Assessment of the Pest Status of Leucaena Psyllid in Northern and South Eastern Queensland

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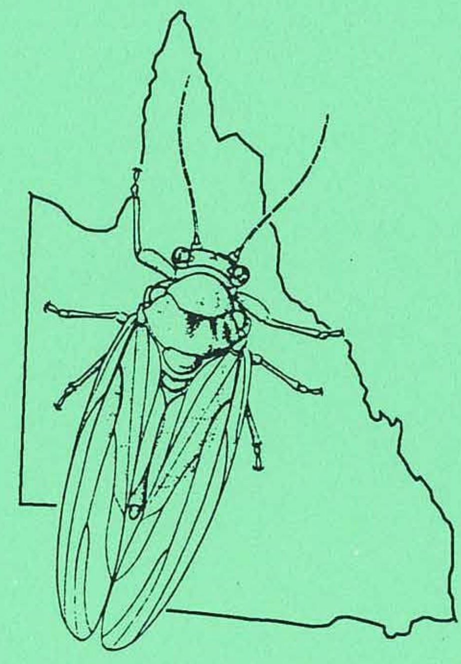

CSIRO AUSTRALIA

FINAL REPORT
to the
MEAT RESEARCH CORPORATION

CONTENTS

FINAL REPORT TO THE MEAT RESEARCH CORPORATION

Project Title:	Assessment of the Pest Status of Leucaena Psyllid in Northern and South Eastern Queensland.
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PART 1

(i) SUMMARY

(A) Objectives

To measure the seasonal abundance and damaging effects of the leucaena psyllid *Heteropsylla cubana* on growth of the tree legume *Leucaena leucocephala* near Townsville and Brisbane and to estimate losses that might occur to cattle production at each site.

(B) Methodology

Research was conducted on leucaena grown at three sites near Townsville and four near Brisbane. Automatic weather stations recorded temperature, sunshine and rainfall at each site. Two treatments, (i) not protected from psyllids, and (ii) protected from psyllids by insecticide, were replicated three times at each site. Psyllid abundance and severity of damage were rated weekly and new growth by leucaena was measured, dried and weighed once a month. The damaging effects of the psyllid were measured by comparing the growth of protected and unprotected leucaena.

(C) Significant Results

Rainfall was unusually low throughout this study, with the exception of flooding rains at Townsville in January and February 1991. This was reflected in little growth of leucaena and low numbers of psyllids at all sites except one which was irrigated and another near a creek. Loss of dry weight accumulation caused by psyllids varied from 3% at the site where leucaena grew least to 75% at the second most productive site.

(D) Significant Conclusions

The productivity of leucaena was affected strongly by temperature and the availability of water. Maximum growth followed good rainfall in summer. The abundance of leucaena psyllid was partly dependent on the presence of new foliage. Infestations are most likely to peak following rain-triggered growth of leucaena in summer and infestations are likely to be minimal during a dry spring. This pattern may be obscured on irrigated or otherwise well-watered leucaena or by migration of the pest from well-watered leucaena onto rain-grown plants. The effects of the

psyllid on leucaena can range from negligible when the insect is scarce to fatal when it is very abundant. It is unclear whether the greatest impact on beef production would come from a small negative effect of the psyllid on leucaena which is growing slowly at times when alternative feed is also likely to be scarce, or a large negative effect on leucaena which is growing vigorously when alternative feed is likely to be abundant.

(ii) Recommendations

(A) Research and Development

In the absence of viable biological or chemical control methods, there is a need for basic information on what conditions lead to changes in psyllid numbers in order to find a weak spot which might be exploited to control the pest. Laboratory studies of psyllid biology and life-table studies of the dynamics of the insect in the field are needed.

(B) Practical Use of Results

Graziers should be advised that when leucaena starts growing rapidly, damaging populations of psyllids are likely to build up soon after, especially in more temperate climates. If practical, the leucaena should be monitored in mid- to late-summer and, as soon as psyllid numbers increase, cattle should be turned into the paddock to remove new growth before the psyllids do.

(C) Commercial Exploitation of Results

The results of this project should be used in further developing the grazing industry's strategy for responding to the psyllid. To do this, the results need to be integrated with other information, such as the economics of replacing leucaena with alternative fodder species. The options open to the industry appear to be:

i) Accept that the psyllid will cause significant reductions in growth by leucaena and decide whether to promote additional plantings.

ii) Support basic research into the biology and ecology of the psyllid with a view to solving the problem through better understanding of psyllid dynamics.

iii) Continue to support research into psyllid-resistant varieties of leucaena with a view to replacing susceptible varieties in existing and/or new plantings.

iv) Combine one or all of options i) to iii) with investigations of manipulation of grazing intensity to optimise leucaena growth and its consumption by cattle rather than psyllids.

v) Explore alternative fodder species.

PART 2

(i) Background to the project

Leucaena is a leguminous tree from central America that is used in Australia as a high protein forage crop for beef cattle in tropical and sub-tropical areas. QDPI estimated the area of leucaena as 4,000 ha in 1985, 30,000 ha in 1988, and suggested that 1.8 million ha may be planted by 1998 out of 6 million ha of suitable land. On average, cattle gain weight twice as fast on a leucaena pasture as on the next most productive Siratro pasture (R.M. Jones and R.A. Bray, personel communication), four to eight times as fast on leucaena as on buffel grass (Elder, personal communication) and twice as fast as on black spear grass (Quirk *et al.*, 1990).

The leucaena psyllid, which sucks juices from leucaena leaves and stems, spread from its native central America to Hawaii in 1984 and to other Pacific islands, Australia, PNG, Indonesia and SE Asia by 1986. Since then it has continued to extend its range westwards. In all the countries it has invaded, the psyllid has caused widespread defoliation and the death of some leucaena trees.

In a short study at two sites, Palmer *et al.* (1989) found that the psyllid reduced growth by leucaena by 55%. A CAB study (Heydon and Alfonso, 1991) predicted cumulative losses in beef production due to psyllid damage to leucaena to be $121 million by 1998 at the then current rate of planting, plus major opportunity losses if the rate of planting should be reduced due to the psyllid. The MRC commissioned the present CSIRO project to obtain more accurate assessments of losses due to the psyllid. This project had research sites near Brisbane and Townsville, and a complementary QDPI project had sites near Rockhampton. QDPI will report separately on that project in which prolonged drought resulted in very low populations of psyllids, little growth by leucaena, and little useful information (Elder, personal communication).

(ii) Objectives of the project

To measure the seasonal abundance and damaging effects of the leucaena psyllid *Heteropsylla cubana* on growth of the tree legume *Leucaena leucocephala* near Townsville and Brisbane and to estimate losses that might occur to cattle production at each site.

(iii) Methodology of the project

Sites

Inspections were made of leucaena stands growing near Brisbane and Townsville. Two areas near each city were selected on the basis of differing climate and soil type which were expected to be reflected in variation in growth by leucaena. Experimental sites were chosen in consultation with property owners on the basis of the size/age of leucaena, all-weather access, and availability for three years of experimentation. Two experimental sites were selected for comparison with one another in each area, except for the area most distant from Townsville where only one site could be visited regularly. In the QDPI component of this study, four sites were selected on an east-west/decreasing-rainfall transect from near Rockhampton, resulting in the study as a whole having eleven sites spread over three geographic regions. Each site was fenced to exclude stock and an automatic weather station was installed.

Near Brisbane, the sites were:

Gardiner's:	on a 10% slope near Esk.
Drynan's:	a flat location 4 km from the previous site.
River:	a moist paddock close to the creek on the CSIRO Research Station, Samford.
Hill:	a well-drained hillside 500 m from the previous site.

Near Townsville, the sites were:

Clare:	a flat flood plain at Burdekin Agricultural College.
Drynie:	on a levee in a flood plain, irrigated in dry spells.
Lansdown:	on a gentle slope.

Site layout

Each site consisted of an area approx. 40 m x 50 m containing at least eight rows of well-established Peru or Cunningham variety leucaena. Each site was split into three blocks, each block consisting of two plots and each plot comprising two rows 10 m long, giving a total of six plots per site. Buffer areas of leucaena 5 m wide were left between plots and between plots and the fence.

The central 5 m portion of each plot was marked with pegs and plastic tape and used for detailed observations. Five main stems per plot, chosen semi-randomly by moving 0.8 m along a row and then counting to the fifth stem along, were marked permanently with acrylic paint and a numbered tag.

Treatments

Three of the six plots at each site were sprayed with 0.03% dimethoate to exclude psyllids. Sprayed plots were selected pseudo-randomly with the restrictions that each block must contain a sprayed (plot 1) and an unsprayed plot (plot 2) and that all three sprayed plots must not be on the same side of the central buffer. This gave five possible layouts:-

1.	sprayed	unsprayed	2.	sprayed	unsprayed
	sprayed	unsprayed		unsprayed	sprayed
	unsprayed	sprayed		unsprayed	sprayed
3.	sprayed	unsprayed	4.	unsprayed	sprayed
	unsprayed	sprayed		unsprayed	sprayed
	sprayed	unsprayed		sprayed	unsprayed
5.	unsprayed	sprayed			
	sprayed	unsprayed			
	unsprayed	sprayed			

Plots were signposted (e.g. BU = block B unsprayed; AS = block A sprayed) and marked semi-permanently using pegs and plastic tape (red tape = sprayed, blue = unsprayed).

Observations

A single soil sample was collected from each block in each site and row spacings were measured. A summary of the routine operations performed at each site is given in Appendix A. Weekly observations were made in the central 5 m portion of each plot. The abundance of psyllid eggs, nymphs and adults was noted on five terminals per plot and the damage to the oldest unfolding leaf of each terminal was rated. (See attachment for rating descriptions.)

Coppicing. At intervals of four weeks, after weekly observations had been made, all leucaena plants inside the fence at each site were coppiced by removing all plant material above 1.0 m. Material from the central 5 m of each plot was kept. Coppicing was carried out in the order:

First: material was cut from each marked stem, bagged and tagged with date, block, treatment and stem number.

Second: all material cut from the remaining stems in each 5 m observation area was collected, bagged and tagged with date, block and treatment.

Third: all remaining plants inside the fence were coppiced and the cut material discarded.

Photographs were taken from fixed positions immediately before and after coppicing to record growth differences between treatments.

Growth measurements. After coppicing, all main stems per plot were counted. For the material removed from each of the marked stems, the number of terminals[1], length of terminal stem and the number of fully expanded leaves bearing at least some pinnules were counted in the laboratory before the material was dried and weighed. The material from the remainder of the plots was dried and weighed. There was no separation of plant material into edible and inedible because it was assumed that all material grown within the four weeks after coppicing would be edible.

Data processing. Observations and plant growth data were recorded in standardised form so that they could be retrieved, analysed and compared between sites using IBM-compatible computers. See Appendix B: Checklist – Sheet 1, Weekly Field Observations – Sheet 2 and Monthly Lab Observation – Sheet 3.

N,P,K plant samples. Five to ten terminals, depending on size, were collected from each plot, but outside the 5 m observation section, during coppicing. These samples were bulked for the three sprayed and the three unsprayed plots, dried, sealed into plastic bags and stored for future chemical analyses if required.

Weather stations. The automatic weather stations recorded hourly screen temperature and relative humidity, daily maximum and minimum temperatures, radiation and rainfall and, at a height of 1.0 m amongst leucaena, hourly temperature and relative humidity.

(iv) ACHIEVEMENT OF THE OBJECTIVES

All of the objectives of the project were achieved. The seasonal abundance and damaging effects of the psyllid on growth of leucaena were measured over two and a half years at three sites near Townsville and four sites near Brisbane. Losses that might occur to cattle production in each region were estimated.

(v) RESULTS AND CONCLUSIONS

Soil Analyses

The soils of all sites were slightly acidic and the soils at the two sites at Samford had significantly higher levels of nitrogen and organic carbon than other sites (Table 1). The cracking clay at Clare is not really suitable for leucaena.

Weather records

Radiation, daily maximum dry (probe 1) and wet (2) temperatures, and daily rainfall are shown for all sites in Figures 1 to 7. The radiation sensors malfunctioned at all three Townsville sites: during June to August 1992 at Clare, March to October 1991 at Drynie, and throughout 1991 at Lansdown. The water supply for wet bulb temperature probes became exhausted, or interrupted by ants or frogs, on occasions at all sites, for example November 1991 at Gardiners. There were flood rains at Townsville in January and February 1991 but otherwise, all sites received lower rainfall than average during the project. Sites near Brisbane experienced less severe drought than sites near Townsville. At Drynie, the leucaena was irrigated to compensate for low rainfall.

Psyllid observations

Ratings of psyllid abundance and damage to leucaena terminals in unprotected plots are shown in Figures 8 to 14. Each of these figures has its x-axis at exactly the same scale as the weather graph for the same site.

[1] A **terminal** is defined to include the first fully open leaf and all material that is younger on the same stem.

Near Brisbane, psyllids were most abundant over the entire study at the River site and least abundant, including apparent absences of several months, at Drynan's. With a few exceptions, fluctuations in psyllid abundance varied considerably between sites, even sites within the same area which experienced almost identical weather conditions. Numbers crashed at all four sites in July/August 1990 and at all sites except Gardiners in August/September 1991 and July/August 1992. These crashes coincided with seasonally cool, dry conditions and periods of minimal growth by leucaena. There was no clear pattern among sites for population increases, though numbers were high at all sites for three months following good rain and rapid growth by leucaena in February/March 1992.

Near Townsville, psyllids were most abundant over the entire study at Drynie and least abundant at Clare. Though very different in size, populations at Clare and Drynie were broadly synchronised but they were out of synchrony with the population at Lansdown. Only at Lansdown were numbers high following the heavy rain of January/February 1991. Psyllids appeared to be absent during periods of leucaena growth in January/February 1991 at Clare and Drynie, and at all sites from February to May 1992.

Damage to leucaena followed the pattern of psyllid abundance at each site, especially the abundance of adults.

Leucaena growth

Increases in dry weight and in length of terminals in the protected and unprotected plots are shown in Figures 8 to 14 and summarised in Tables 2 and 3. Between 106 and 129 harvests were carried out at each site.

Near Brisbane, growth was clearly seasonal and reached a peak in January-March and a trough in July/August each year. At Gardiner's and Drynan's, the peak in 1992 was bigger than the one in 1991, probably because more rain was received in 1992. The seasonal pattern of growth near Townsville was similar to that near Brisbane, with peaks occurring after summer rain, but the particularly heavy rains in early 1991 did not result in exceptional growth by leucaena.

Psyllid attack reduced growth by leucaena at all sites as measured by all techniques except numbers of terminals and leaves and lengths of terminals (Tables 2 and 3). The significant exceptions occurred at Samford Hill where random selection of plots had resulted in two of those protected from psyllids being located in positions particularly exposed to wind and dehydration compared with unprotected plots. The importance of this was not recognised at the time plots were selected. Exposure appeared to inhibit the growth of new terminals and leaves and the elongation of existing terminals. Even so, protected plants added more weight than unprotected plants due to protected/exposed terminals and leaves being particularly robust and sturdy.

Losses caused by the psyllid correlated reasonably well with the productivity of protected plants. The greatest loss in weight gain (75%) occurred at Samford River where dry weight accumulation was 5,205 kg/ha/year, and the least loss (3%) occurred at Clare where dry weight accumulation was only 1,004 kg/ha/year. This is consistent with the time-sequence results which showed that psyllids were most abundant at times when there was abundant new growth on the leucaena.

Losses that might occur to cattle production at each site

The effect of psyllids on cattle productivity depends on a number of factors additional to reduction of leucaena growth by psyllids. These factors include the presence in variable amounts of alternative fodder plants of different nutritional value and attractiveness to stock, selection or avoidance of psyllid-infested leucaena by stock and increases in nitrogen-content of other plants grown in association with leucaena. Much additional research would be needed to quantify all relevant relationships and a fairly complex model would be needed to integrate all effects to make predictions for particular situations. In the absence of such a model and much of the information needed to drive it, the following extrapolations should be regarded as indicative only.

Quirk *et al.* (1990) found that at 0.7 animals/ha, steers gained 60, 127 and 205 kg/year when grazed on paddocks of black speargrass in which 0, 25 and 100% of the area had been sown to leucaena respectively. That is, a reduction of 75% in the availability of leucaena had resulted in a reduction of 38% liveweight gain. Under similar conditions, psyllid attack resulting in 75% less new growth of leucaena as at Samford River might cause a similar reduction in liveweight gain in cattle.

An alternative interpretation might be based on the effects of psyllids on stocking rate. In this case, the percentage reduction in leucaena growth might indicate directly the percentage reduction in the maximum stocking rate which could be sustained, i.e. a reduction as great as 75% at Samford River under conditions favourable for growth by leucaena and a reduction as small as 3% at Clare under conditions unfavourable for leucaena.

Both of these extrapolations suffer from the major defect that they do not allow for any impact of grazing on psyllid populations through reducing the quantity of high-quality food available to the psyllids. It is very likely that a negative effect of grazing on the psyllids would result in the psyllids having smaller effects on liveweight gain of stock and stocking rates than indicated above. This question can only be answered by conducting grazing experiments in leucaena protected and unprotected from psyllids. Note that in any such experiment, half of the livestock would be required to eat insecticide-contaminated fodder.

(vi) Intellectual property resulting from the project

None.

(vii) Recommendations for commercial exploitation of results

Graziers should be advised that when leucaena starts growing rapidly, most commonly following rain in summer, damaging populations of psyllids are likely to build up soon after. If practical, the leucaena should be monitored and, as soon as psyllid numbers increase, cattle should be turned into the paddock to remove new growth before the psyllids do.

The results of this project should be integrated with other information, such as the economics of replacing leucaena with alternative species, in further developing the grazing industry's strategy for responding to the psyllid. The options open to the industry appear to be:

i) Accept that the psyllid will cause significant reductions in growth by leucaena and decide whether to promote additional plantings.

ii) Support basic research into the biology and ecology of the psyllid with a view to solving the problem through better understanding of psyllid dynamics.

iii) Continue to support research into psyllid-resistant varieties of leucaena with a view to replacing susceptible varieties in existing and/or new plantings.

iv) Combine one or all of options i) to iii) with investigations of manipulation of grazing intensity to optimise leucaena growth and its consumption by cattle rather than psyllids.

v) Explore alternative fodder species.

If measures for managing the psyllid are to be developed in this context, there is a need for basic understanding of the conditions which lead to changes in psyllid numbers. Laboratory studies of psyllid biology and life-table studies of the dynamics of the insect in the field are needed.

(viii) Contributions of the MRC to the project

$176,031 over three years.

(ix) Impact of the Results on the Livestock Industry

(A) At the Date of this Report

Confirmation that the psyllid is a serious pest under conditions favouring growth by leucaena emphasises the continuing difficulty in deciding whether further plantings of leucaena should be made.

(B) In the next five years from the date of this Report

The impact in the next five years will depend on how the AMRC uses the results to develop a strategy for responding to the psyllid. If the AMRC should decide to fund research into the biology, ecology and management of the psyllid, techniques for managing the pest to minimise damage could be under test five years from now and qualified support might be given to additional planting of leucaena. Alternatively, should the AMRC decide not to fund such research, practical experience and economic analyses might indicate that further planting of leucaena should be discouraged in most areas.

Preparedness of CSIRO Division of Entomology to Participate in Recommended Activities

The CSIRO Division of Entomology is prepared to collaborate in an economic analysis of the results obtained in the present project, to conduct laboratory studies of the basic biology of the psyllid and field life-table studies of the population dynamics of the psyllid, and to collaborate in experiments to explore interactions between grazing and psyllids on the basis of full cost recovery.

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Quirk, M. F., Paton, C. J. and Bushell, J. J. (1990). Increasing the amount of leucaena on offer gives faster growth rates of grazing cattle in South East Queensland. *Australian Journal of Experimental Agriculture* **30**, 51–54.

APPENDIX A

SUMMARY SCHEDULE OF ACTIVITIES FOR A SITE

Note site 1 should begin on week 1 on, say, Monday. Site 2 should begin a week later, also on Monday. Site 3 a week later, week 3, but on Tuesday and site 4 a week later, week 4, also on Tuesday. This will permit two sites to be visited in one day but only one of them will require coppicing on the same day. If this schedule can be maintained it will allow two field days and three lab days per week.

In the field

beginning (initial coppicing)

Collect 5 terminals per plot for N,P,K analyses. Keep 'sprayed' and 'unsprayed' separate to see if there are differences at the start.
Coppice all plants within the fence to 1.5 m (photo before and after).
Measure row spacing.
Count stems per plot.
Activate weather station
Randomly select, mark and tag five stems per plot.
Randomly allocate treatments, fix signs and apply treatment spray.

week 1 — Check 5 terminals per plot, rating psyllid abundance and plant damage.
Rockhampton – collect terminals for psyllid counts.
Down load weather station.
Apply treatment spray to three 'sprayed' plots.

week 2 — As for week 1

week 3 — As for week 2

week 4 — Rate psyllid abundance and damage.
Rockhampton – collect terminals for psyllid counts.
Site photos (before coppicing)
Coppice and bag separately plant material for each of the marked stems per plot.
Coppice remainder of stems in each plot and bag per plot.
Collect terminals for N,P,K and bag separately for sprayed and unsprayed.
Count main stems in each plot.
Coppice remainder of plants, i.e. plant in buffer zone.
Site photos (after coppicing).
Down load weather station.
Apply treatment spray to 'spray' plots.

week 5 to 7 — As for week 1 to 3

week 8 — As for week 4
etc, etc.

In the laboratory

beginning — Dry and store terminals for N,P,K analyses.
Record data: number of stems per plot, row spacing

weeks 1–3 — Record data for psyllid abundance and plant damage.
Transfer weather data to IBM PC.
Rockhampton – wash terminals and count psyllids.

week 4 — Count number of terminals, measure length of terminal stem and number of leaves per marked stem and record data.
Dry and store terminals for N,P,K analyses.
Dry and record weights for a) marked stems and
b) all other stems; discard material.
Record data for psyllid abundance and plant damage.
Rockhampton – wash terminals and count psyllids.
Transfer weather data to IMB PC.

APPENDIX B

PSYLLID PEST STATUS EXPERIMENTS — CHECKLIST – SHEET 1

REGION ___________ SITE __________ DATE ___/___/___

WEEK 1___ 2___ 3___ 4___ (COPPICE)

(tick appropriate week) (Region either South, Central or North)

(tick as tasks completed)

EVERY WEEK

Psyllids absent _____ present ______(see sheet 2)

Treatment applied ______ Weather station down loaded _____

(apply treatment last)

WEEK 4 (COPPICE)

N,P,K sample sprayed ______ unsprayed _______

Photo before coppicing _____

Marked stems coppiced and bagged - Block 1, Plot 1 ____ Plot 2 ____

(Note Plot 1 = sprayed; Block 2, Plot 1 ____ Plot 2 ____

Plot 2 = unsprayed) Block 3, Plot 1 ____ Plot 2 ____

2 X 5 m rows per plot coppiced and bagged ________

Number of stems per plot - Block 1, Plot 1 ___ Plot 2 ___

Block 2, Plot 1 ___ Plot 2 ___

Block 3, Plot 1 ___ Plot 2 ___

Remainder coppiced ______

Photo after coppicing _______

PROBLEMS:

COMMENTS:

PSYLLID PEST STATUS EXPERIMENTS

WEEKLY FIELD OBSERVATIONS – SHEET 2

REGION ____________ SITE __________ DATE ___/___/___

WEEK 1___ 2___ 3___ 4___ (COPPICE)

(tick appropriate week)

FOR UNSPRAYED PLOTS ONLY

TERMINAL NO.	ADULT			NYMPH			EGG	
DAMAGE								
BLOCK 1	1 = none	2 = few	3 = many	1 = none	2 = few	3 = many	1 = none	3 = 0 to 6 many
1								
2								
3								
4								
5								
6								
7								
8								
9								
10								
BLOCK 2								
1								
2								
3								
4								
5								
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10								
BLOCK 3								
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3								
4								
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6								
7								
8								
9								
10								

TO ASSESS PSYLLID ABUNDANCE

Randomly select ten (10) terminals in each sprayed plot (5 per row).

Check for presence/absence of psyllids.

If present record the following per terminal;

ADULTS

2 = Few	if 5 or less observed
3 = many	if more than 5 observed

NYMPHS

2 = Few	if nymphs are present but scattered and not clustered anywhere on the terminal
3 = Many	if nymphs are obviously numerous and clustered

EGGS

3 = Many	if eggs are obvious on very young developing leaves without using a hand lens.

TO ASSESS PLANT DAMAGE

Using the same terminals selected for psyllid abundance make observations on the oldest unfolding leaf, i.e. the second oldest leaf on the terminal.

Rate damage to that leaf as follows:

0	no damage
1	slight puckering of pinnules
2	yellowing of pinnules and loss of up to 25% of pinnules
3	more than 25% of pinnules lost
4	all pinnules missing
5	all pinnules missing plus blackening of younger leaves and growing points
6	all pinnules missing plus collapse of growing points

PSYLLID PEST STATUS EXPERIMENTS

MONTHLY LAB OBSERVATIONS - SHEET 3

REGION____________SITE____________ DATE ___/___/___

WEEK 4, COPPICE

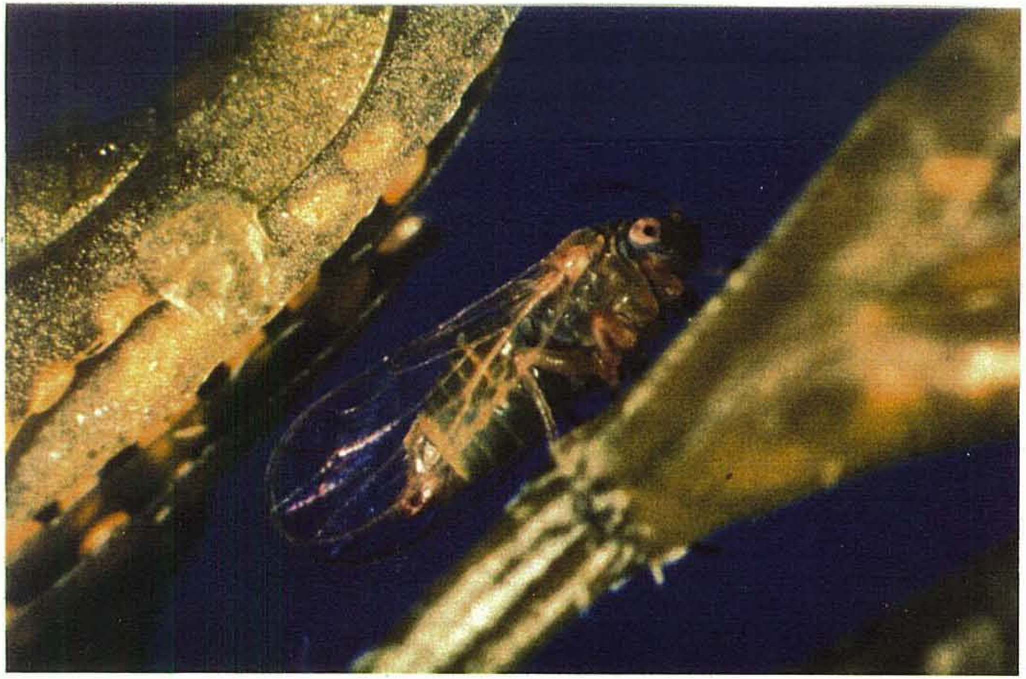
	MARKED STEMS 1	2	3	4	5	6	Remainder
BLOCK 1							
Plot 1 Sprayed							
no. terminals							
no. leaves							
total terminal length							
dry weight terminals							
dry weight others							
Plot 2 Unsprayed							
no. terminals							
no. leaves							
total terminal length							
dry weight terminals							
dry weight others							
BLOCK 2							
Plot 1 Sprayed							
no. terminals							
no. leaves							
total terminal length							
dry weight terminals							
dry weight others							
Plot 2 Unsprayed							
no. terminals							
no. leaves							
total terminal length							
dry weight terminals							
dry weight others							
BLOCK 3							
Plot 1 Sprayed							
no. terminals							
no. leaves							
total terminal length							
dry weight terminals							
dry weight others							
Plot 2 Unsprayed							
no. terminals							
no. leaves							
total terminal length							
dry weight terminals							
dry weight others							

TABLE 1. SOIL TYPES AND RESULTS OF CHEMICAL ANALYSES OF THE A1 HORIZON

Site	Great Soil Group	pH	%Total N	Organic C
Gardener's	Solodic	6.6	0.16	2.2
Drynan's	Brown clay	6.8	0.11	1.1
River	Lithosol	5.1	0.32	5.4
Hill	Non-calcic brown soil	6.3	0.32	5.0
Clare	Solodic	6.0	0.06	0.7
Drynie	Alluvial soil	6.9	0.09	1.6
Lansdown	Red podzol	6.5	0.06	0.9

TABLE 2. GROWTH BY LEUCAENA PROTECTED (P) ANDUNPROTECTED (U) FROM PSYLLID: TOTAL INCREASES OVER ALL GROWTH PERIODS

	No. growth periods		No. terminals /terminal	No. leaves /term.	Length terminals cm/term.	Dry weight g/m row	Dry weight kg/ha/y
Brisbane sites							
Gardeners	129	P:	281.6	779.3	1121.0	3316.7	4237
		U:	205.1	557.9	767.7	1745.4	2230
Drynans	126	P:	179.2	500.6	890.7	2007.5	2044
		U:	157.9	431.5	783.3	1791.0	1824
River	120	P:	321.9	879.5	1319.8	4074.4	5205
		U:	170.3	387.2	569.1	1029.0	1314
Hill	122	P:	138.3	336.4	369.0	1688.6	4358
		U:	246.6	614.8	637.6	1309.4	3379
Townsville sites							
Clare	109	P:	44.6	96.2	137.6	849.4	1004
		U:	44.8	99.8	132.7	827.4	978
Drynie	111	P:	126.1	361.7	630.8	4392.2	7270
		U:	99.1	236.4	392.8	2518.9	4169
Lansdown	106	P:	63.8	156.4	259.6	1679.4	2015
		U:	36.4	86.6	171.3	857.9	1029



Adult leucaena psyllid

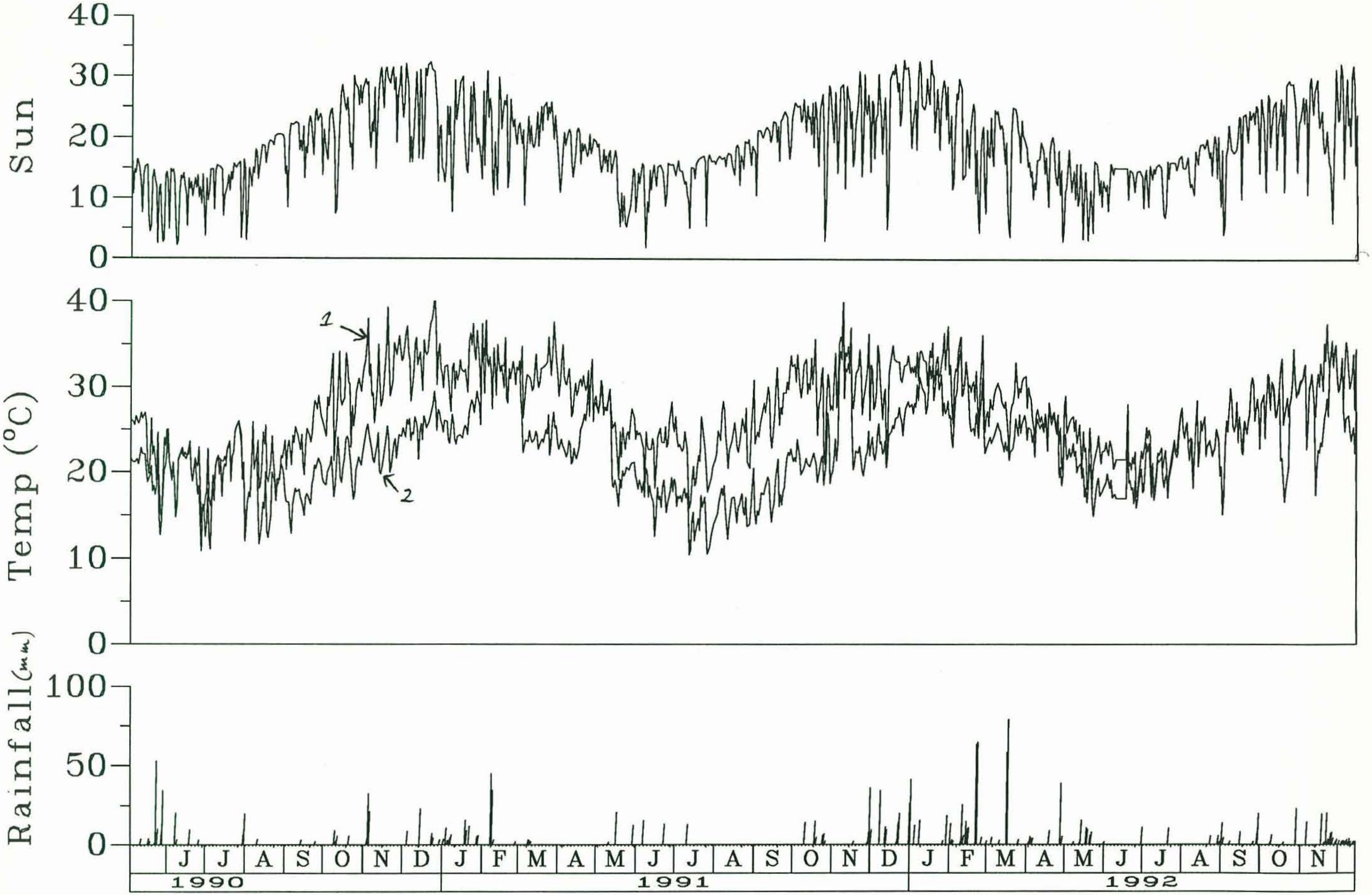
Nymph of leucaena psyllid

Frond of leucaena infested with psyllid

`Samriver' site before harvest

TABLE 3. PERCENT LOSS IN LEUCAENA GROWTH CAUSED BY THE LEUCAENA PSYLLID

	No. growth periods	No. terminals	No. leaves	Length terminals	Dry weight
Brisbane sites					
Gardeners	129	27	28	32	47
Drynans	126	12	14	12	11
River	120	47	56	57	75
Hill	122	-78	-83	-73	22
Townsville sites					
Clare	109	0	-4	4	3
Drynie	111	21	35	38	43
Lansdown	106	43	45	34	49



Start 03/05/90 Site = Esk Gardners Temperature probes 1 2 End 15/12/92

DRY WET

Fig. 1

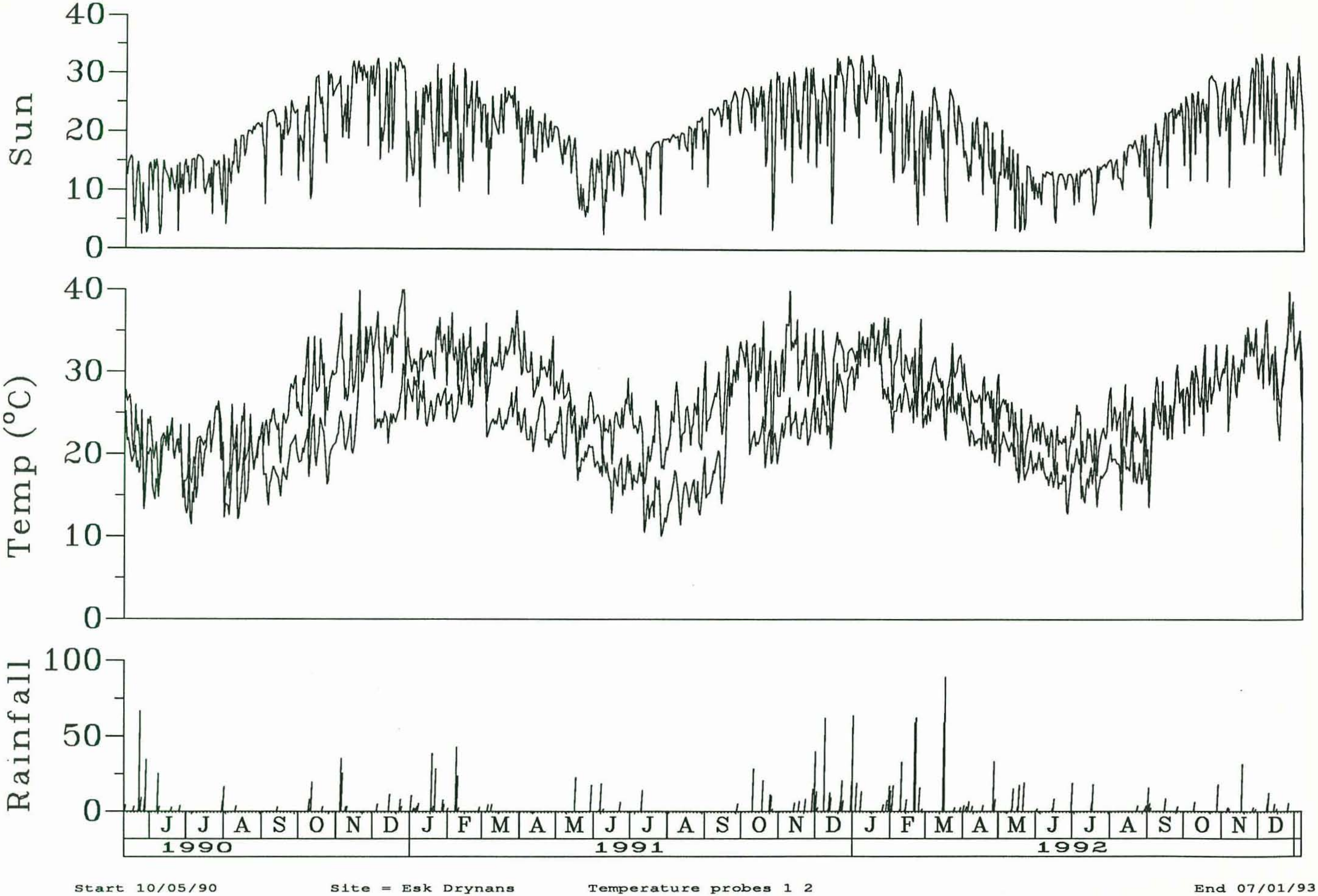
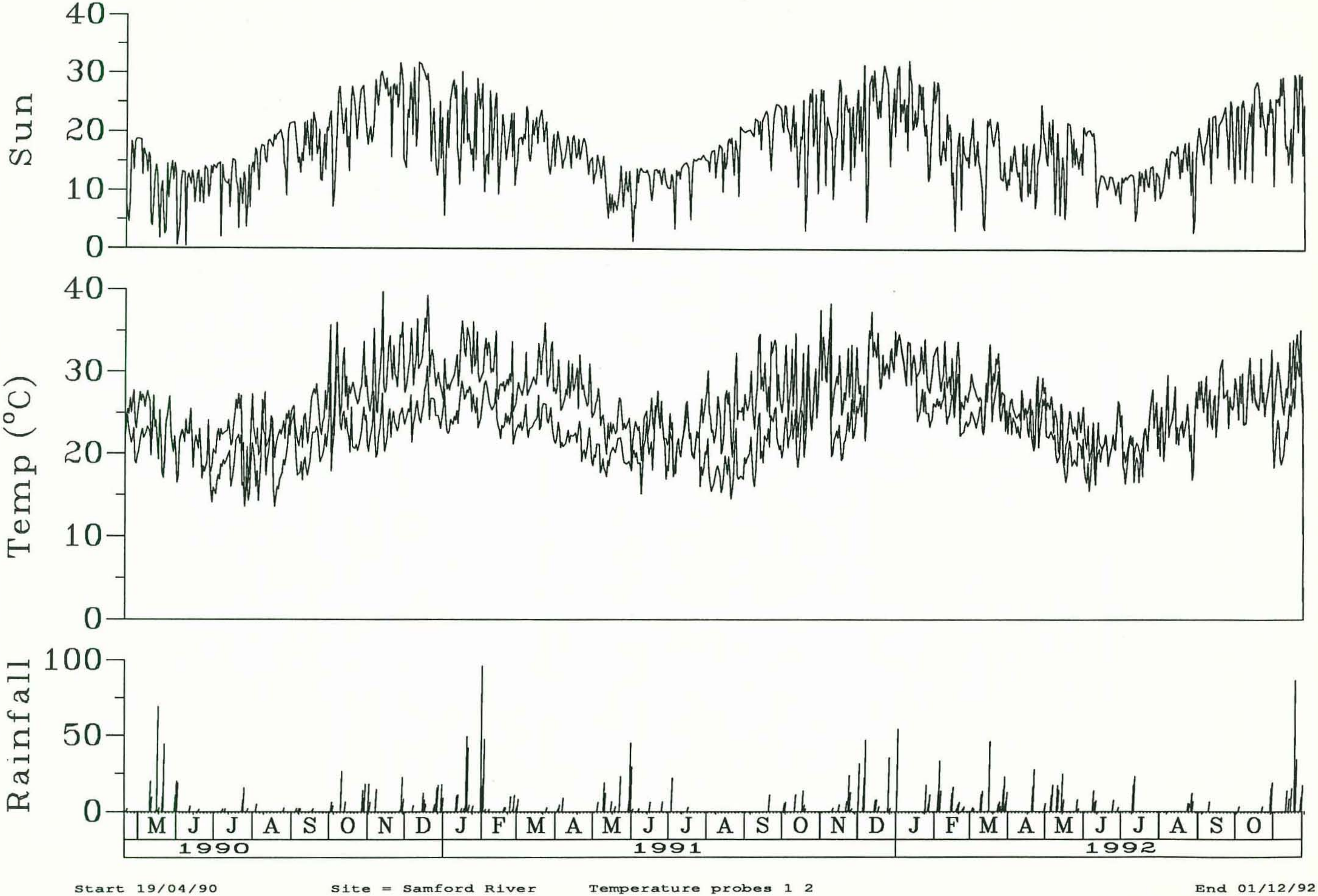
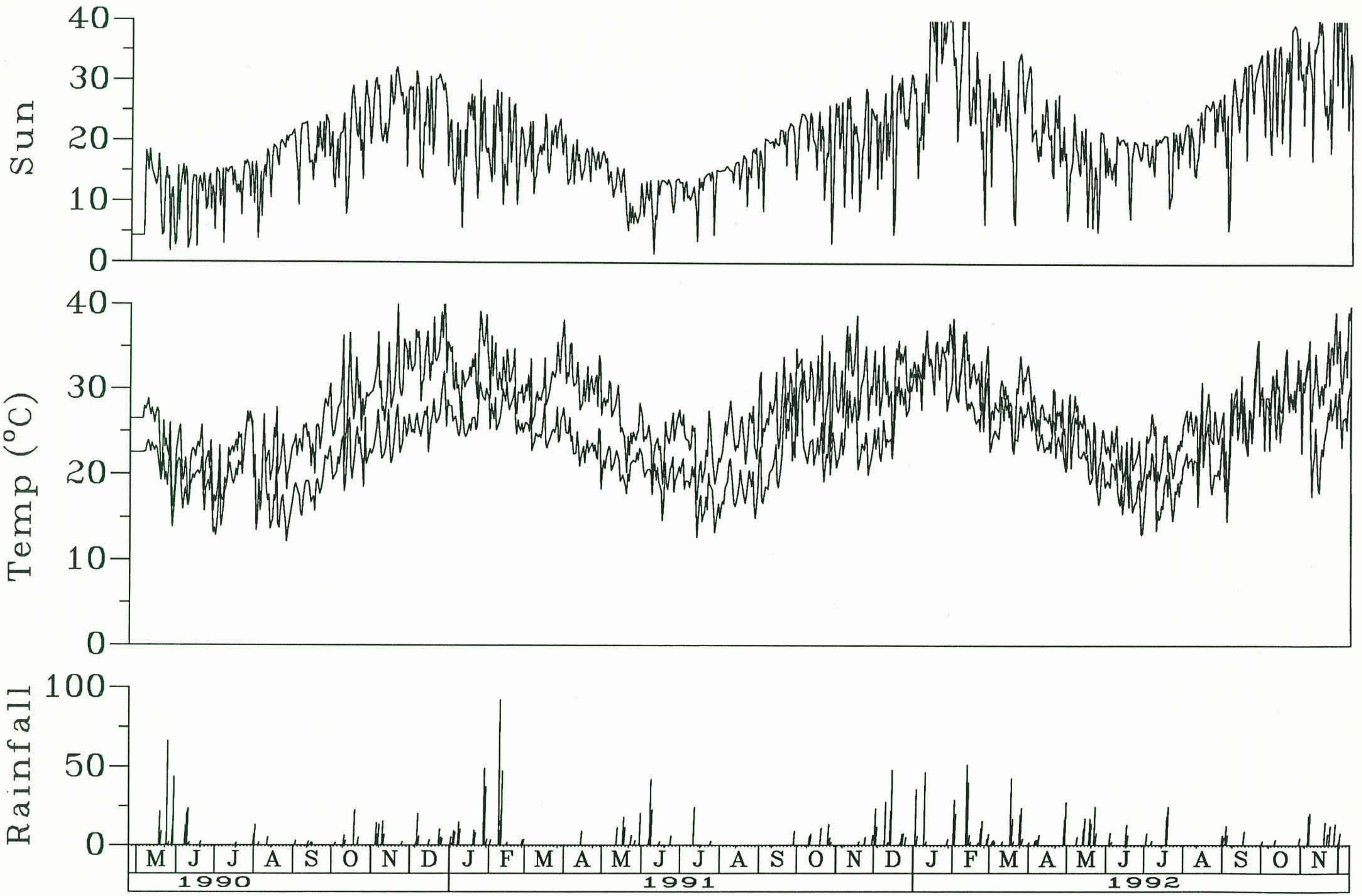

Sun
Temp (°C)
Rainfall
40
30
20
10
0
100
50
J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D
1990
1991
1992
Start 10/05/90
Site = Esk Drynans
Temperature probes 1 2
End 07/01/93

Fig. 2.

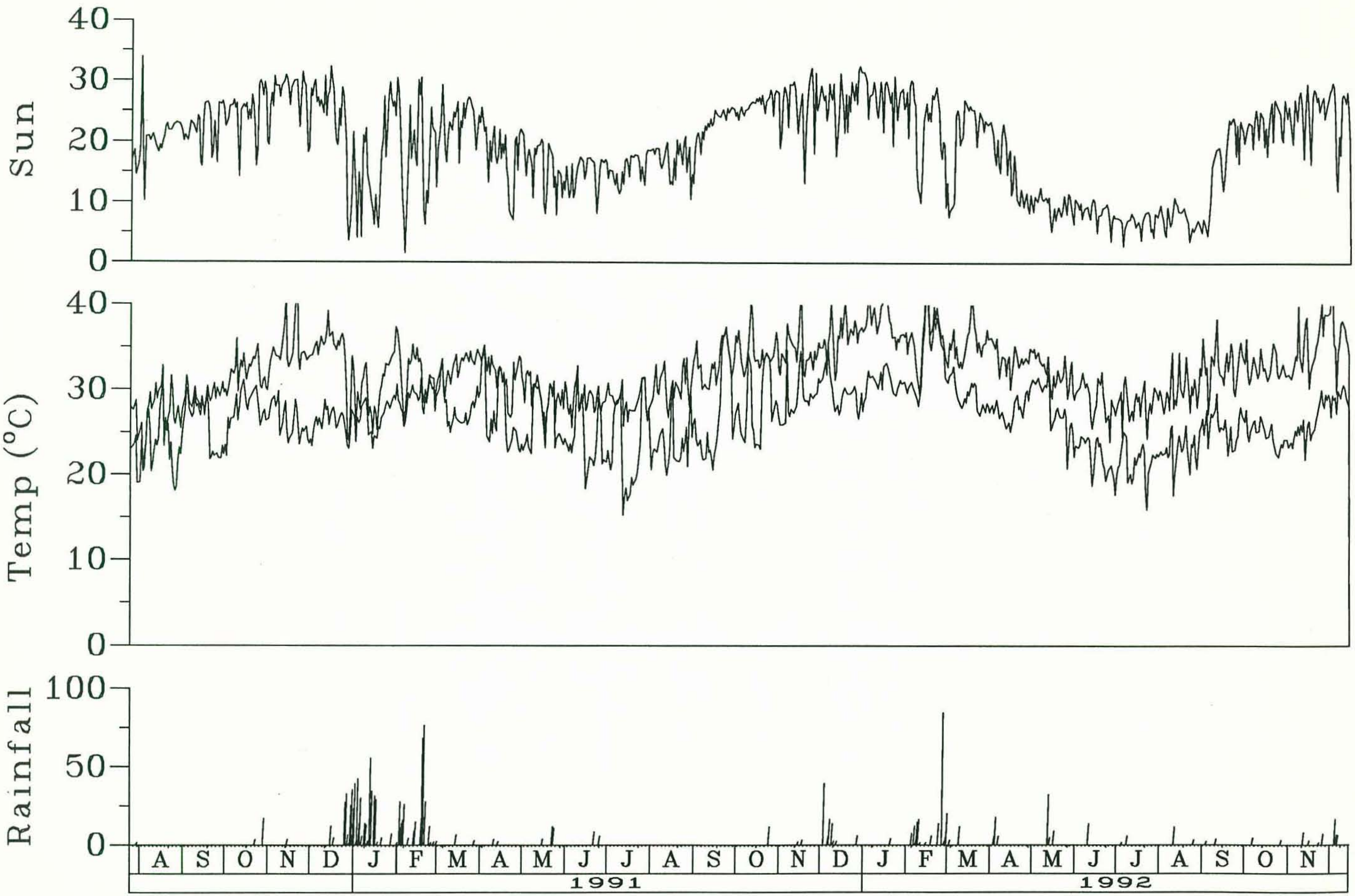


Sun
0
10
20
30
40
Temp (°C)
0
10
20
30
40
Rainfall
0
50
100
M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O
1990
1991
1992
Start 19/04/90
Site = Samford River
Temperature probes 1 2
End 01/12/92

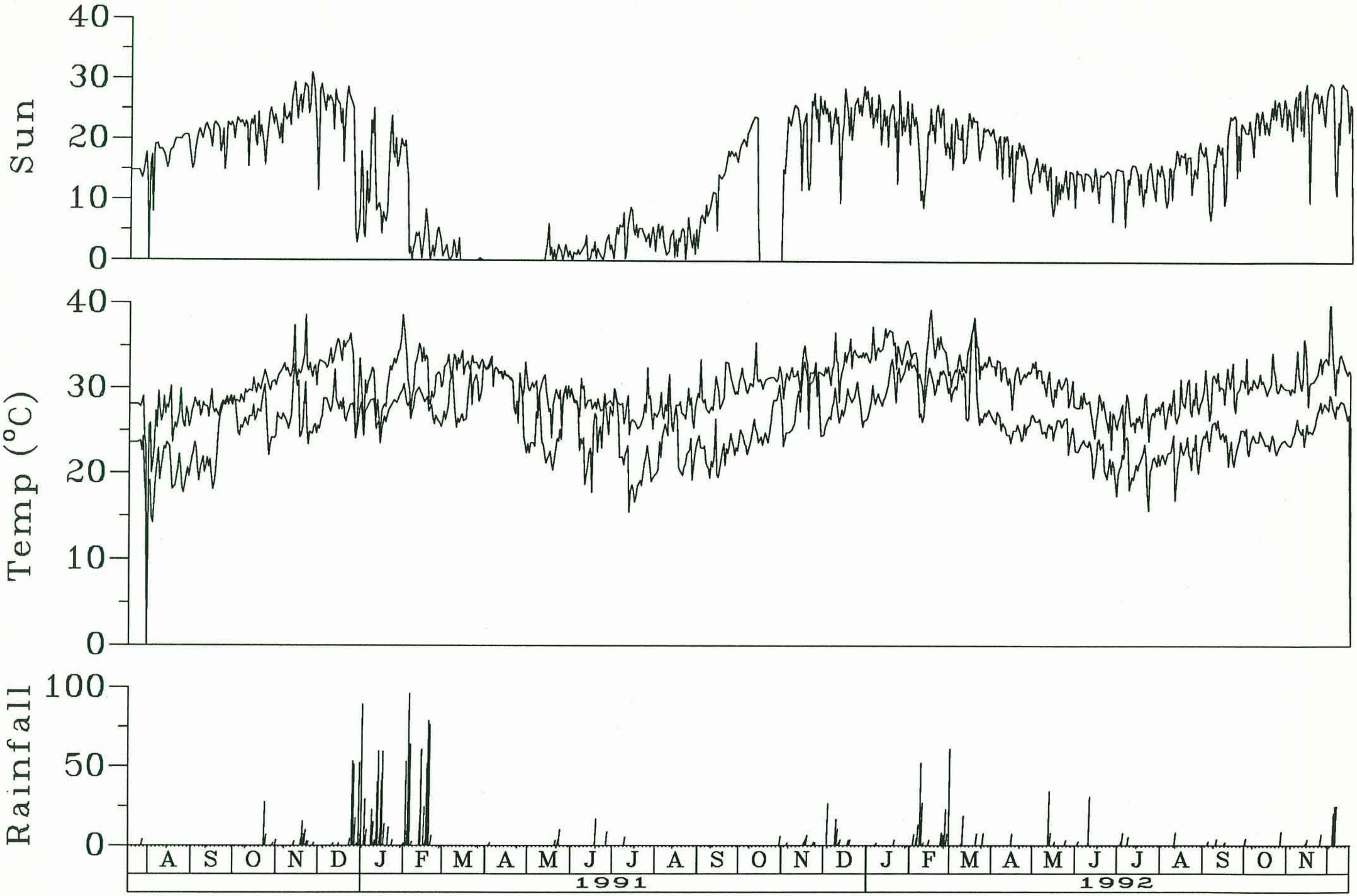
Fig. 3.



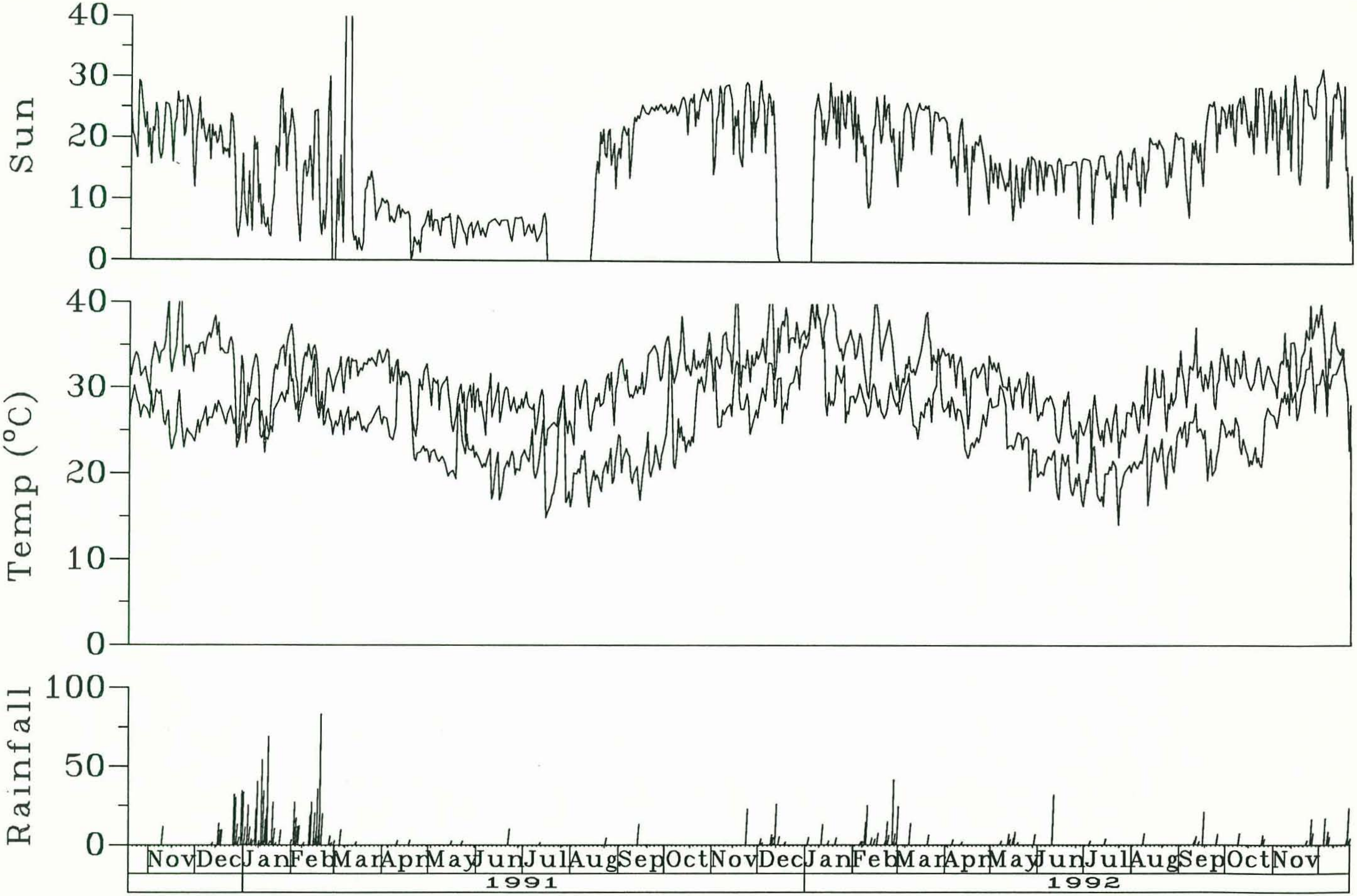
Start 24/04/90 Site = Samford Hill Temperature probes 1 2 End 08/12/92



Start 24/07/90 Site = Tville Clare Temperature probes 1 2 End 14/12/92



Start 17/07/90 Site = Tville Drynie Temperature probes 1 2 End 16/12/92



Start 18/10/90 Site = Tvlle Lansdown Temperature probes 1 2 End 21/12/92

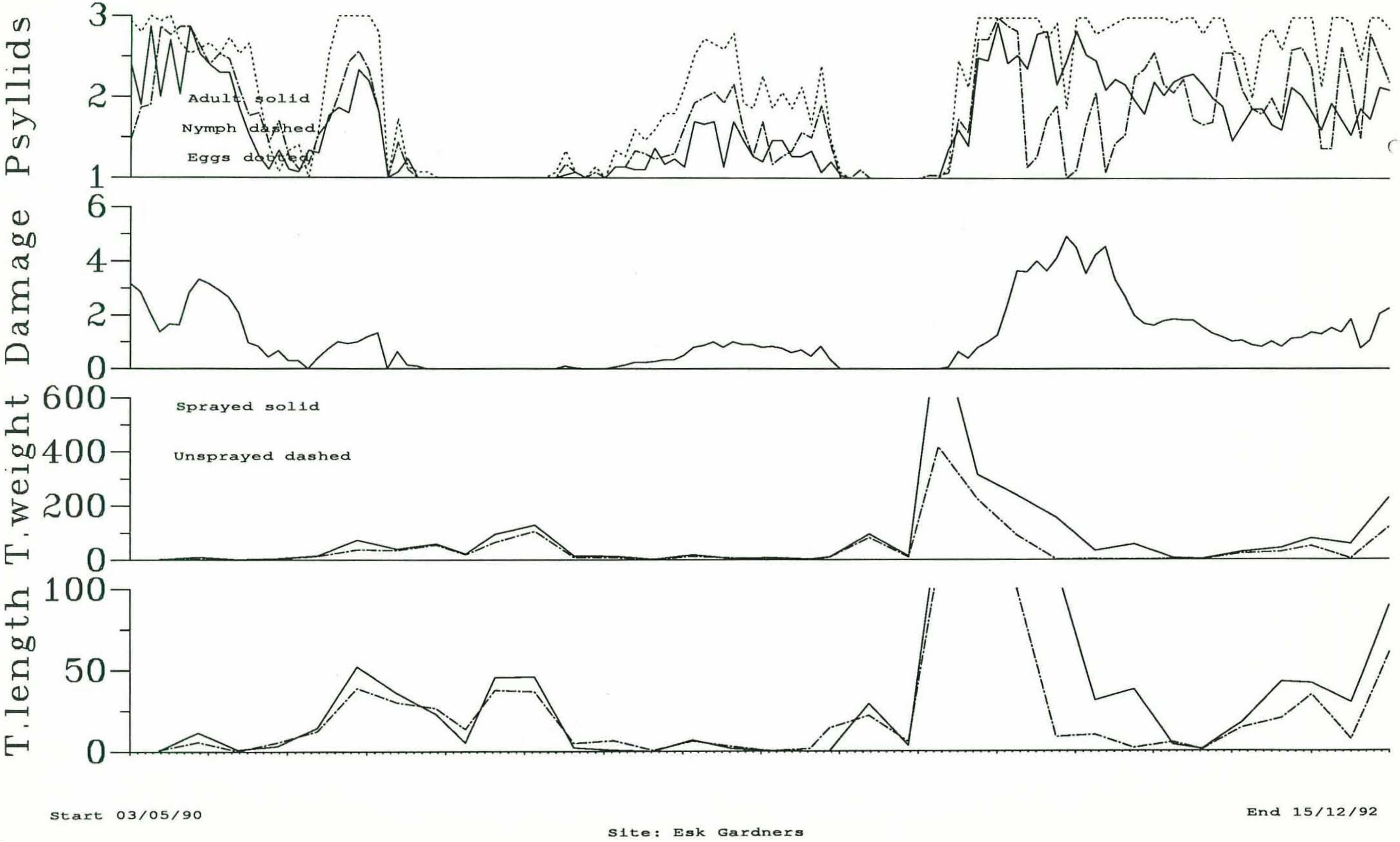
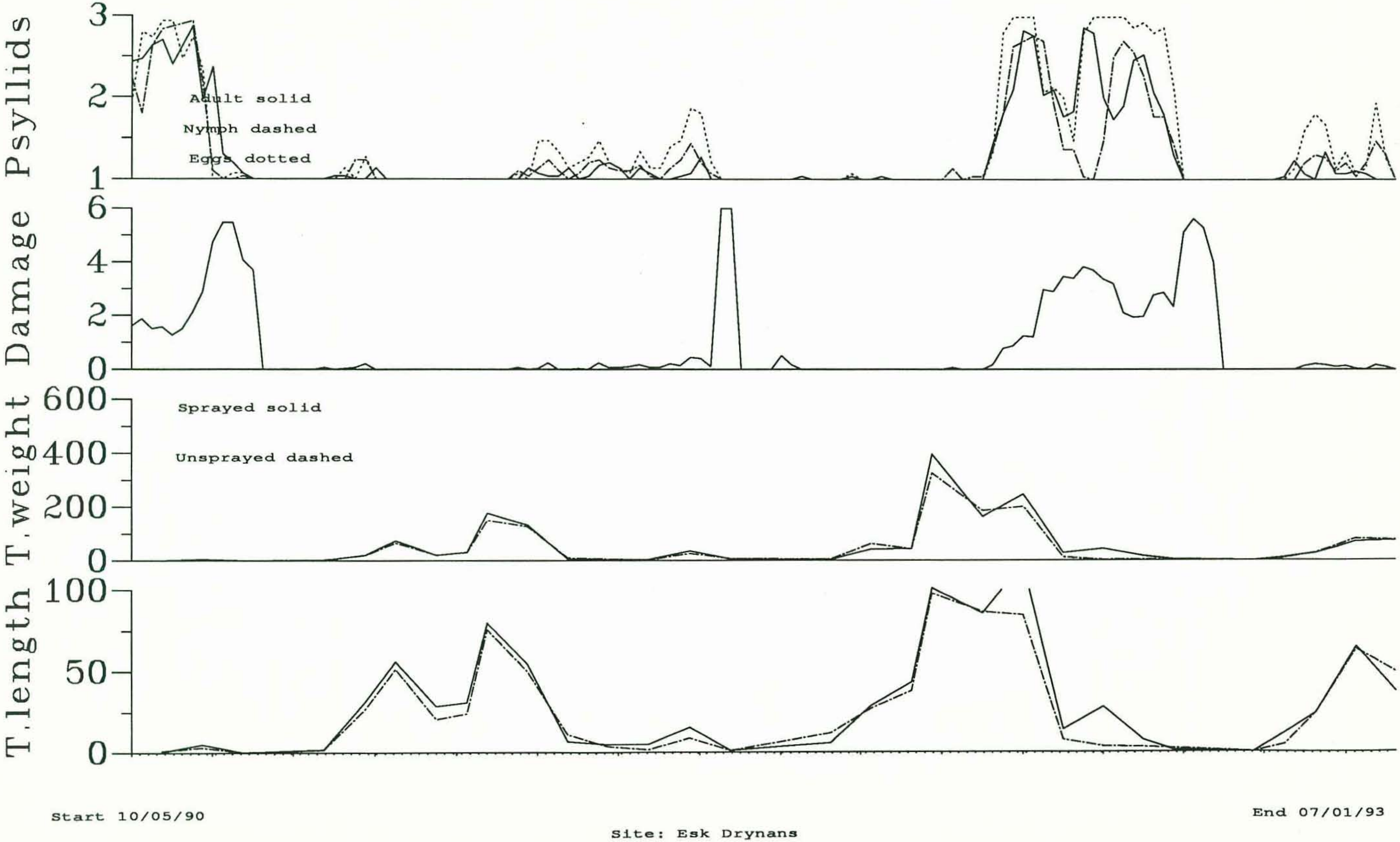
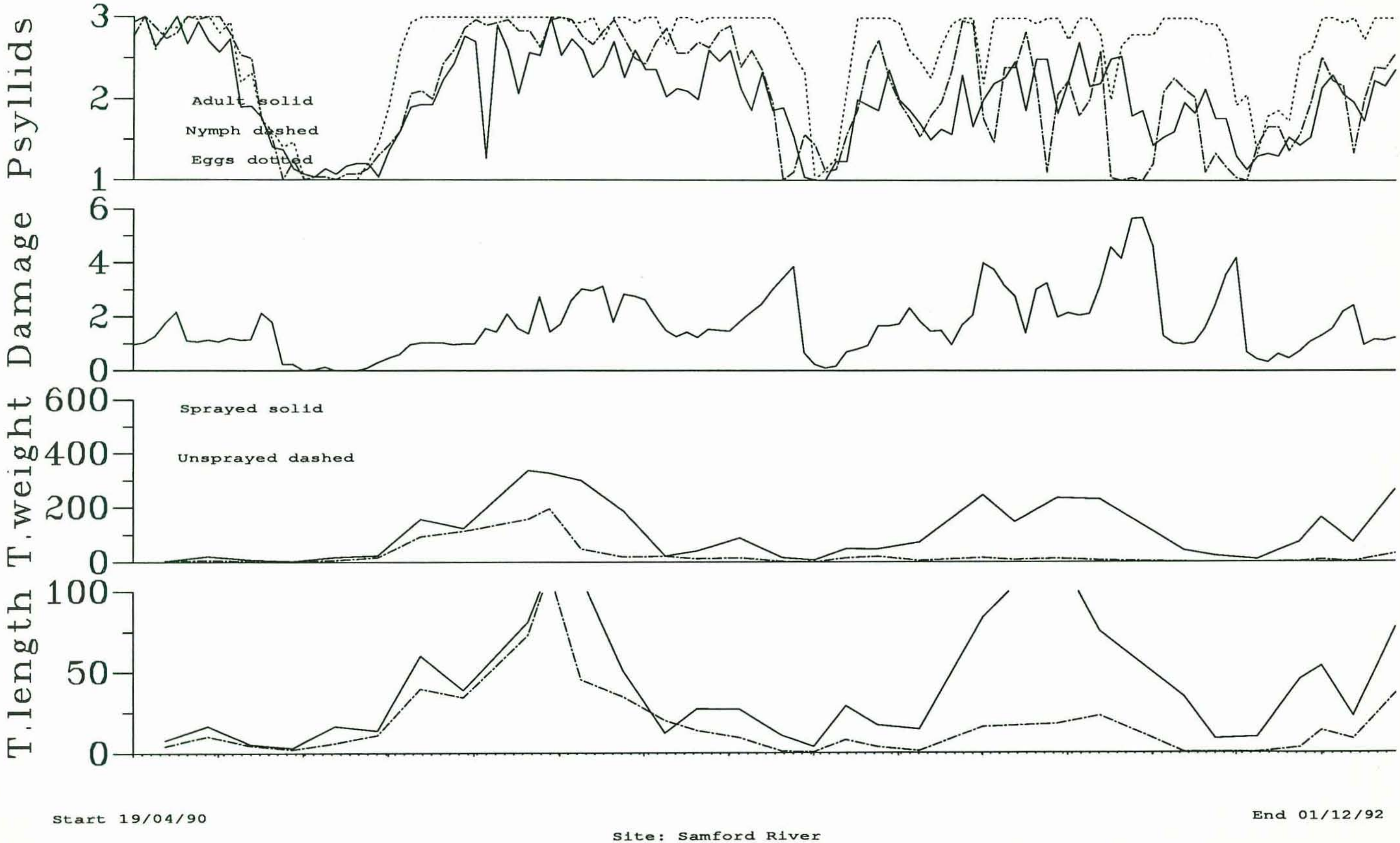
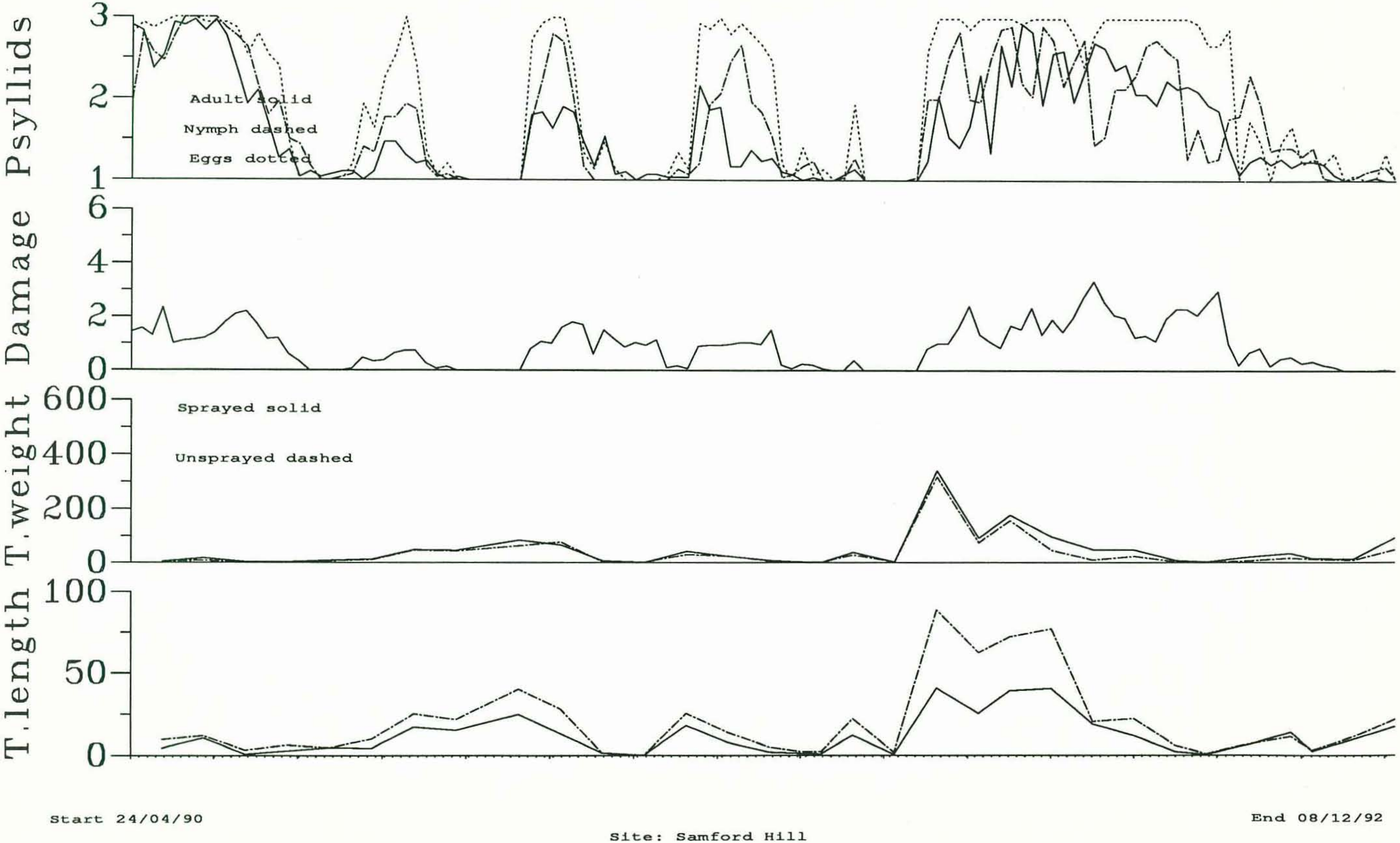

Psyllids
3
2
1
Adult solid
Nymph dashed
Eggs dotted
Damage
6
4
2
0
T.weight
600
400
200
0
Sprayed solid
Unsprayed dashed
T.length
100
50
0
Start 03/05/90
End 15/12/92
Site: Esk Gardners

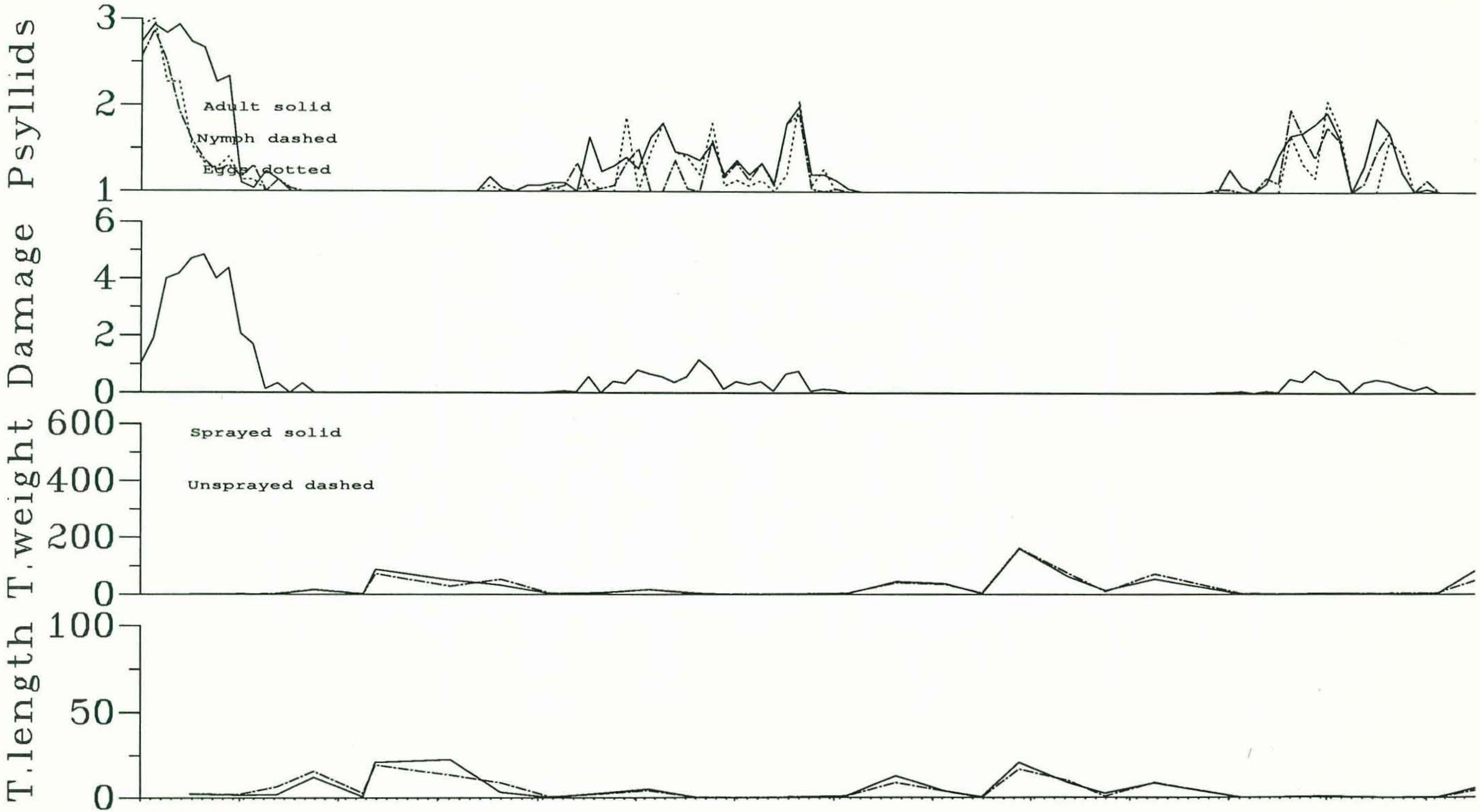
Fig. 8


Psyllids
1
2
3
Adult solid
Nymph dashed
Eggs dotted
Damage
0
2
4
6
T.weight
0
200
400
600
Sprayed solid
Unsprayed dashed
T.length
0
50
100
Start 10/05/90
End 07/01/93
Site: Esk Drynans


Psyllids
3
2
1
Adult solid
Nymph dashed
Eggs dotted
Damage
6
4
2
0
T.weight
600
400
200
0
Sprayed solid
Unsprayed dashed
T.length
100
50
0
Start 19/04/90
End 01/12/92
Site: Samford River

92 Fi. 10

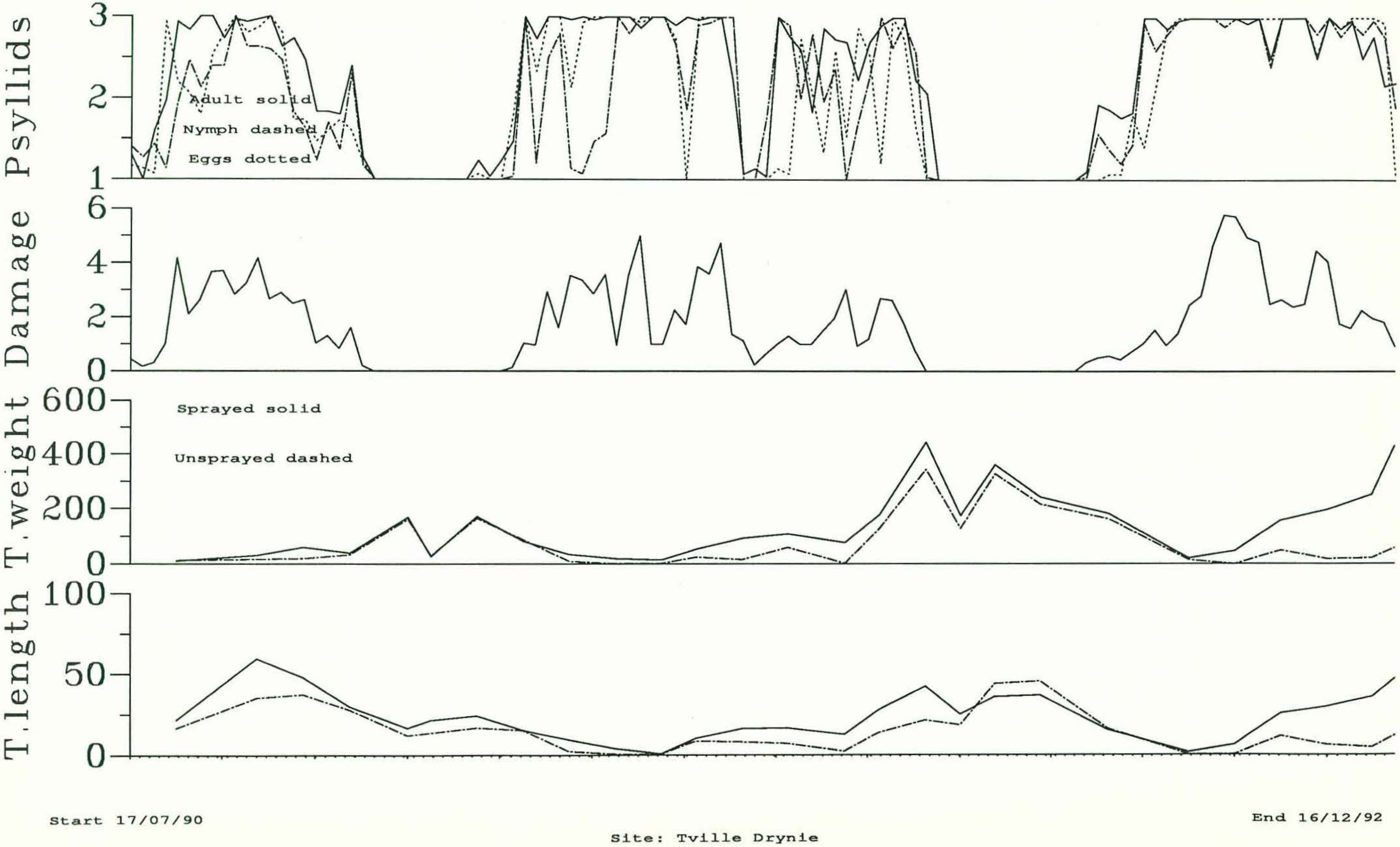

Psyllids
3
2
1
Adult solid
Nymph dashed
Eggs dotted
Damage
6
4
2
0
T.weight
600
400
200
0
Sprayed solid
Unsprayed dashed
T.length
100
50
0
Start 24/04/90
End 08/12/92
Site: Samford Hill



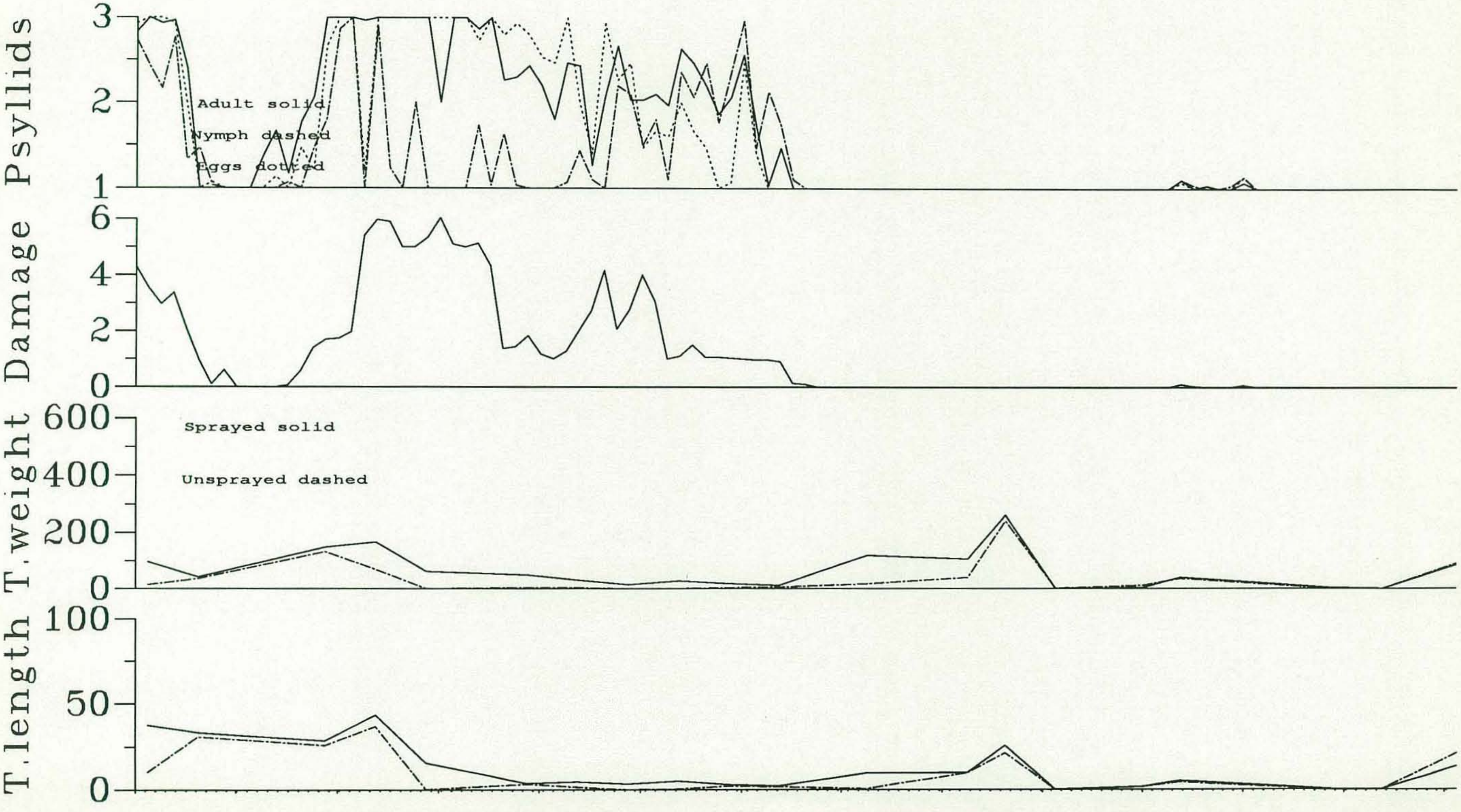
Start 24/07/90

End 14/12/92

Site: Tville Clare



Psyllids
3
2
1
Adult solid
Nymph dashed
Eggs dotted
Damage
6
4
2
0
T.weight
600
400
200
0
Sprayed solid
Unsprayed dashed
T.length
100
50
0
Start 17/07/90
End 16/12/92
Site: Tville Drynie



Start 18/10/90

End 21/12/92

Site: Tvle Lansdown

Fig. 14