. At Hermitage, overwintering of eggs is a much rarer occurrence and overwintering of larvae is also marginal.

The computer model described in section 5.2 was used to assess overwintering ability at each site by specifying an initial very small population size in the Autumn and then assessing the presence and size of the subsequent spring generation. The size of the initial infestation was set at 1 tick engorging/beast/week for 10 weeks from the beginning of March.

Figure 24. Simulated Overwintering of Cattle Ticks at Nanango during 1967.

Initial population = 1 tick/beast/week from weeks 10 to 19.

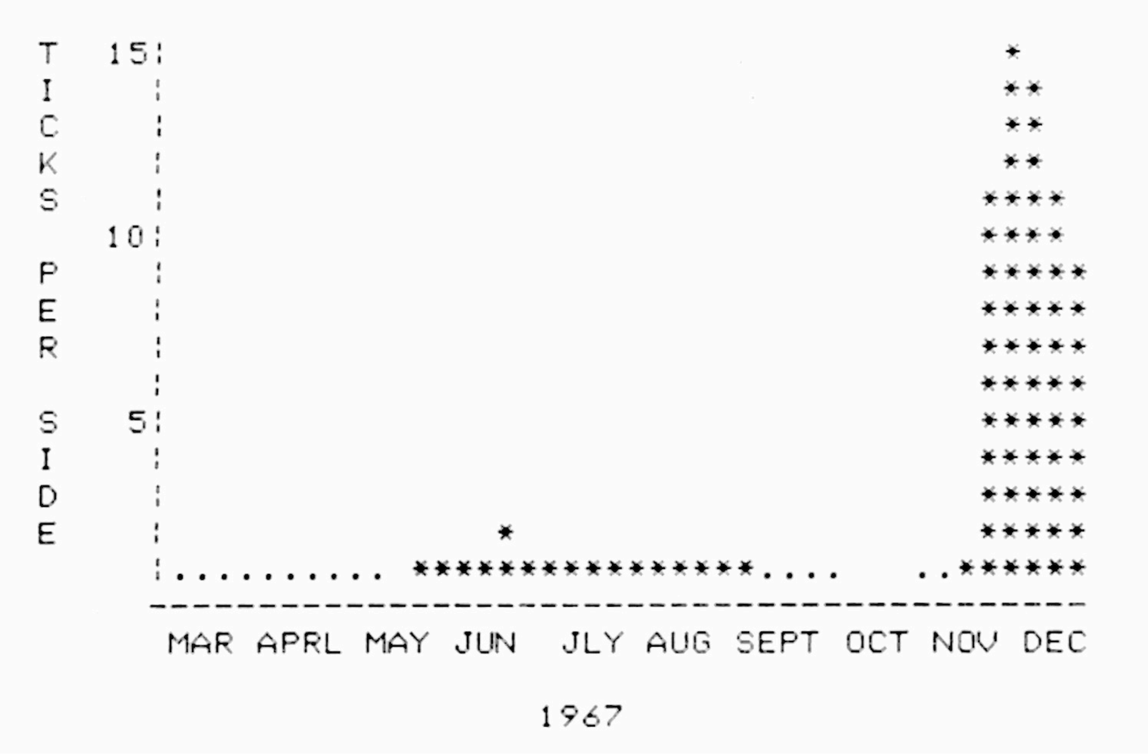


Figure 24 shows the simulated overwintering of ticks during the winter of 1967 at Nanango. As expected, ticks overwintered very easily and a quite large spring rise was predicted.

Figures 25 (a), (b), (c), (d) show that ticks would have overwintered at Toowoomba each year of the study, although some years were better than others. In particular, the winter of 1982 appeared to be quite harsh for ticks.

At Hermitage, overwintering appears to be quite marginal (figures 26 (a), (b), (c), (d)). Ticks did not overwinter during the winter of 1982 and the spring rise in the other years was very small.

Ticks overwintered successfully at Harrow (Figures 27 (a), (b)) but the spring rise was smaller than at Toowoomba. This was because of shorter larval survival times.

FIGURE 25 (A) SIMULATED OVERWINTERING OF CATTLE TICKS AT TOOWOOMBA DURING 1981.

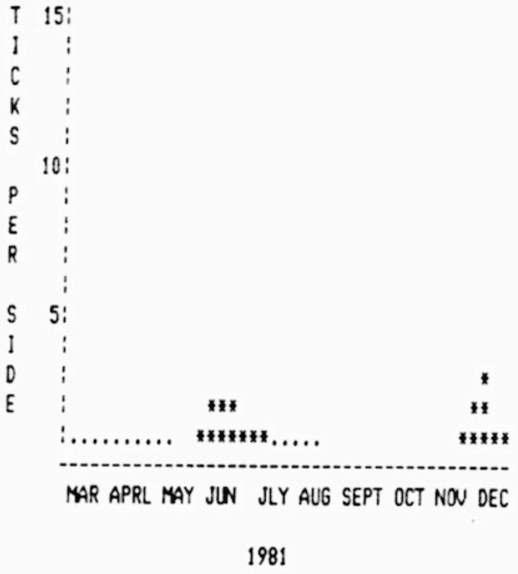


FIGURE 25 (B) SIMULATED OVERWINTERING OF CATTLE TICKS AT TOOWOOMBA DURING 1982.

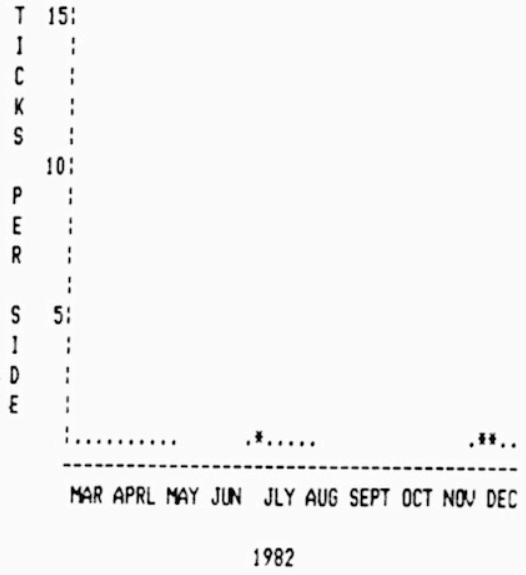


FIGURE 25 (C) SIMULATED OVERWINTERING OF CATTLE TICKS AT TOOWOOMBA DURING 1983.

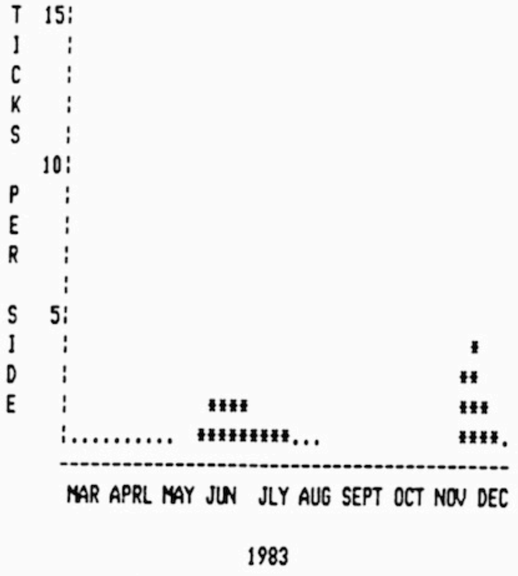


FIGURE 25 (D) SIMULATED OVERWINTERING OF CATTLE TICKS AT TOOWOOMBA DURING 1984.

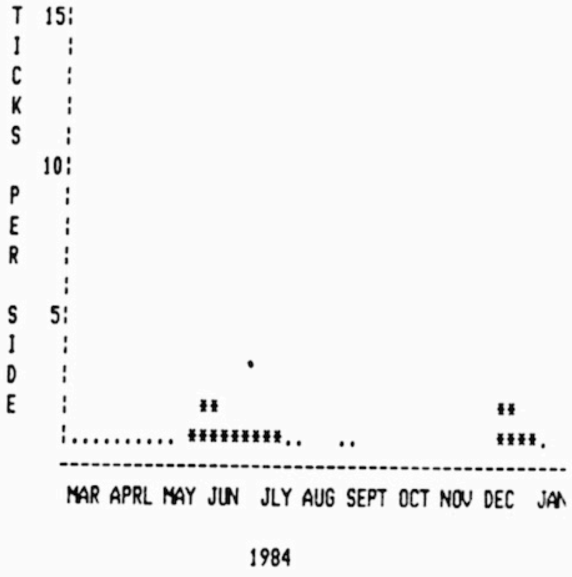


FIGURE 26 (A) SIMULATED OVERWINTERING OF CATTLE TICKS AT HERMITAGE DURING 1981.

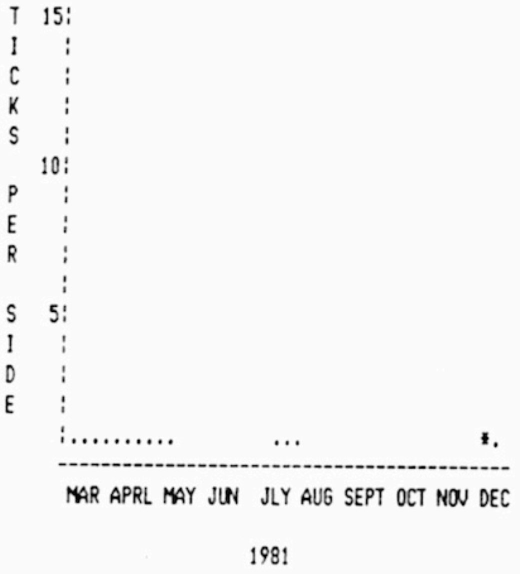


FIGURE 26 (B) SIMULATED OVERWINTERING OF CATTLE TICKS AT HERMITAGE DURING 1982.

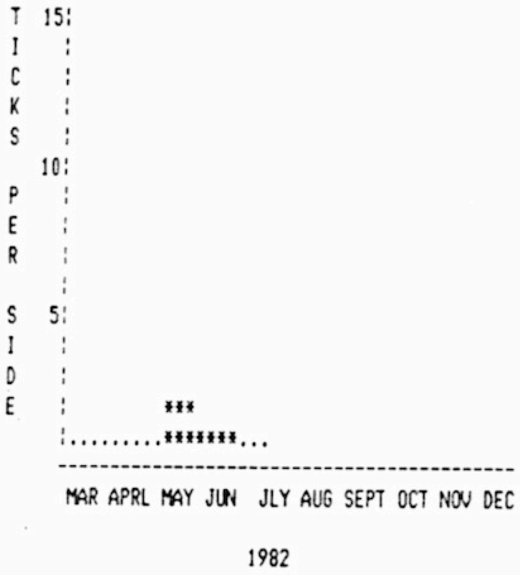


FIGURE 26 (C) SIMULATED OVERWINTERING OF CATTLE TICKS AT HERMITAGE DURING 1983.

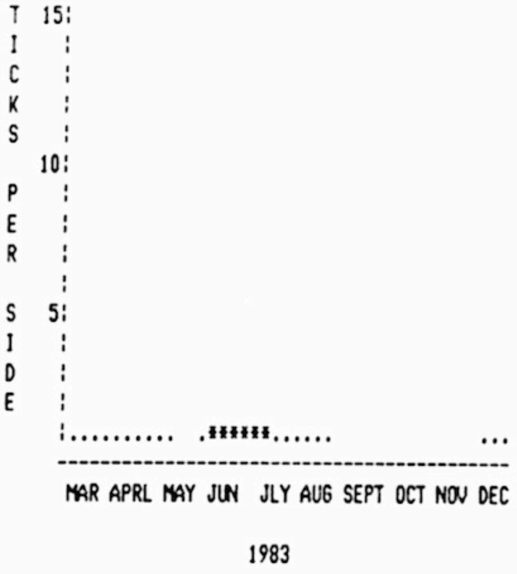


FIGURE 26 (D) SIMULATED OVERWINTERING OF CATTLE TICKS AT HERMITAGE DURING 1984.

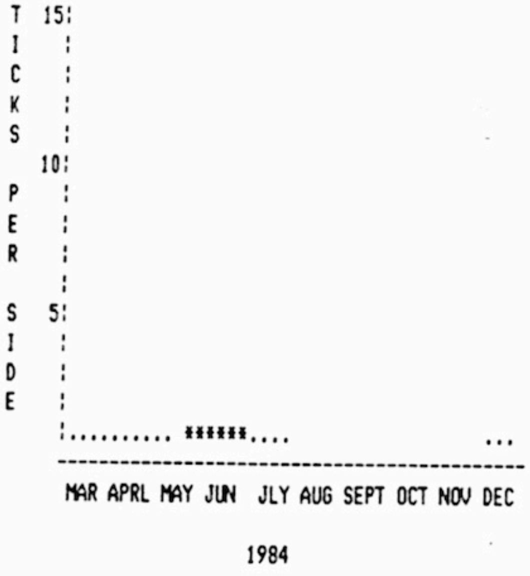


FIGURE 27 (A) SIMULATED OVERWINTERING OF CATTLE TICKS AT HARROW, CAMBOOYA DURING 1983.

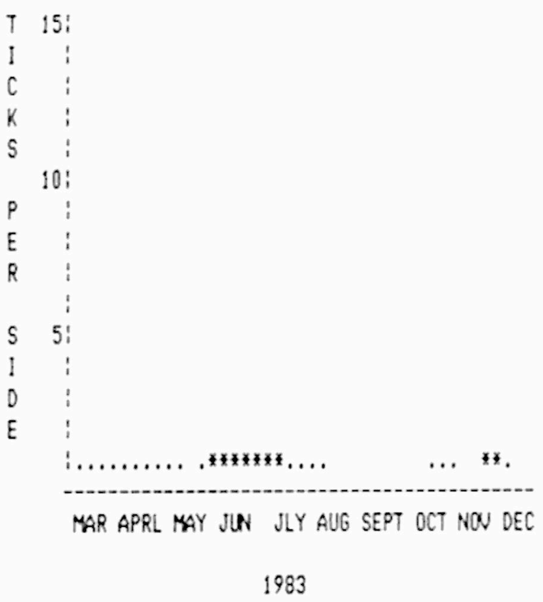
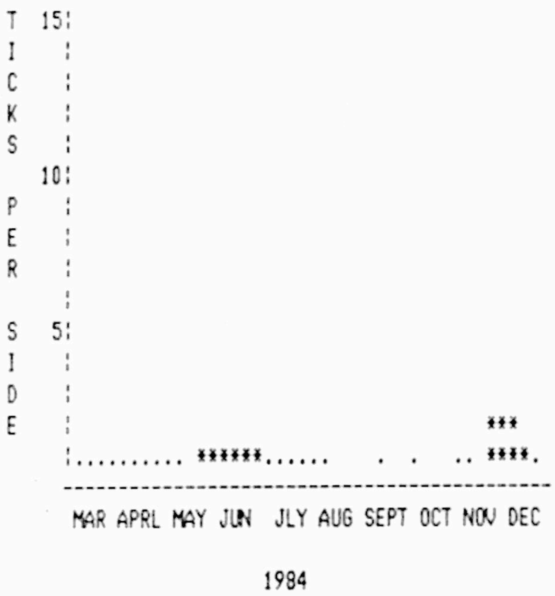


FIGURE 27 (B) SIMULATED OVERWINTERING OF CATTLE TICKS AT HARROW, CAMBOOYA DURING 1984.



To assess the stability of overwintering at these sites, the same simulations were run with larval survival times reduced by 50%. As expected, the size of the spring rise was reduced in all cases, but ticks were still able to survive the winter at Nanango, Harrow and Toowoomba (although only just at Toowoomba). At Hermitage, winter survival under these conditions was only possible in one of the four years of the study. This was in 1981 when the tick plot was at its' original, warmer site.

From these results it can be concluded that ticks will normally survive the winter quite easily on the eastern Darling Downs, provided some of the population are dropped in a reasonably favourable site e.g. an eastern slope. Colder microclimates e.g. low lying areas, southern slopes and shaded areas, are much more marginal.

5.3.5 Assessment of Summer Growth Potential

The potential for tick populations to build up over the summer propagation period was assessed using the model by specifying an initial small spring population of ticks (1 tick dropping/beast/ week during August) and then assessing the size of subsequent generations.

Of the sites studied, Toowoomba had the greatest potential for build up of tick populations (figures 28 (a), (b), (c)). If given the chance, very high populations are possible and this has been seen on occasion. Even during the dry summer of 1982/83, quite heavy infestations were possible.

Although not quite as conducive to tick propagation as Toowoomba, the Harrow site also showed considerable potential for populations to build up over the summer (see figures 29 (a), (b)). A major difference between the two sites was that four generations of ticks per year could occur at Harrow whereas only three were possible at Toowoomba. This was partly because of the shorter generation times at the warmer Harrow site and partly because of better tick propagation in the Autumn.

Populations were lower at Hermitage but significant build ups were still possible (see figures 30 (a), (b), (c)).

Four generations per year also occurred at Nanango (figure 31 (a)). The size of the build up was not great, but the summer of 1966/67 was apparently quite dry and I would expect propagation to be better in most years. Figure 31 (b) shows the sort of summer build up that could be expected theoretically in a good season.

FIGURE 28 (A) MODEL PREDICTIONS FOR NUMBERS OF TICKS ON CATTLE AT TOOWOOMBA STARTING WITH AN INITIAL POPULATON OF 1 TICK DROPPING/BEAST/WEEK FOR 4 WEEKS IN AUGUST 1981.

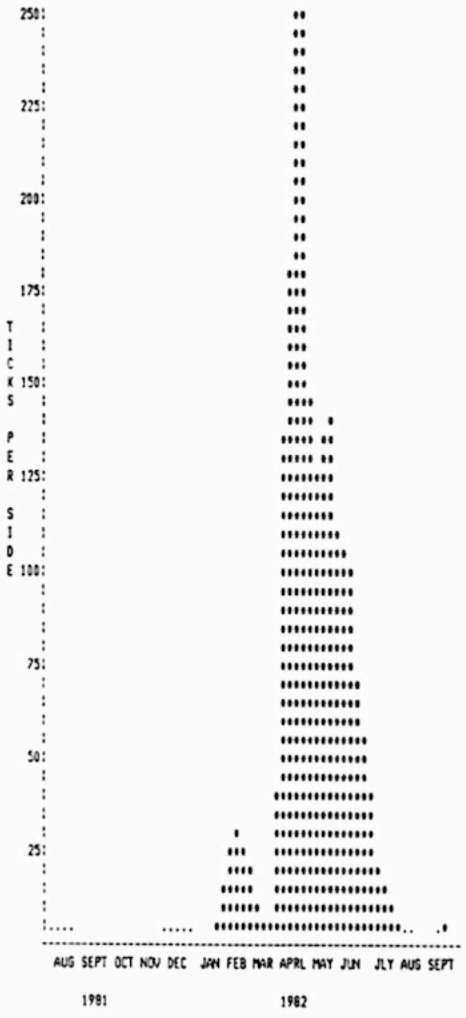


FIGURE 28 (B) MODEL PREDICTIONS FOR NUMBERS OF TICKS ON CATTLE AT TOOWOOMBA STARTING WITH AN INITIAL POPULATON OF 1 TICK DROPPING/BEAST/WEEK FOR 4 WEEKS IN AUGUST 1982.

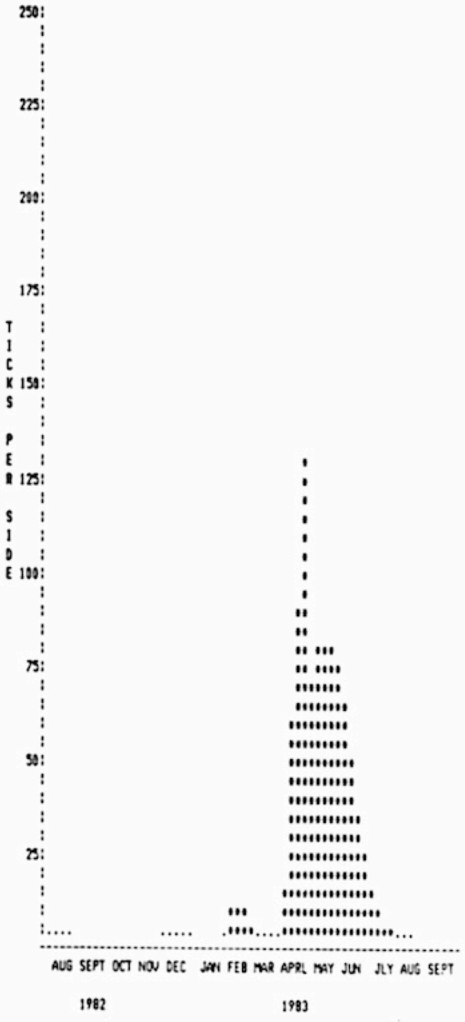


FIGURE 28 (C) MODEL PREDICTIONS FOR NUMBERS OF TICKS ON CATTLE AT TOOWOOMBA STARTING WITH AN INITIAL POPULATON OF 1 TICK DROPPING/BEAST/WEEK FOR 4 WEEKS IN AUGUST 1983.

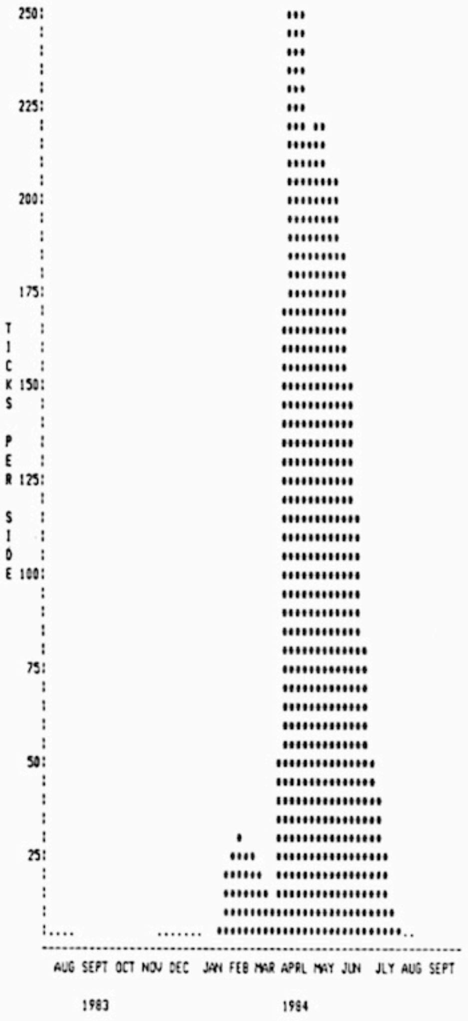


FIGURE 29 (A) MODEL PREDICTIONS FOR NUMBERS OF TICKS ON CATTLE AT HARROW STARTING WITH AN INITIAL POPULATON OF 1 TICK DROPPING/BEAST/WEEK FOR 4 WEEKS IN AUGUST 1982.

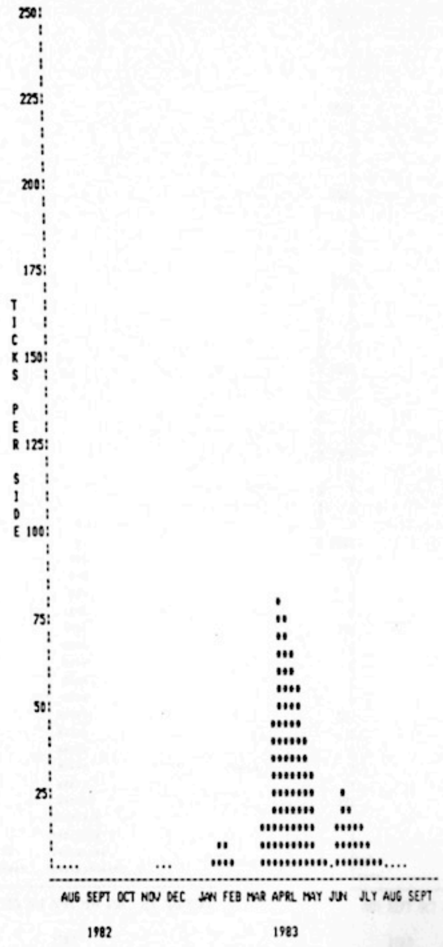


FIGURE 29 (B) MODEL PREDICTIONS FOR NUMBERS OF TICKS ON CATTLE AT HARROW STARTING WITH AN INITIAL POPULATON OF 1 TICK DROPPING/BEAST/WEEK FOR 4 WEEKS IN AUGUST 1983.

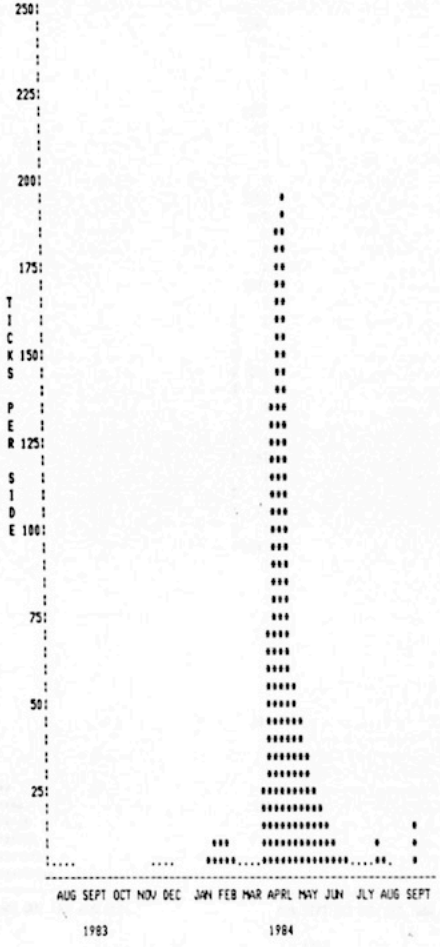


FIGURE 30 (A) MODEL PREDICTIONS FOR NUMBERS OF TICKS ON CATTLE AT HERMITAGE STARTING WITH AN INITIAL POPULATON OF 1 TICK DROPPING/BEAST/WEEK FOR 4 WEEKS IN AUGUST 1981.

FIGURE 30 (B) MODEL PREDICTIONS FOR NUMBERS OF TICKS ON CATTLE AT HERMITAGE STARTING WITH AN INITIAL POPULATON OF 1 TICK DROPPING/BEAST/WEEK FOR 4 WEEKS IN AUGUST 1982.

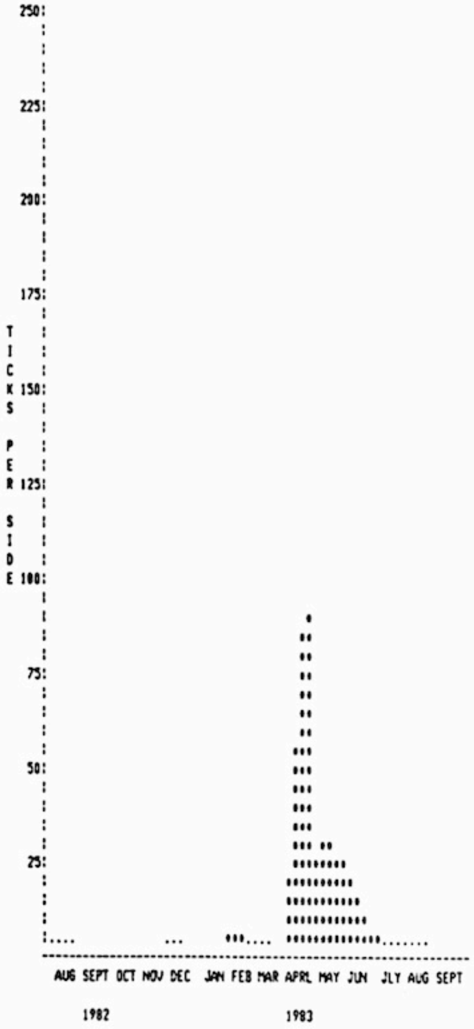


FIGURE 30 (C) MODEL PREDICTIONS FOR NUMBERS OF TICKS ON CATTLE AT HERMITAGE STARTING WITH AN INITIAL POPULATON OF 1 TICK DROPPING/BEAST/WEEK FOR 4 WEEKS IN AUGUST 1983.

FIGURE 31 (A) MODEL PREDICTIONS FOR NUMBERS OF TICKS ON CATTLE AT NANANGO STARTING WITH AN INITIAL POPULATON OF 1 TICK DROPPING/BEAST/WEEK FOR 4 WEEKS IN AUGUST 1966.

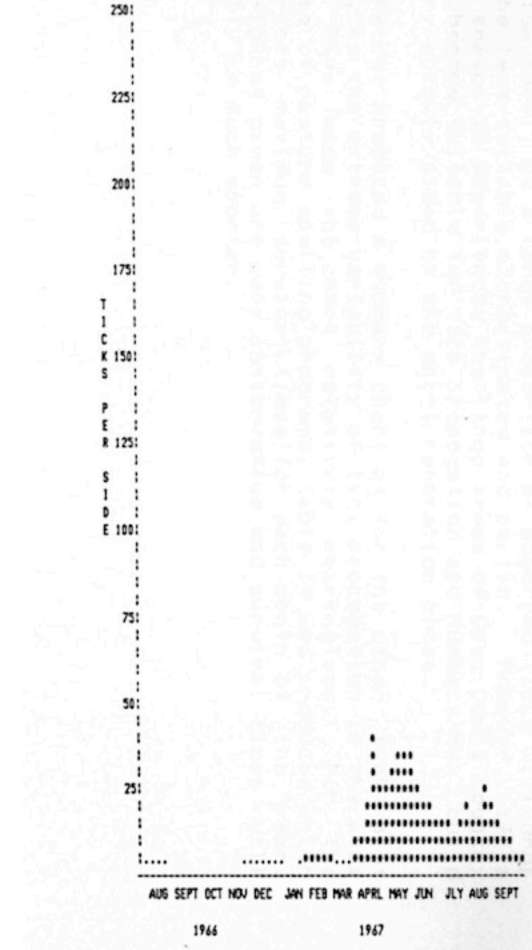
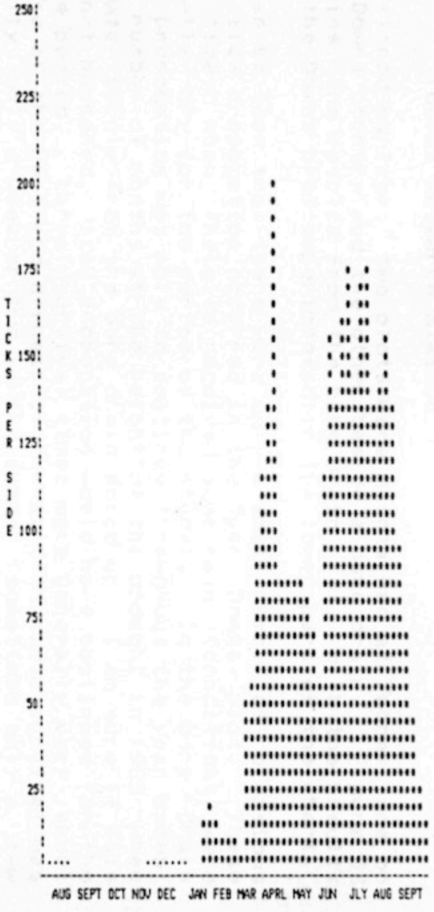


FIGURE 31 (B) MODEL PREDICTIONS FOR NUMBERS OF TICKS ON CATTLE AT NANANGO DURING A GOOD SEASON STARTING WITH AN INITIAL POPULATION OF 1 TICK DROPPING/BEAST/WEEK FOR 4 WEEKS IN AUGUST.



5.4 NORTH WEST TICK PLOT RESULTS

5.4.1 Toorak Research Station

As outlined earlier, two plots were maintained at Toorak, one on open Downs country and the other beside a bore drain. Figure 32 contains the results from the bore drain plot, with the results from the Downs plot superimposed in the lower part of the chart.

It can be seen that there were only a small number of occasions when tick propagation occurred in the Open Downs plot. These were times when the site received some rain (conditions were generally dry for the period of the study). In the bore drain plot, propagation was able to continue throughout the year except for a number of months at the height of the drought in 1983 when the water supply from the bore drain dried up. I am confident that if this had not happened, tick propagation would have continued for the entire period. Larval survival times were generally very short because of the heat and dryness of the air. Maximum survival was normally only a week or two in the summer (sometimes only a few days) and 1-2 months in the winter. Longer survival times were, measured when larvae were placed right next to water with a good grass cover.

From these results it can be concluded that under normal (dry) conditions, tick populations will not survive in this area unless they have access to moist microclimates such as along bore drains, around dams or marshes created by poorly managed bore drains. Under these conditions the tick population will remain at a low level, as a large proportion of engorged ticks will drop in the less suitable microclimates and perish. However, if a good season is experienced the large areas of Open Downs country will become suitable for tick propagation and numbers may build up very quickly aided by the short generation times.

I have not produced a summary chart as for the other tick plot sites, as the extreme variability of tick propagation in the area would have made the chart relatively meaningless. For the purpose of pasture spelling programs, table 14 was produced which summarises maximum survival times for each month of the year. The figures given are very conservative and survival times will normally be much shorter.

Figure 32. Tick Plot Results, Toorak Research Station, Julia Creek

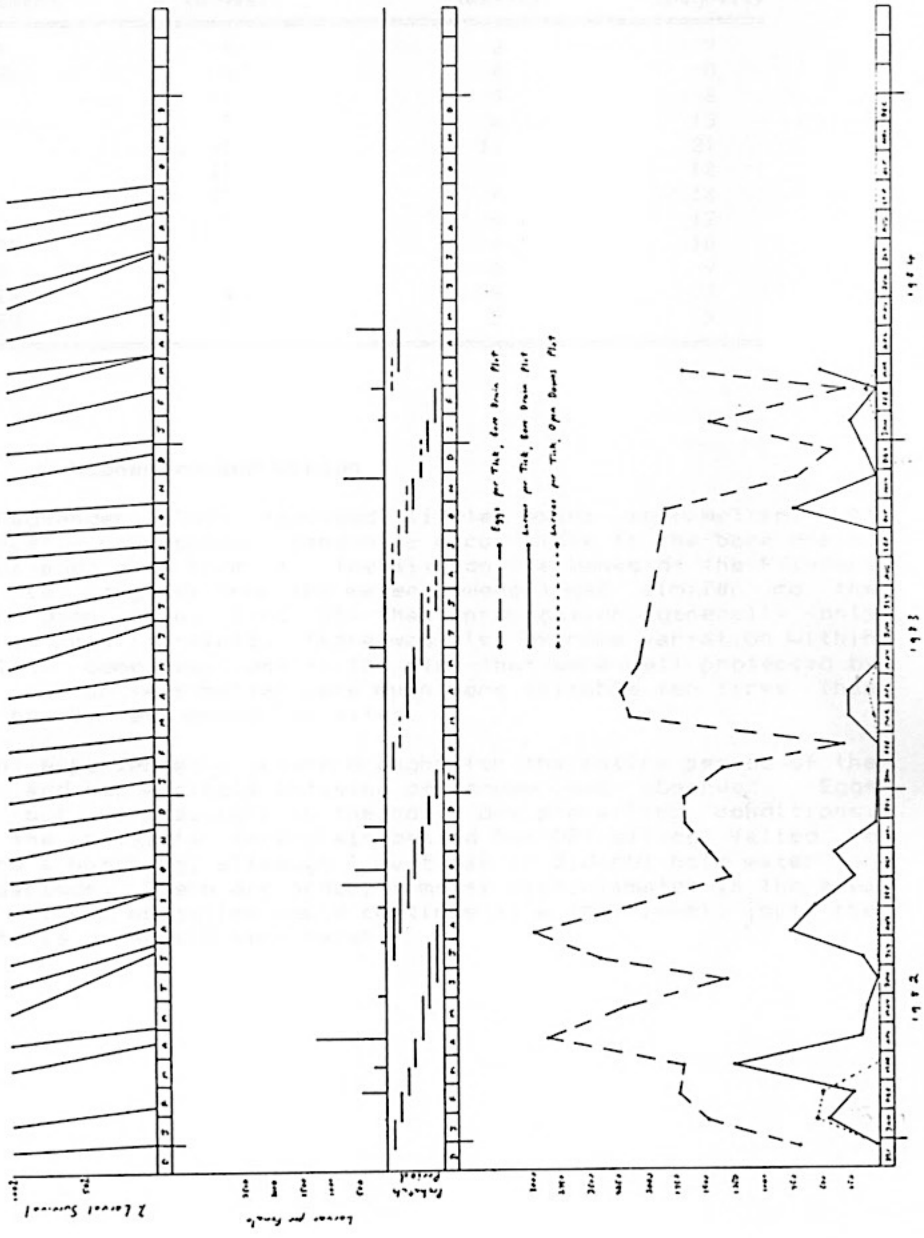


Table 14. Maximum Survival Times for Cattle Ticks at Toorak Research Station.

Month of Engorgement	Prehatch Period (weeks)	Larval Longevity (weeks)	Total Longevity
January	4	3	7
February	4	4	8
March	4	4	8
April	7	6	13
May	10	11	21
June	12	6	18
July	12	4	16
August	8	4	12
September	6	4	10
October	6	3	9
November	4	3	7
December	4	3	7

5.4.2 Hughenden and Winton

The Hughenden plots provided little extra information. At "Dunluce", propagation tended to occur close to the bore drain, but was poor away from it. The site on the banks of the Flinders river (a long way from the water however) was similar to the Toorak Open Downs plot in that propagation generally only occurred when it rained. There was also extreme variation within the plot. Some positions in the plot that were well protected by shade and/or leaf matter were much more suitable for ticks than other nearby less protected sites.

Winton experienced a severe drought for the entire period of the study and not a single hatching of larvae was observed. Eggs dried out very quickly in the hot, dry prevailing conditions. Even the artificial bore drain behind the DPI office failed to produce a hatching, although I must say it did not hold water for long periods. There are probably moist microclimates in the area where tick propagation could continue at a low level, but the climate is generally very harsh.

5.5 GENETIC ADAPTATION

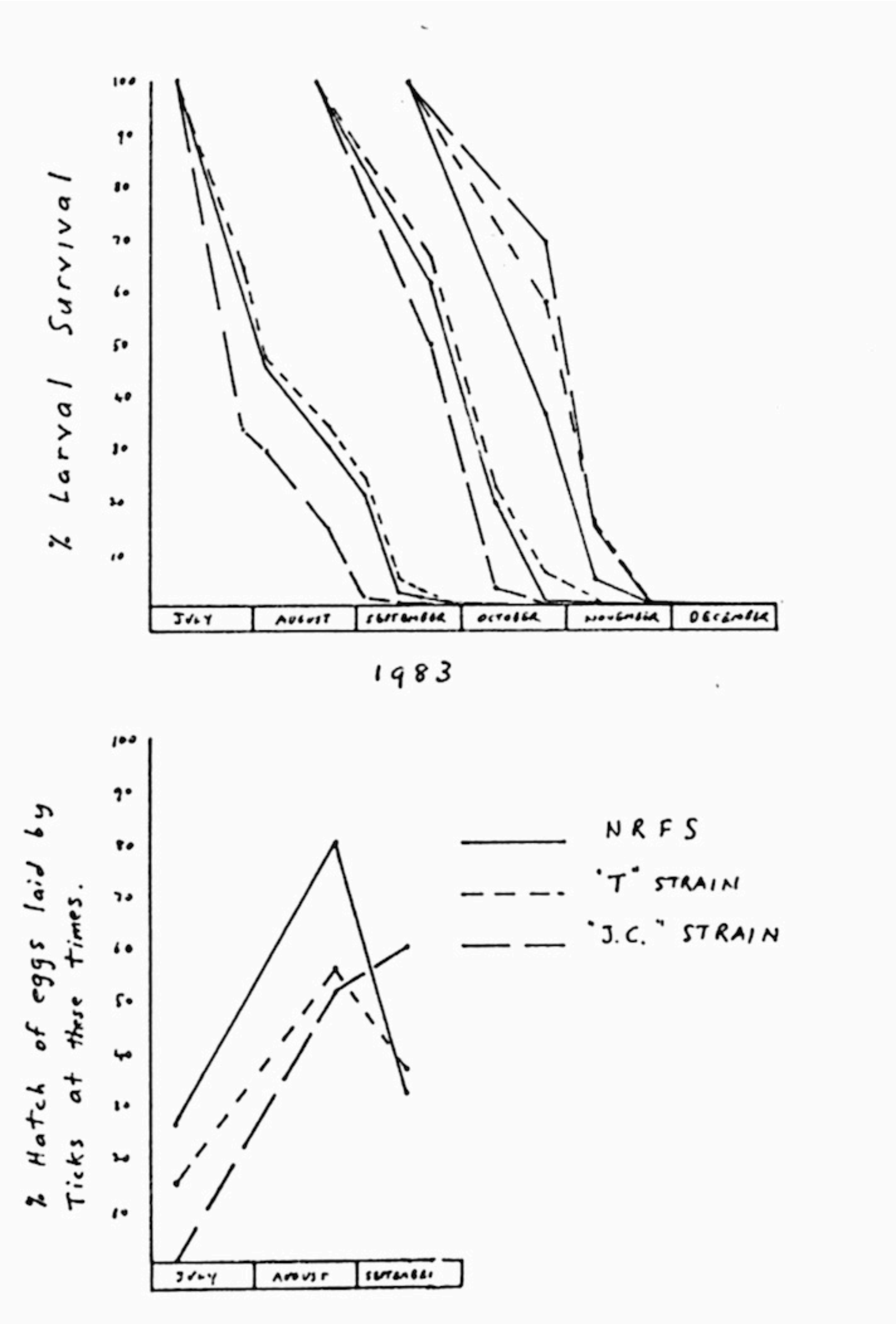
Most tick survival studies have been done using a limited number of laboratory reared strains of ticks. For example, the tick plot work in this study was done with the Non Resistant Field Strain (NRFS) which is maintained at ARI and was started from field collections a number of years ago. The question has often been asked - can ticks adapt to different climates? For example, if ticks are introduced to so called marginal country, can they adapt to the extent that the country would no longer be marginal. If so, all our studies would be irrelevant.

To study this problem, two new strains of ticks were established at ARI from field collections. Ticks were collected at Julia Creek to start the "J.C." strain and from the area south of Toowoomba to start the "T" strain. Work is now continuing to compare these two strains with the NRFS. Early results show some survival differences.

Figure 33 shows the results of engorged female and larval exposures done at Toowoomba in July, August and September of 1983. The most striking differences were seen in ticks exposed in July which is a marginal month for tick propagation at Toowoomba. Very few eggs laid by "J.C." strain ticks hatched, whereas the "T" strain and NRFS produced small but significant hatches. "J.C." larvae exposed at the same time also died off much quicker than the other two strains. This effect was evident to a lesser extent in the August exposure and did not occur in the September exposure. Similarly, strain differences in egg hatchability were not so evident in August or September. These results suggest that the "J.C." strain is not well adapted to cold conditions, but performs quite well when conditions warm up (it produced the highest percentage hatch in September).

Exposures at Julia Creek in October 1983 showed no significant differences. Laboratory studies are proceeding. The NRFS has performed well in comparison to the field strains in all studies done to date, so we can be reasonably confident that our tick plot results are valid. Much more work would be needed to determine whether the cattle tick is capable of further adaptation to adverse climates.

Figure 33. Comparison of Larval Production and Survival of Three Different Strains of Ticks at Toowoomba



5.6 MISCELLANEOUS FINDINGS

Except when conditions were very hot, normally very few larvae died during the first month of their life. They then started to die off at a steady rate depending on the prevailing conditions until only a small percentage were still alive. These last few larvae then tended to linger on for up to another month. The larval survival curves therefore took a typical sigmoid shape.

Frosts did not affect larval survival to any treat extent and survival was good even when frosts were experienced for a number of weeks. Under these conditions, larvae tended to go dormant overnight and were revived when conditions warmed up later in the day. One exception to this rule was the very cold week experienced in July 1984 when snow falls were recorded in Toowoomba. Temperatures were very low throughout the day and a strong wind was blowing. A large proportion of larvae in the field at this time succumbed to these cold conditions although a small number still survived.

A sudden onset of hot weather in the spring can also cause a sudden die off of larvae in the field, with larvae of various ages dying at about the same time. For example, at Toowoomba the long lived larvae from the May, June and July 1983 exposures all died in late September.

Eggs normally hatched best under reasonably moist conditions, but I also found that they did not like excessive moisture, which may waterlog and rot them. This is especially so in the marginal months of April and July. Presumably, excessive moisture also kept them cooler so that development was hindered. Egg development in these marginal months was very sensitive to small microclimatic changes e.g. long grass cover or shade significantly slowed down or stopped egg development.

6. CSIRO MODEL PREDICTIONS

A CSIRO group headed by Dr. Rob Sutherst at Long Pocket Laboratories have developed a computer model called Climex, which integrates weather data and our known information on tick survival to produce a climatic index for tick survival at specific locations. Figures 34 (a, b, c) show the Model indices for all the sites in Queensland where we have the required long term weather data.

Accompanying each location are two numbers.

1. The first is the **growth index** and refers to the potential for populations to build up over the growing season e.g. the summer in southern Queensland. The higher the figure, the greater the potential for heavy infestations to build up.
2. The second number is the **ecoclimatic index** which gives an assessment of potential survival from one season to the next. For example, on the Darling Downs it would refer to the ability of the tick to survive the winter while in the North West it would refer to the tick's ability to survive hot, dry periods.

As would be expected, the growth index is highest on the coast with a gradual westerly gradation until a very low growth potential is predicted for the far west. The important point is that the model predicts that significant build ups could occur in many areas west of the tick line if populations were present at the beginning of the growth season. The figures generally agree with tick plot results i.e. Toowoomba is more suitable than Cambooya, which is more suitable than Warwick. The growth indices are quite low in the Maxwelton special area, which agrees with the situation there where tick population sizes are generally small.

Ecoclimatic indices are also generally high in the tick infected area, with coastal centres being the most suitable for tick survival. On the Darling Downs, Warwick has a figure of 3 compared with 2 and 4 for Toowoomba and Cambooya respectively. This does not agree with the tick plot results where winter survival was worse at Hermitage than at Toowoomba. However, the Hermitage plots were on a cold, southerly slope and I am confident that winter survival would be much better in a more favourable site. Because of the tick plot results, I will assume that figures in the order of 2 to 4 indicate a climate that is stable in that ticks will normally survive the winter, but marginal in that they will only survive the winter in low numbers. Mt. Tamborine in the tick infected area also has an index of 4 and ticks survive the winter there quite well, although only in small numbers.

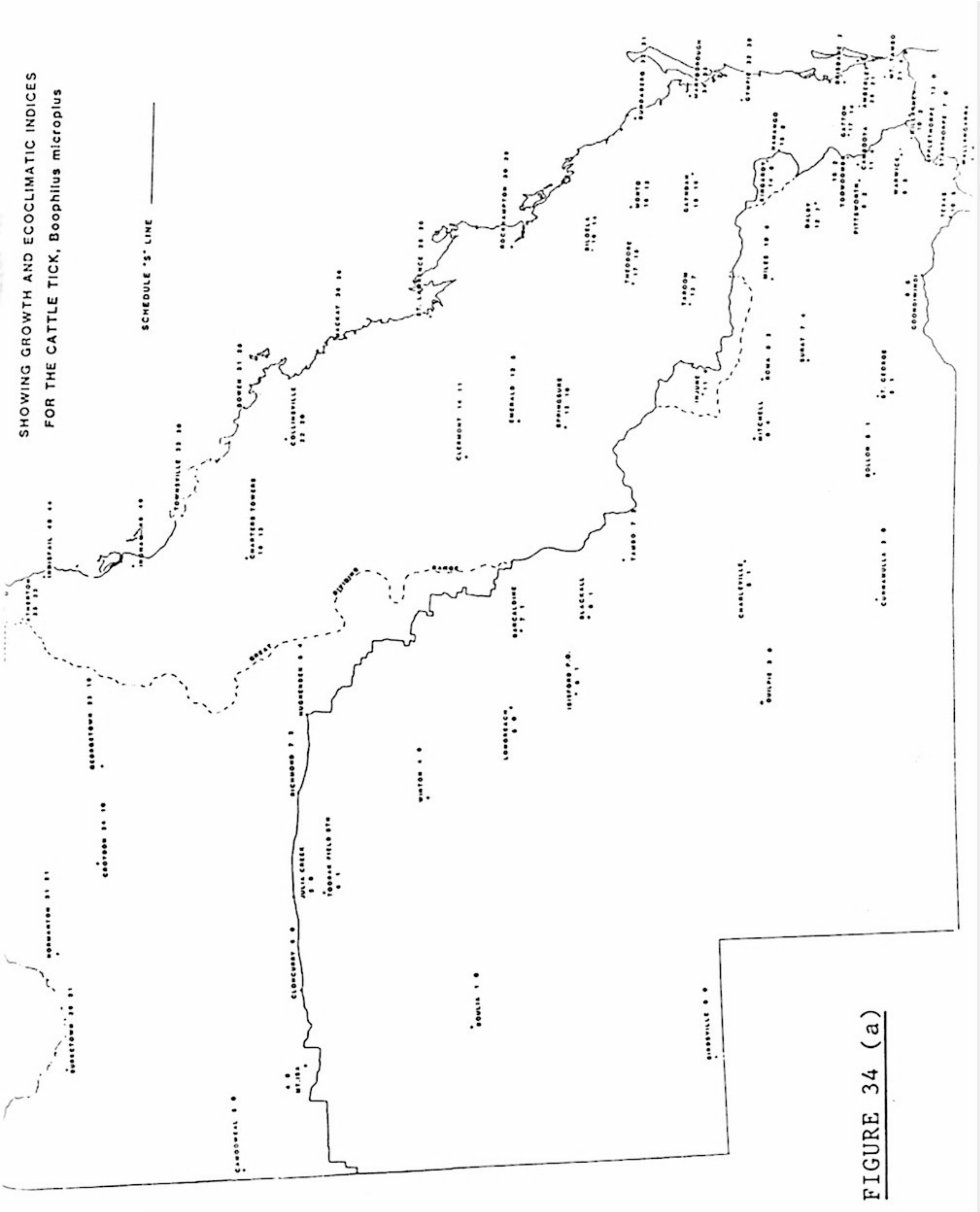


FIGURE 34 (a)

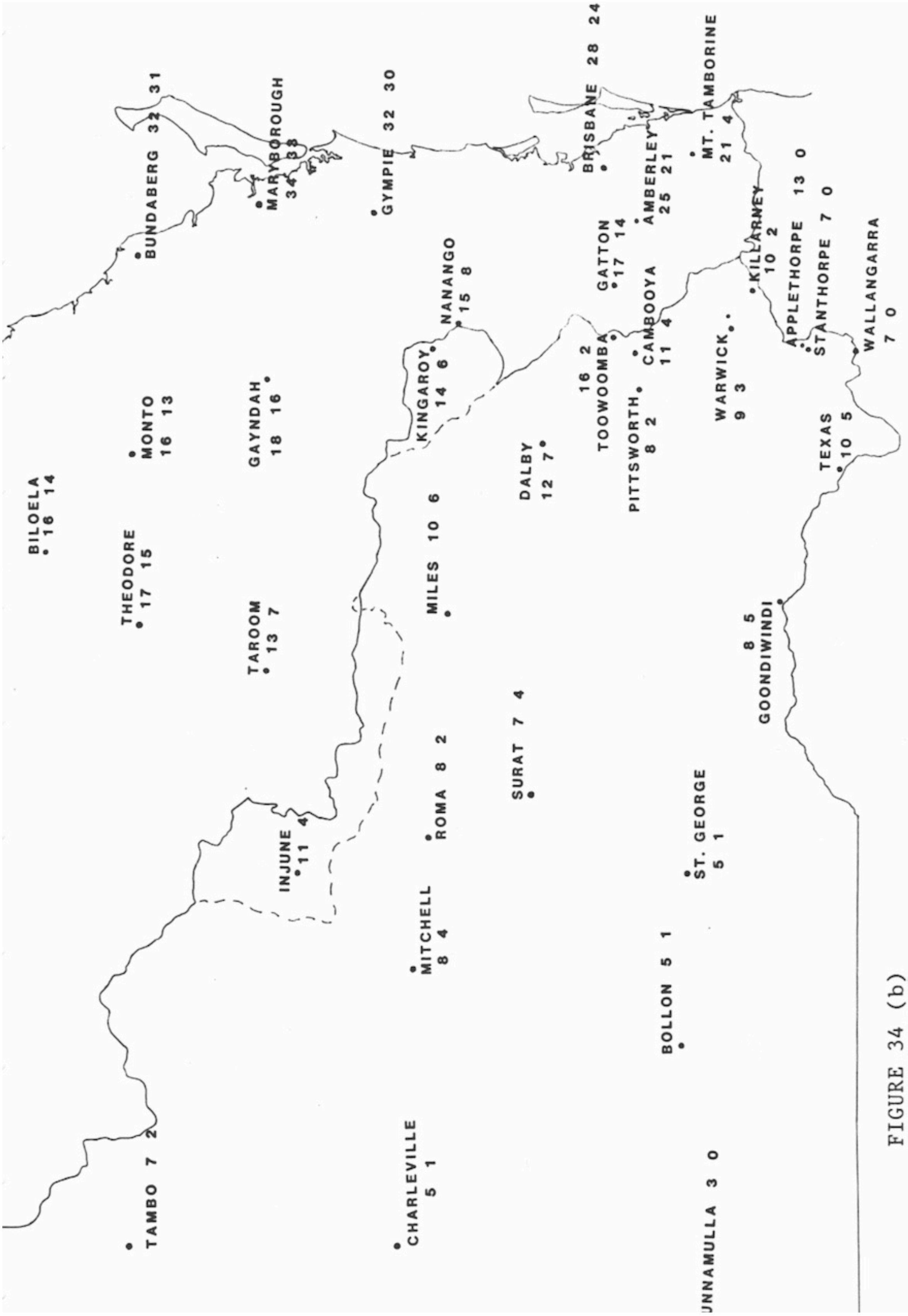

BILOELA 16 14
MONTO 16 13
BUNDABERG 32 31
MARYBOROUGH 34 33
GYMPIE 32 30
BRISBANE 28 24
MT. TAMBORINE 21 4
AMBERLEY 25 21
GATTON 17 14
NANANGO 15 8
KINGAROY 14 6
GAYNDAH 18 16
THEODORE 17 15
TAROOM 13 7
MILES 10 6
DALBY 12 7
TOOWOOMBA 16 2
CAMBOOYA 11 4
PITTSWORTH 8 2
WARWICK 9 3
KILLARNEY 10 2
APPLETHORPE 13 0
STANTHORPE 7 0
WALLANGARRA 7 0
TEXAS 10 5
GOONDIWINDI 8 5
SURAT 7 4
ROMA 8 2
INJUNE 11 4
ST. GEORGE 5 1
MITCHELL 8 4
BOLLON 5 1
CHARLEVILLE 5 1
TAMBO 7 2
UNNAMULLA 3 0

FIGURE 34 (b)

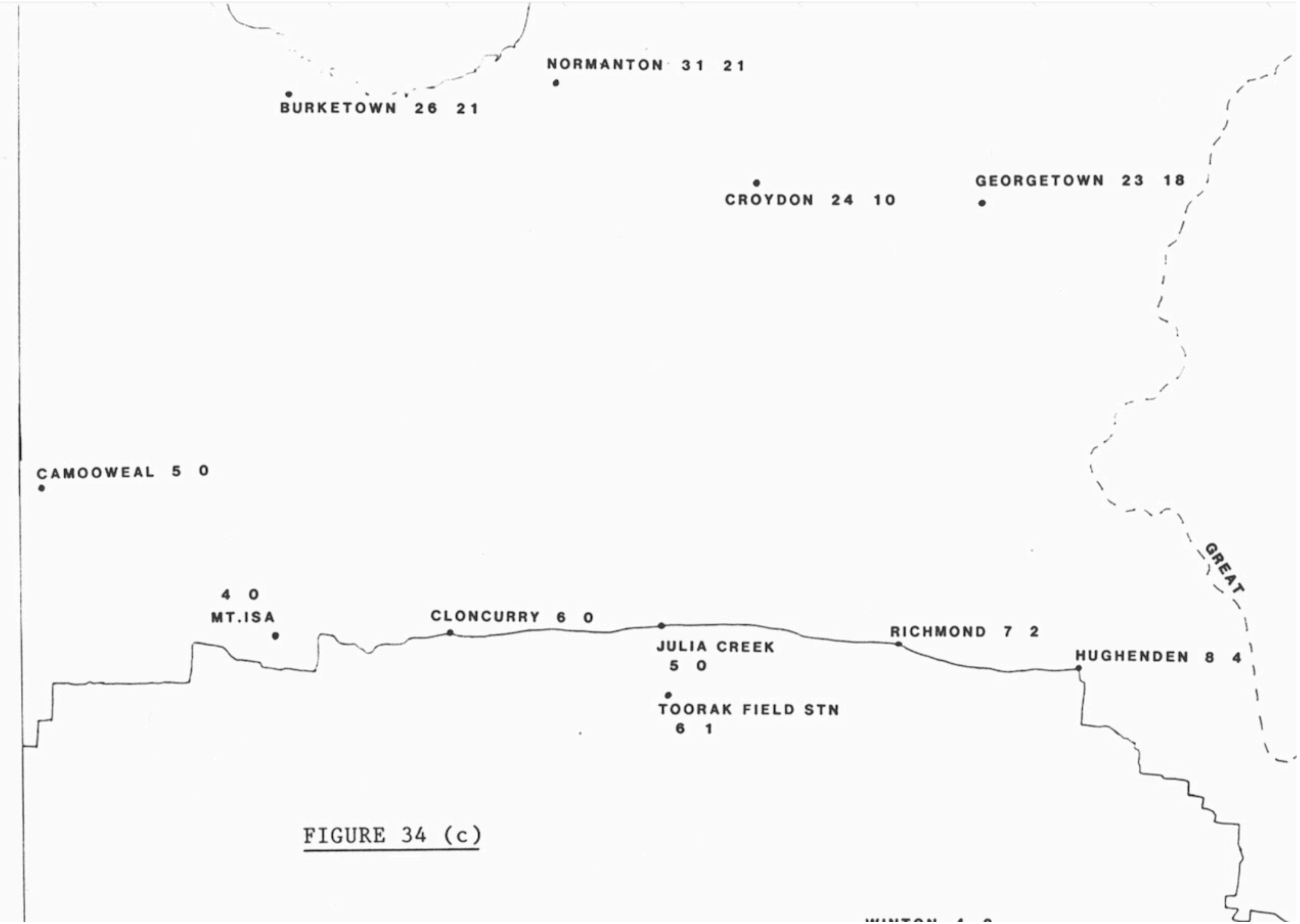

NORMANTON 31 21
BURKETOWN 26 21
CROYDON 24 10
GEORGETOWN 23 18
CAMOOWEAL 5 0
4 0
MT.ISA
CLONCURRY 6 0
JULIA CREEK
5 0
TOORAK FIELD STN
6 1
RICHMOND 7 2
HUGHENDEN 8 4
GREAT

FIGURE 34 (c)

The model predicts that ticks would survive the winter better at Dalby, Miles, Texas and Goondiwindi than at Toowoomba. Apart from the southern highlands, which have very cold winters, most of the Downs experiences warmer winters than the eastern section adjacent to the tick line and therefore winter survival should he more stable. Dalby has indices similar to Taroom which is well into the tick infested area and has a very stable climate for winter survival (see figure 23). This is supported by the Jones' case study in section 4.6 where ticks survived the winter in significant numbers on a property between Dalby and Chinchilla.

Although it is impossible to precisely define the potential limits of permanent tick infestation, the model predicts that ticks could survive permanently over a wide area of the Darling Downs. On purely climatic grounds, the potential infected area would extend at least as far west as a line running between Goondiwindi and Mitchell. Further west, conditions become too dry for permanent tick survival, although ticks could survive for extended periods given a good season. These predictions are supported by the historical evidence given in section 4.1.

Besides gross climatic influences, there are also a number of other factors that can affect tick microclimates and thus tick survival. The most important of these on the Downs are aspect as discussed earlier, ground cover and soil type. The latter two mainly affect moisture retention in tick microclimates, e.g. sandy soils and/or sparse ground cover would seriously affect tick survival in a climate that is already marginal. There are many such areas of harder country on the Downs which are unlikely to be suitable for tick survival, so the pattern of infestation would most likely be patchy. Lower stocking rates would also make the Darling Downs more marginal and contribute to the patchy distribution of infestations, as would the higher proportion of sheep grazing properties. However, the cattle tick can be highly tenacious, as evidenced by the case in section 4.6 where ticks cycled at Inglewood during a severe drought, so they should not be underestimated.

The model predicts, as do tick plot results, that the Kingaroy area is very favourable for tick survival and that the area would become heavily tick infested if controls were lifted. On climatic grounds the area should never have been included in the tick free area. We should certainly not support continued efforts at eradication in adjacent schedule "S" areas. On the Darling Downs proper, infestations would mostly be light, although some very heavy infestations are possible in good seasons. This occurrence would be more common on the eastern and north eastern Downs.

Predictions for the rest of the tick free area indicate that ticks will not be a permanent problem and this is supported by historical evidence. Outbreaks have occurred in the Blackall,

Isisford, Longreach etc. areas but they have been easily controlled. However, the situation is more complex in the Maxwelton special area. The climate is normally very harsh for ticks and this is reflected in the climatic indices but ticks still survive there, albeit in very low numbers at times. This is because the model does not take into account local microclimatic influences (e.g. bore drains) which make tick survival possible.

6.1 CONTROL OF INFESTATIONS

As discussed earlier, infestations on the Darling Downs are normally controlled quite easily, especially when very light infestations are found. Some of these very light infestations are even controlled with little or no treatment. This would be expected as the laws of chance are working against a very small population becoming established. However, if the population is given the chance to build up to large numbers, more stringent control programs must be used. As some farmers on the eastern Downs have found out, inefficient programs can result in uncontrolled tick populations.

Using the computer model described in section 5.2, different control strategies were tested to determine the most efficient program for eradicating ticks on the Downs. The base simulation used for these studies is shown in figure 35. The simulation starts with an infestation of two ticks dropping/beast/day for 10 weeks from the beginning of March 1983 and uses Harrow tick plot data. In this simulation, ticks were able to survive the winter through both egg and larval survival and a very large population of ticks were able to build up over the following year.

Figure 36 shows the effects of dipping during the May - August period when ticks are normally most prevalent and visible on cattle. Winter larval survival was prevented but eggs laid by ticks dropping in April were still able to survive the winter and quite heavy infestations resulted in the following year. Treating cattle in the March - April period would have prevented this, but it must be remembered that tick numbers on cattle are normally highest at this time of the year, so there is less chance that treatments will be 100% efficient. Nevertheless, on the southern Downs, when very light infestations are present, treating cattle during March - April would theoretically eradicate ticks or at least greatly reduce the size of the spring rise. However, this would only be successful at locations where no tick propagation occurs in May or June e.g. at Toowoomba or Warwick but not at Nanango.

Figure 37 shows that an efficient treatment program starting at about the time of the spring rise and continuing until late February will normally eradicate ticks. This is the shortest program conducted at any time of the year that has a chance of being successful. At this time of the year, tick numbers are very low, generation and larval survival times are at their shortest and there are no dormant eggs in the pasture. The success of any program depends on efficient treatments and figure 38 shows that even a small drop in efficiency can result in failure. This would be typical of the farmer who uses hand sprays to control his ticks. The obvious solution to this problem is to change to a more efficient treatment method e.g. Bayticol but if this is not possible, a longer treatment program may succeed. Figure 39 shows that commencing treatments in July should (but is not guaranteed to) eradicate ticks under these conditions. This is because the size of the spring rise is reduced, thus giving the summer program a greater chance of success.

Six treatments at three weekly intervals (or four treatments .at five weekly intervals with Bayticol) would be the minimum recommended regime for eradication during the summer period. Figure 40 shows that if larval survival times are prolonged, for example during a wet, mild summer, this program may fail, even with efficient treatments. However, one extra treatment should overcome, this problem.

In summary, I recommend that eradication programs on the Darling Downs should be based on a summer program of six, three weekly or four, five weekly (Bayticol) treatments starting in the first or second week of November. If a good season is experienced, an extra treatment should be added either at the beginning or the end of the program and if there is some doubt as to the efficiency of treatments, they should start in July and continue through to the end of February. If ticks are found in the Autumn, cattle should be treated during the March - April period but there is little point in treating after that.

If ticks were allowed to become widespread on the Downs, infestations would generally be lighter than in the present tick infested area although heavy infestations would develop at times. A few treatments in the November - January period would normally keep infestations at a very low level, so the economic effect of these infestations would be low (not taking into account possible outbreaks of tick fever). As with many infestations already seen on the Downs, many properties would require little or no control.

In the Maxwelton Special Area, generation and larval survival times are short and tick population sizes are generally low, so tick control should be relatively easy. However, the well known problems of incomplete and difficult musters and lack of facilities mean that this is not always so. Pasture rotation has been used as an adjunct to dipping programs and control of or access to specific microclimates could possibly be tried, e.g. improve management of bore drains, use troughs etc.

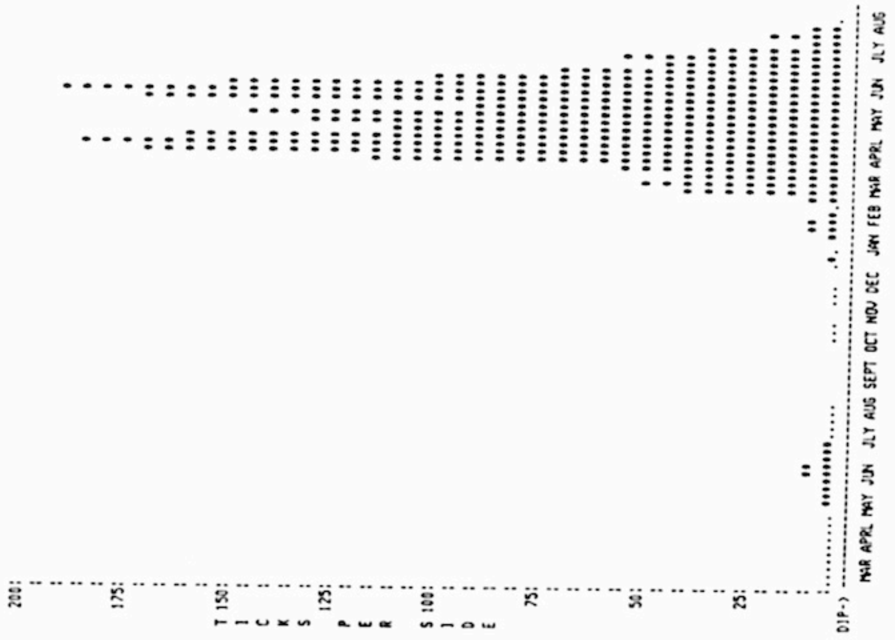


FIGURE 35 BASE SIMULATION USED FOR TESTING THE EFFICIENCY OF DIFFERENT ERADICATION STRATEGIES. SIMULATION STARTS WITH 2 TICKS DROPPING/BEAST/DAY FOR 10 WEEKS FROM THE BEGINNING OF MARCH 1983, USING HARROW TICK PLOT DATA.

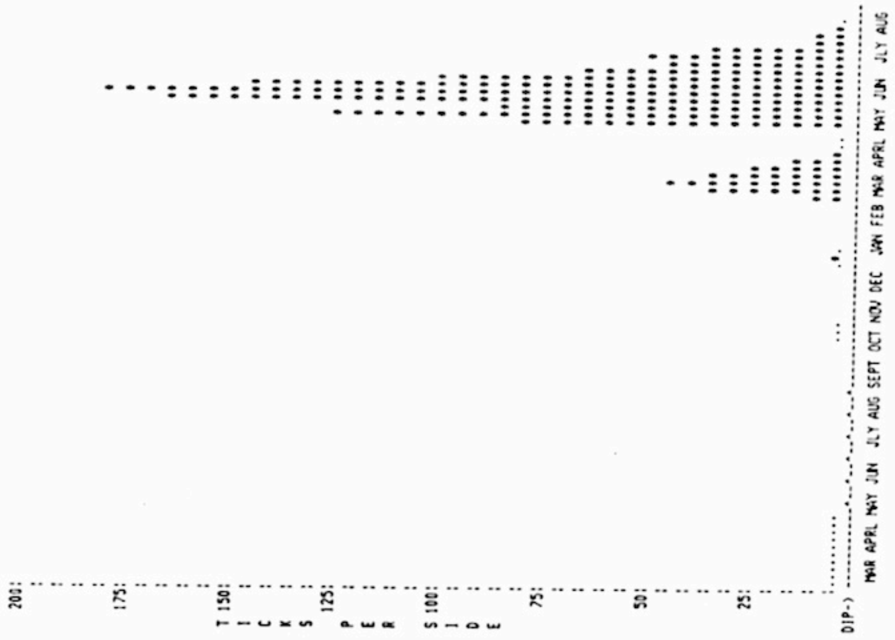


FIGURE 36 SIMULATION SHOWING THE EFFICIENCY OF ERADICATION BY TREATMENT DURING THE AUTUMN/WINTER WHEN TICK NUMBERS ARE GREATEST. TREATMENT EFFICIENCY = 99.8%.

FIGURE 37 SIMULATION SHOWING THE EFFICIENCY OF ERADICATION USING 6 TREATMENTS STARTING AT THE TIME OF THE SPRING RISE. EFFICIENCY OF TREATMENT = 99.8%.

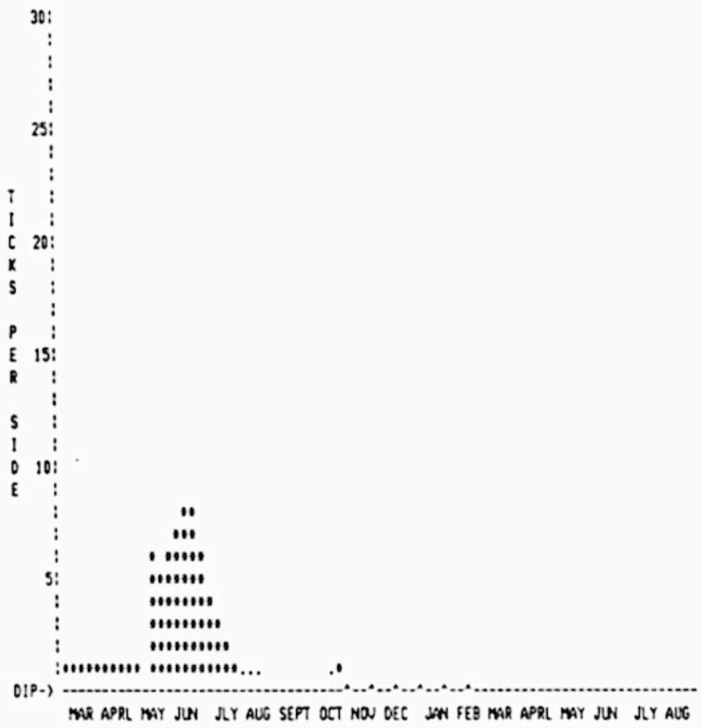


FIGURE 38 SIMULATION SHOWING THE EFFICIENCY OF ERADICATION USING 6 TREATMENTS STARTING AT THE TIME OF THE SPRING RISE. EFFICIENCY OF TREATMENT = 97.0%.

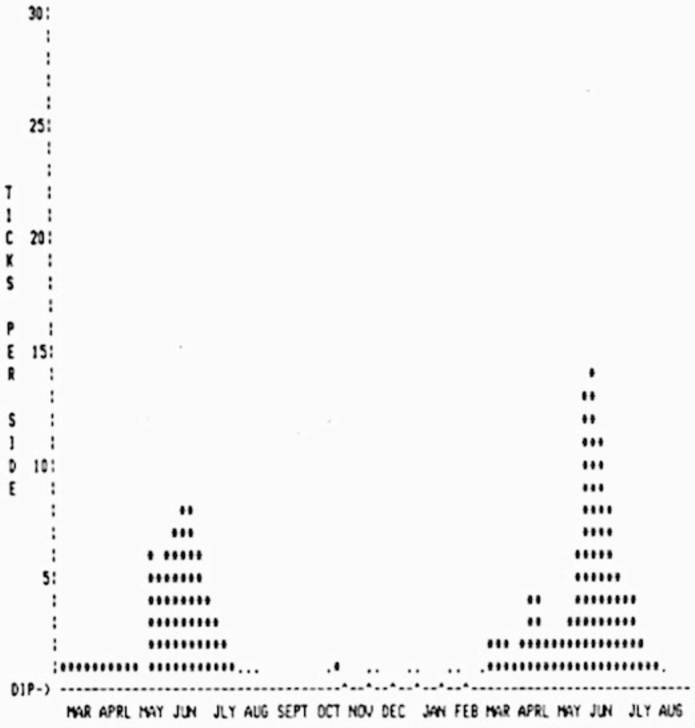


FIGURE 39 SIMULATION SHOWING THE EFFICIENCY OF ERADICATION USING INEFFICIENT TREATMENTS STARTING IN EARLY JULY. EFFICIENCY OF TREATMENT = 97.0%.

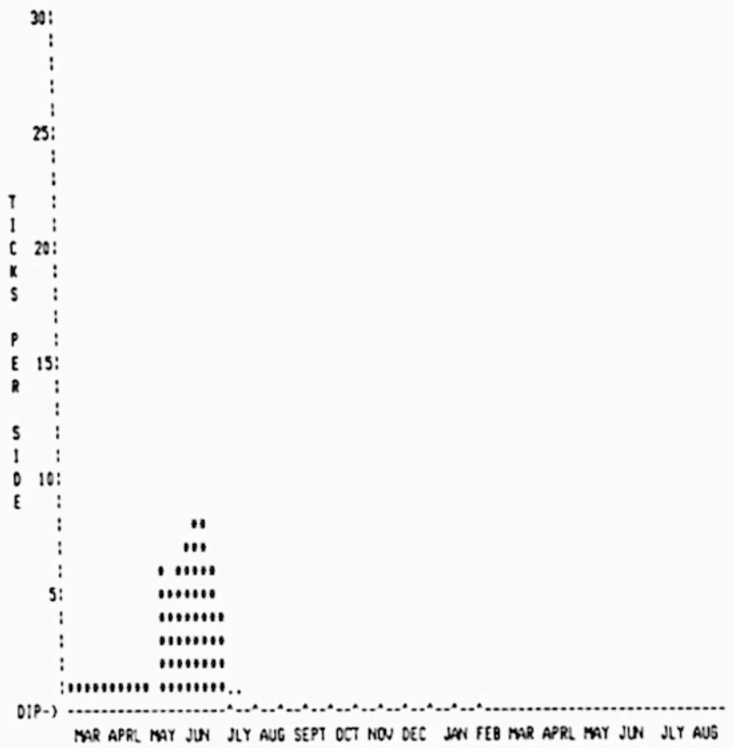
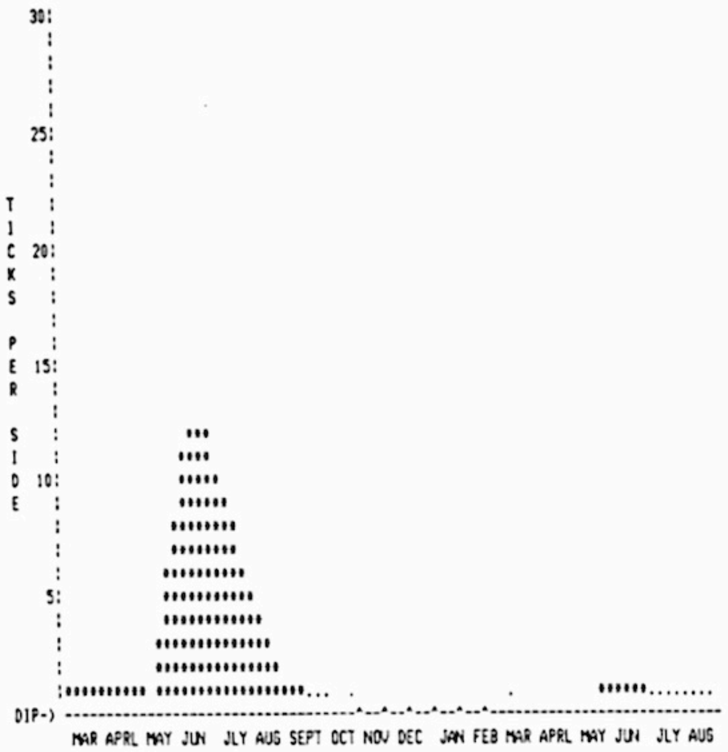


FIGURE 40 SIMULATION SHOWING THE EFFICIENCY OF ERADICATION USING 6 TREATMENTS STARTING AT THE TIME OF THE SPRING RISE IF LARVAL SURVIVAL TIMES ARE PROLONGED. TREATMENT EFFICIENCY = 100.0%.



7. SUMMARY OF CONCLUSIONS

(1) Large areas of the Darling Downs are suitable for tick survival and if controls were released, ticks could be expected to become established as least as far west as Goondiwindi and Mitchell.

(2) If this did occur, infestations would be patchy in distribution and generally light although heavy infestations could be expected on the Eastern and North Eastern Downs and in other areas in good years.

(3) Control of infestations would not be difficult, provided facilities were available.

(4) The economic effect of infestations would not generally be great although precautions against tick fever would have to be taken as the area would be enzootically unstable for tick fever.

(5) For the rest of Queensland, the tick line is positioned at about the limit of climatic suitability for ticks. However, it must be remembered that ticks will cycle just about anywhere in Queensland for limited periods during a favourable season.

(6) Tick survival is marginal in the Maxwelton Special Area but is made possible by small, moist microclimates (e.g. bore drains, dams etc.)

(7) Tick control in this area should be relatively easy provided adequate facilities are available and cattle can be controlled.

(8) When no buffer occurs between infested and clean areas, an overflow of infestations is likely to occur, especially in more intensive areas. Tick dispersal occurs at a low rate throughout the state associated with cattle movements and in the more intensive areas from other mechanical methods beyond our control (e.g. possibly wind).

(9) This overflow of infestations has occurred in the fringe areas of the eastern Darling Downs and in some of these areas infestations have become established, especially to the south of Toowoomba.

(10) Infestations in these areas would be fairly easily eradicated with a properly planned program but reinfestation is likely. However, infestations could certainly be kept at a much lower level than at present, as a large proportion of new infestations arise from infestations already present in the area. Owner apathy is the main problem here.

(11) The Kingaroy area is climatically very suitable for ticks and probably should never have been included in the tick free area. If the tick line was altered to follow the Great Dividing Range, the area would become tick infested. It is likely that dispersal of ticks to the north eastern Downs would increase as a consequence of this and there would be a higher incidence of tick outbreaks in this area.

(12) If the tick line was moved to the west in the Toowoomba - Warwick area, ticks would spread to the west with it. It is difficult to predict the level of dispersal to the area west of the new tick line but it would certainly occur, probably at a level less than occurs at present.

(13) Ticks in the Upper Warrego Special Area should be eradicable and recent changes to National Parks in the area should lessen the risk of reinfestation.

8. GENERAL DISCUSSION

This study has allowed us to define with a reasonable level of accuracy the epidemiological and ecological limits of cattle tick infestations in Queensland. We now know that to maintain the current tick free area, our present system of movement requirements is necessary. We can no longer give credence to the often heard statement "they would be there now if they could live there". In fact, they have been there before and had to be eradicated. However, it is also evident that if ticks were allowed to spread into the tick free area, they would not normally be an economically important disease, especially with modern control methods.

Therefore, when reviewing the position of the tick line, we must first make the major decision as to whether we need a tick line at all. Disregarding political considerations and interstate movement requirements, there is little economic reason for maintaining a tick line. Very few properties would experience heavy infestations, but for those that would, the availability of pour-on acaricides has largely eliminated the problem of lack of facilities. The main danger is that the area would be enzootically unstable for tick fever, which may necessitate widespread vaccination of stock.

Unfortunately, epidemiological considerations alone do not and will not determine whether we will keep the tick line. We must accept that, in the foreseeable future, industry and producer pressure will ensure that we keep the tick line. When considering the position of the tick line we have three options.

(1) Major Movement of the Tick Line

If the line was moved to include all the country that could support tick infestations, it would have to be moved somewhere west of Goondiwindi and Mitchell. However, there would be no practical reason for doing this, as the line could be easily maintained far to the east of here. If a major movement of the line was contemplated, a more practical move would be to the vicinity of the current "T" line. Compared with the current position of the line, infestations in the new "S" would be much lighter which, combined with the more extensive grazing systems, would mean that the rate of tick dispersal would be much lower. The line would therefore be much more easily maintained.

(2) Move the "S" Line to Include the Current Problem Areas

From an ecological point of view, the Kingaroy stock district and to a lesser extent, the area south of Toowoomba should be included in the tick infected area. The logical position of the new boundaries would be the Great Dividing Range in the Kingaroy area and the New England Highway in the Toowoomba area. The Warwick area presents a problem as there is no natural boundary that defines the endemic areas close to the Range. In this area there is a large tract of clean country between the infested area and the Highway.

However, from an epidemiological point of view, the picture is not as clear cut. If the line was moved, ticks would certainly move with it and these areas would become endemic. The relatively clean areas to the west already experience regular tick outbreaks and I consider that the incidence of these would increase if the line was moved. We may in fact just move our problem areas, although I doubt that they would be as bad. The rate of dispersal to these new areas would not be as great, although once introduced, ticks could survive quite well.

There is no real case for moving the line in the Maxwelton Special Area, especially if cattle movements are brought under control with the fence currently being built.

(3) Leave the Line in its Present Position

Leaving the line where it is would be the easiest course to take and there are some strong arguments in favour of doing this. The position of the line is well defined and well known. Moving the line any distance. would certainly disrupt established marketing practices and would mean that many properties that have never experienced tick infestations would suddenly find themselves classed as tick infested. Moving the line a short distance to include those areas that are currently causing problems may also only partially solve the problem as we may find that we still have a similar problem but further west.

Being realistic, I feel that producer pressure will ensure that this option is adopted. If this is done, then we should review our currently used methods of control. Over the years, grazier (and DPI) attitudes to the problem have become blasé and I am sure that properly planned programs where everyone participated would eradicate current infestations. Reinfestations will occur, but their number and size should remain low. This would eliminate the current problem where a large proportion of new infestations arise from within the area. The advent of pour - on acaricides with long residual periods could help overcome the problem of grazier complacency.

We should also rethink our "eradication" mentality and possibly formalise an already existing informal classification where we have part of the "tick free" area recognised as endemic for ticks with our main aim being to keep infestations at a low level so that they do not pose a threat to neighbouring clean country. These areas could be deregulated to the extent that properties with low rates of infestation are allowed relatively free movement. This already happens to a certain extent in the Toowoomba area. The important point is that a buffer be maintained between infected and clean country. Including these areas in "S" would mean that control of infestations would be lost. We already have "clean S" areas, so perhaps we could call these areas "dirty T". This system would be workable if narrow tracts of country such as south of Toowoomba were involved, but could become unwieldy if large areas such as the whole Kingaroy stock district were included.

In my opinion, if a line is to be maintained, then it should stay in its current position, with deregulation of the current problem areas so that they are maintained as buffer areas. A policy based on this concept is currently being developed by a team of District Inspectors of Stock within Veterinary Services Branch. The proposal involves establishment of buffer areas along the tick line in south east Queensland. Cattle will be treated on entry to or exit from the area, but there will be no compulsory treatment within the area. Graziers who keep their cattle free of ticks will be given movement concessions.

Using a well planned extension program, we should attempt to introduce the widespread use of planned treatment programs in these areas. The release of an effective pour-on acaricide means that such a program is now much more likely to succeed. Treatment facilities on most properties in these areas are poor and it is difficult to maintain enthusiasm with a program based on hand spraying. If these practices were widely adopted, I am sure the problem would largely disappear.

If major deregulation is envisaged, the tick line should be abandoned altogether.

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11. APPENDIX: DESCRIPTION OF THE TICK PLOT BASED CATTLE TICK POPULATION MODEL

Note – this is an abridged version of what was provided in the original report.

A. GENERAL

This Cattle Tick Population Model uses data from tick plots to predict numbers of ticks on cattle and pasture once the initial population characteristics have been specified. The predicted numbers are for an average cow of the type specified at the beginning of the simulation. At the beginning of each simulation, the user initial Tick Population on the cattle and/or on model then predicts the numbers of Ticks subsequent week for a specified length of time. Data from any of a number of Tick Plots can be specified to run the model and thus simulate tick populations in different climatic areas.

Once a realistic simulation has been achieved for the chosen area, any combination of the following management tools can be tested:

- Treatment with acaricide
- Pasture rotation (between two paddocks)
- Resistant cattle

The model runs in either of Two Modes. In the first mode, the paddocks are assumed to be uniform for tick propagation, whereas in the second mode each paddock may have two different Microclimates of variable size and favourability to ticks. This is particularly useful when studying tick populations in areas such as the hot North - West of the state where tick propagation is generally poor, but areas such as along bore drains exist which are favourable to ticks.

A simple economic analysis can be obtained for each management strategy simulated by the model.

B. Parameters in Initial Conditions List

MODE 1: When using 1 microclimate/paddock

Label 1. Year of Start of Run.

Label 2. Week of Start of Run.

These specify when the simulation run is to start. The week refers to the week of the year. A list of which months each week refers to is displayed when changing parameter 2. The simulation must start somewhere between the start -and end of the chosen tick plot data.

Label 3. Length of Run.

Determines the length of the simulation. eg. if the length of run = 50, the model will predict the numbers of ticks on cattle and pasture each week for 50 weeks from the starting week.

Label 4. Initial Infestation on Cattle.

You may specify the number of engorged female ticks/side/day dropping from cattle for the first 1 to 10 weeks of the run. Note that a value of less than 1 can be entered eg. 0.15 ticks/side/day = approx. 1 tick/side/week.

Label 5. Initial Hatch in Paddock 1.

You may set up an initial infestation of larvae on pasture by specifying the number of larvae/beast hatching in the first week of the run. Label 5 refers to paddock 1.

Label 6. Initial Hatch in Paddock 2.

Same as label 5 except refers to paddock 2.

Label 7. Summer Host Finding Rate.

Host finding rate is the rate at which larvae on pasture attach to a host eg. a host finding rate of 0.25 means that 25% of larvae on the pasture attach to a host per week. This would be a typical figure for a stocking rate of 1 beast/2 ha. (Sutherst et al. 1978, Sutherst et al. 1979).

Label 8. Winter Host Finding Rate.

Larvae are less active in winter and therefore attach to a host less readily. At the above stocking rate, a typical figure would be 0.10. The winter HFR is used if the preoviposition period for that week is > 1. If this data is not available, the winter HFR operates between weeks 14 and 39. The host finding rate is also halved for the first week after larval hatching.

Label 9. RB: Breed Dependent Host Resistance Factor.

The percentage of larvae attaching to a host that mature as engorged females(yield) is dependent on a number of factors; the main ones being breed, season, nutrition and the actual number of larvae attaching(the larger the number attaching, the smaller the % yield). The number of larvae maturing is described by the function:

$$(RB)*L^{(1-B)}$$

where: RB depends on the breed of the animal
L is the number of larvae attaching and
B depends on the season and nutrition of the animal.

You can alter the value of RB to simulate the use of cattle with different levels of tick resistance. Typical values are 0.25 for European cattle and 0.08 for Zebu - Cross cattle. (Sutherst et al. 1973, Sutherst, Utech, Kerr and Wharton 1979, Sutherst et al 1983).

Label 10. Correction Factors.

Correction for Prehatch Conditions. Normally have this operating when using data from TOOWOOMBA, HERMITAGE, HARROW, OR TOORAK. This is because laboratory reared larvae were used to obtain larval survival rates at these sites. These are not influenced by variable prehatch conditions as experienced in the field. We have no hard data on the relationship between the prehatch period and subsequent larval mortality, so an intuitive one was developed which reduces larval survival times progressively when the prehatch period exceeds 6 weeks.

Extra Larval Mortality. Overall larval mortality can be increased by from 0 to 100%. This is normally set at about 20% when using data from the above tick plots. This is necessary because this survival data was obtained from larvae held in gauze cylinders. Survival times under these conditions are generally greater than for larvae free on grass (see section 5.1).

Female Wastage. Mortality of engorged females before laying can be increased by 0 to 100%. In tick plots, female ticks normally have the maximum possible chance of laying eggs, given the prevailing conditions. In the paddock, some ticks fail to find a suitable site for laying, some fall victim to predators etc. Normal wastage is in the order of 40% (Sutherst pers com.).

Label 11. Treatment Protection Period and Efficiency.

This can be set at any number of weeks (A treatment that killed all the ticks on the cattle at the time of treatment but had no residual protection would have a protection period of 3 weeks).

The protection period and/or the efficiency of dipping may be altered to any desired value (e.g. an efficiency of 95% means that 95% of ticks on the cattle are prevented from maturing). You can specify a separate efficiency for each of the weeks of the protection period or the same efficiency for each week.

If you wish to simulate the effects of incomplete musters, this can only be done by altering the efficiency of dipping.

Label 12. Dippings.

You may specify any number of Planned dippinos or alter the timing of any dippings that have already been specified. For each dipping you must enter the week and year when they are to occur (Dipping is assumed to occur at the beginning of the week).

You may also elect to adopt an Unplanned dipping policy. This may take the form of:

Threshold Dipping where you must specify the number of engorged ticks/side tolerated before dipping is applied (Dipping is assumed to occur half way through the week). or:

Optional Dipping where you are given the option of dipping the cattle at the end of each week during the simulation.

Label 13. Pasture Rotations.

Cattle can move at any time from one paddock to another. Cattle are assumed to start in paddock 1. You may specify any number of rotations that you wish to take place and then for each of these, specify the week and year when they are to occur and the paddock the cattle are to move to. You may also change the timing of rotations that have already been specified.

MODE 2: When using 2 microclimates/paddock

Labels 1-4	As in mode 1.
Labels 5-8	As in labels 5 & 6, Mode 1, except the initial infestation of larvae can be specified for each microclimate in each paddock.
Labels 9-12	As in labels 7 & 8, Mode 1, except separate host finding rates can be specified for each microclimate.
Label 13	As in label 9, Mode 1.
Label 14	As in label 1O,Mode 1.
Label 15	You can specify the percentage of engorged ticks that drop in each microclimate in each paddock.
Label 16-18	As in labels 11-13, Mode 1.

C. Economic Analysis

If an economic analysis of the simulation is required, you will be asked the price per Kg. of beef, the cost of acaricide (if dippings occurred) and the cost of mustering(if dippings and/or pasture rotations occurred). The model determines the lost production from ticks on the basis of 1400 ticks producing a production loss of 1 Kg liveweight and then presents a table of costs of lost production and the costs of the management strategy used (Sutherst, Norton, Barlow, Conway, Birley and Comins 1979).

The model does not take into account the different growth rates of different breeds of cattle.

d. Model Validation

Data from a CSIRO run tick plot at Mt. Tamborine was used to validate the model. Tick counts on a small herd of cattle run in a paddock next to the tick plot were available to compare with predictions made by the model (Sutherst, 1983). Simulations were made by specifying an early spring population (August-September) the same as that measured on the cattle and then letting the model predict the size of subsequent generations. Figures 41 (a) & (b) show the actual counts made on the cattle during 1971/72 and the models' predictions. Figures 42 (a) & (b) show the same data for 1972/73.

Although some details are different, the overall patterns are very similar. In particular, the model accurately predicted the difference in tick population sizes between the two years.

FIGURE 41 (b)
SIMULATED TICK COUNTS ON EUROPEAN CATTLE AT MT. TAMBORINE, 1971/72

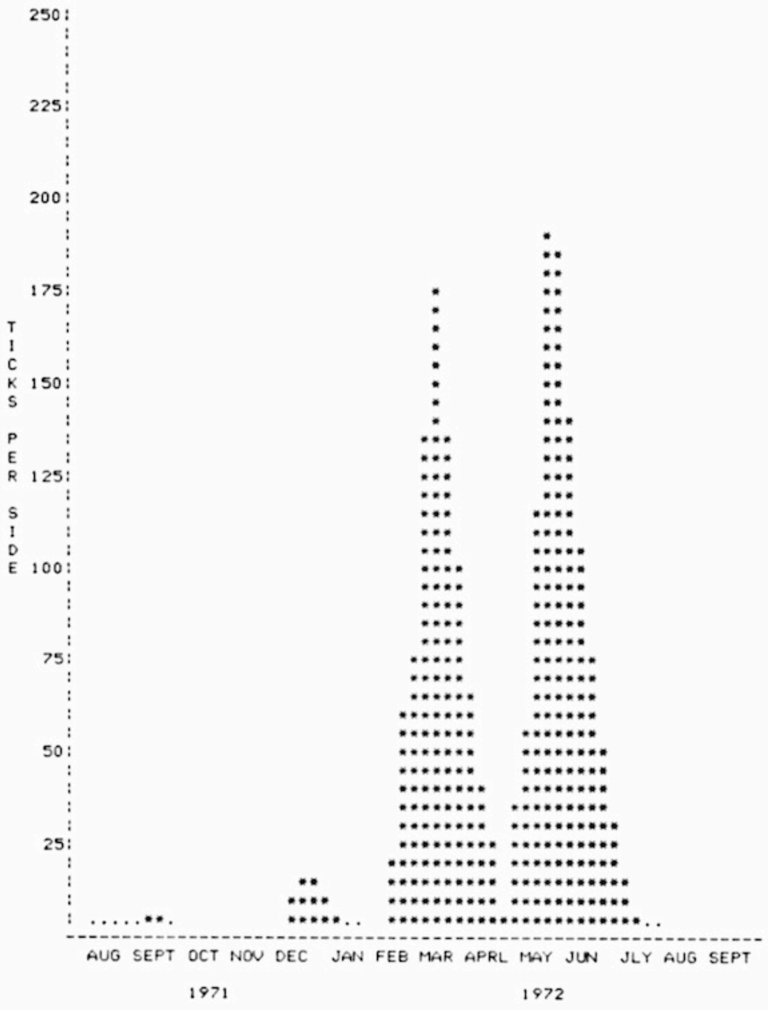

FIGURE 41 (a)
TICK COUNTS ON EUROPEAN BREED CATTLE AT MT. TAMBORINE DURING 1971/72

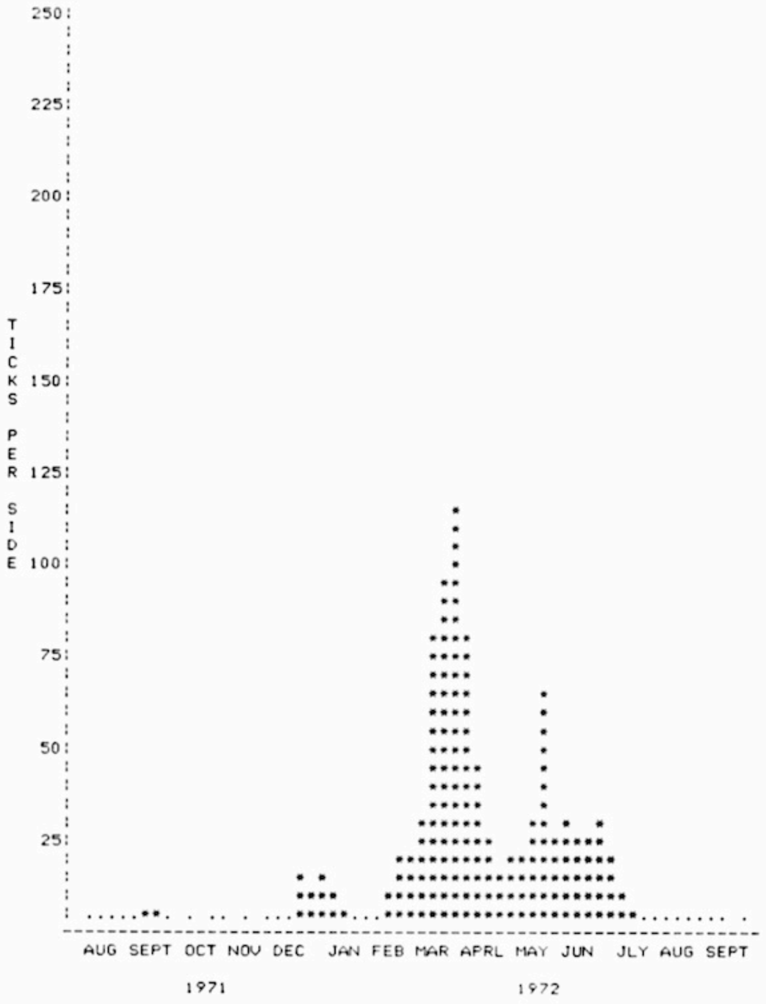

FIGURE 42 (a)

TICK COUNTS ON EUROPEAN CATTLE AT MT. TAMBORINE DURING 1972/73

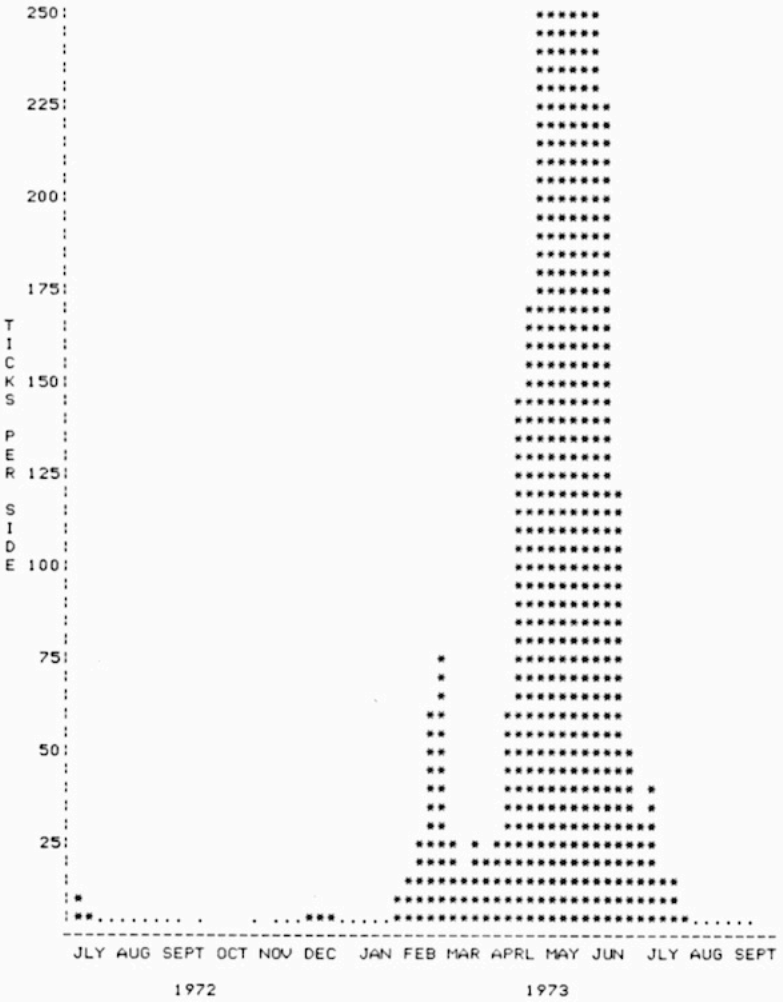

FIGURE 42 (B)

SIMULATED TICK COUNTS ON EUROPEAN CATTLE AT MT. TAMBORINE, 1972/73