

Predation by ladybird beetles (coccinellids) on immature stages of the *Eucalyptus* leaf beetle *Chrysophtharta bimaculata* (Olivier)

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Abstract

Population counts of the adult life stage of two predaceous ladybirds, *Cleobora mellyi* and *Harmonia conformis*, and egg larvae and adult leaf beetles (*Chrysophtharta bimaculata*) were conducted on a weekly basis at a site in northern Tasmania over the summer season. The predation of *C. bimaculata* was assessed in relation to the populations of adults and larvae of the coccinellid species. The movement of adult ladybirds within the plantation was also examined and compared to adult leaf beetle migration.

The aim of the study was to (i) determine the effect of predation on leaf beetle egg-deposition peaks during the season, (ii) monitor the change in coccinellid populations on *Eucalyptus regnans* trees throughout the season in relation to the eggs, young larvae and adults of *Chrysophtharta bimaculata* and, (iii) provide an indication of the timing and potential of supplementary release of adult ladybirds in order to enhance the level of biological control in the integrated pest management strategy.

Predation of *C. bimaculata* eggs by ladybirds occurred in both early and late season egg-laying peaks but was much higher early in the season. Comparison of actual consumption of eggs by ladybirds with potential consumption figures indicates that there is a theoretical potential to increase predation levels by methods such as augmentative releases of ladybirds.

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Introduction

Predation by adults and larvae of the coccinellid species *Cleobora mellyi* Mulsant and *Harmonia conformis* (Boisduval) (Photo 1) can have a major impact on populations of the immature stages of the chrysomelid leaf beetle *Chrysophtharta bimaculata*, a major defoliator of young eucalypts in Tasmania, (de Little 1989; de Little *et al.* 1990).

Elliott and de Little (1980) demonstrated the potential of these coccinellid species to complete larval development and to feed over a long period on a diet of *C. bimaculata* eggs in laboratory studies.

In New Zealand, Bain *et al.* (1984) devised several artificial diets for mass rearing *Cleobora mellyi*, which was introduced from Tasmania in an attempt to control *Paropsis*



Photo 1. Adult ladybird species, *Cleobora mellyi* Mulsant (left) and *Harmonia conformis* (Boisduval), predators of *Chrysophtharta bimaculata* eggs.

charybdis Stal, a chrysomelid from Australia, which caused severe and repeated defoliation to plantation-grown *Eucalyptus* species. At least one mass adult release was made, but long-term establishment was not achieved.

The integrated pest management (IPM) strategy currently employed in Tasmania for the control of *Chrysophtharta bimaculata* attempts to delay the application of insecticide until the natural enemies (mainly ladybirds and soldier beetles) have had an opportunity to reduce populations of eggs and young larvae, in many cases eliminating the need for intervention. There is potential to enhance the effect of these natural enemies by:

- (a) Release of adult ladybirds during *C. bimaculata* peaks. Reduction of larval and subsequent adult populations resulting from the egg-laying peak which commonly occurs in mid-late summer would reduce the degree of late season defoliation considerably; and
- (b) 'Seeding' with ladybirds of young, isolated plantations, particularly those on former pasture land, may enable significant predatory control to be effective at the time of initial leaf beetle occupation.

This study examines the effect of ladybirds on field populations of *C. bimaculata* as a basis for considering future manipulative use of ladybirds in control programs.

Methods

Site

This study was undertaken during the spring and summer of 1996/97 in a four-year-old trial planting of *Eucalyptus regnans* (8 ha) and *E. nitens* (12 ha) at Castra, compartment 114A, near Sprent in north-western Tasmania (1:100 000 TASMAR, Forth, Sheet 8115, grid reference 277280). The western boundary adjacent to the site was mature native forest consisting mainly of *E. obliqua* and *Acacia melanoxylon*. The other boundaries were bordered by agricultural crop fields. Both

E. regnans and *E. nitens* in the plantation have suffered annual defoliation from *C. bimaculata* since 1993.

Sampling

The *E. regnans* trial plantation trees were planted in three blocks in rows orientated north/south. A sampling scheme was devised in which five trees within a height range of 1.8–2.6 m were selected in every third row of each of the three blocks. At alternate weekly monitoring periods, the first row selected was moved down a row then back the following period. Thus, at every other monitoring period, the same trees were examined. The total number of trees sampled in 30 rows ranged from 120 to 150 per sampling period. This system was initiated to determine the area of 'hot spots' of *C. bimaculata* aggregations and the distribution of coccinellid adults.

On each tree, the total number of observed *Harmonia conformis* and *Cleobora mellyi* adults and larvae was recorded. The number of leaves occupied by *C. bimaculata* egg batches or larvae was recorded but the larvae were not segregated into instars. Adults of *C. bimaculata* were recorded in three categories: 0 = nil present; 5 = 1 to 5 present; 10 = more than 5 present. An observation period of one minute was allowed for each tree. Sampling was conducted weekly from 17 October 1996 to 4 April 1997. One week was missed in late November and another in late December.

The data were converted to express the density of each stage and species for 100 trees (Appendix 1). The variance-to-mean ratio was used as an index to measure spatial patterns of tree occupancy by ladybirds at times of both high and low prey populations (Hoel 1943).

The incidence of adult ladybirds on juvenile and mature foliage on the adjacent *E. nitens* plantations was measured. Ten shoots in the lower canopy of each of 10 trees were examined weekly for ladybirds. One hundred shoots of mature foliage and 100

shoots of juvenile foliage were examined at each sample period. The trees had egg batches of *C. bimaculata* on mature current-season growth or egg batches of *C. agricola* on juvenile foliage.

Results

Populations

The adult population of both *C. bimaculata* and the two coccinellid species had started to emerge from overwintering sites in the adjacent native forest and moved into the plantation at the commencement of sampling in mid October (Figure 1). Adult populations of *C. bimaculata* and the ladybirds peaked in early November (week 4) and slowly declined until

mid December. There was another peak of *C. bimaculata* adults at the end of December (week 10) followed by a decline until late January when the new generation of adults began to emerge. There was only one initial peak of adult coccinellid activity, which declined by late December to stable low levels until April. There was no peak of newly emerged ladybirds present on the trees late in the season. It was noted in April that blackwood seedlings bordering the plantation carried large numbers of newly emerged ladybirds feeding on psyllids prior to overwintering. The ladybirds were not found in the plantation at this time despite some chrysomelid eggs being available on the plantation eucalypts. Chrysomelid egg deposition closely mirrored adult *C. bimaculata* presence (Figure 2) but did not mirror coccinellid presence.

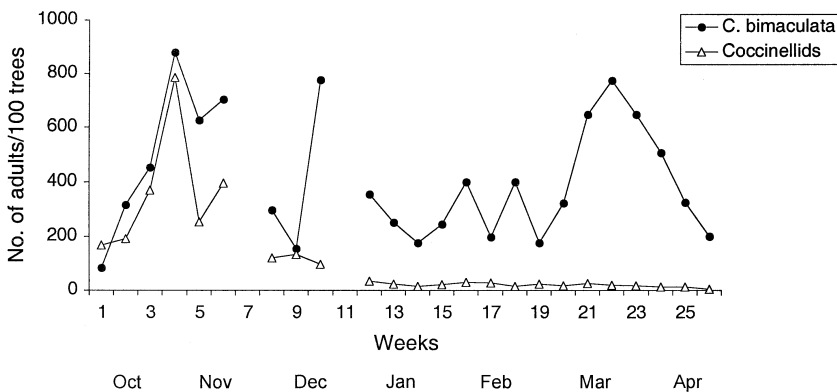


Figure 1. Numbers of *Chrysophtharta bimaculata* and coccinellid adults during the sampling period.

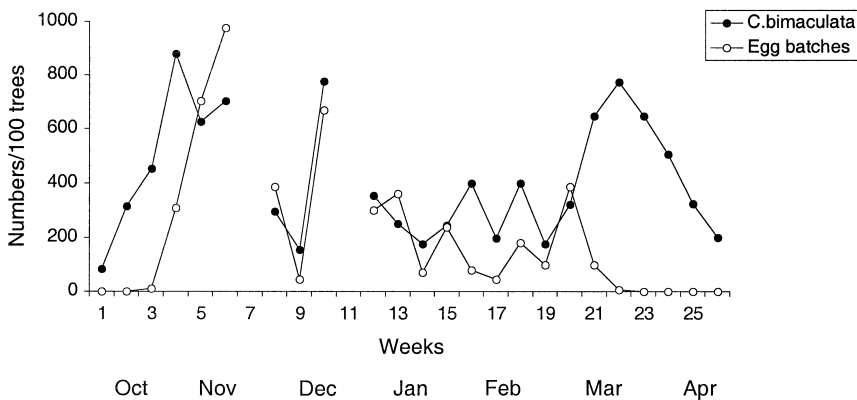


Figure 2. Comparison of *Chrysophtharta bimaculata* adults and egg-batch populations during the sampling period.

The population of *Harmonia conformis* was much smaller than that of *Cleobora mellyi* but followed the same pattern of an early season peak followed by a residual population throughout the remainder of the season. The coccinellid population remained in the plantation throughout the season, unlike *Chrysophtharta bimaculata* which has been recorded as being mobile, with loosely aggregated flights of beetles into and out of coupes (Clarke *et al.* 1997). Table 1 presents the distribution of both *C. bimaculata* and adult ladybirds on trees within the plantation at periods of high and low adult chrysomelid

density. Adult *C. bimaculata* exhibited large fluctuations between weeks in numbers present in the plantation, adults being scarce or very aggregated on patches of trees. The coccinellid population declined over time as old adults died, but distribution of individuals remained relatively even in the plantation throughout the season. Table 2 presents an analysis of the distribution of the coccinellid population over time within the plantation. The ladybirds were distributed throughout the plantation with high populations (> 1/tree) early in the season with a relatively high variance-to-mean ratio, declining to a

Table 1. Distribution of coccinellids in Castra Plantation during (a) high *Chrysophtharta bimaculata* adult population and (b) low *C. bimaculata* adult population. Numbers in the body of the table represent three classes for *C. bimaculata*, cb, such that 0 = no beetles, 5 = 1–5 beetles and 10 = more than 5 beetles. For coccinellids, c, numbers represent the actual numbers of beetles recorded (both coccinellid species combined).

(a) 6/11/99

Tree row	Block A					Block B					Block C				
	1 cb c	2 cb c	3 cb c	4 cb c	5 cb c	1 cb c	2 cb c	3 cb c	4 cb c	5 cb c	1 cb c	2 cb c	3 cb c	4 cb c	5 cb c
1	10 7	10 1	10 1	10 4	10 6	10 7	10 8	5 2	10 5	10 3	10 0	10 2	10 1	10 1	10 2
2	10 5	5 3	10 14	10 4	10 7	10 16	10 5	10 0	10 10	10 5	10 7	10 2	10 3	10 4	10 1
3	10 11	10 11	10 7	10 6	10 3	10 4	10 5	10 5	10 2	10 3	10 3	10 0	10 0	10 1	10 0
4	10 5	10 8	10 4	10 1	10 10	10 8	10 10	10 8	10 0	10 16	10 1	10 0	10 0	10 0	10 0
5	10 3	10 18	10 5	10 5	10 4	10 1	10 10	10 8	10 3	10 1	10 0	10 3	10 2	10 5	10 0
6	10 5	10 9	5 3	10 13	10 2	10 8	10 11	10 8	10 17	10 5	10 0	10 0	10 4	10 0	10 1
7	10 3	10 6	10 18	10 3	10 2						10 4	10 0	5 2	10 1	10 0
8	10 4	10 3	10 3	10 0	5 7						10 4	5 0	5 0	0 2	0 3
9	10 5	10 8	10 7	10 3	10 4						0 1	5 0	5 2	0 3	0 0
10	10 2	5 3	10 2	10 13	5 3										
11	10 6	10 7	10 4	10 5	10 3										
12	5 1	5 0	5 2	5 2	5 0										
13	5 4	0 3	5 3	0 0	0 0										

(b) 12/12/96

Tree row	Block A					Block B					Block C				
	1 cb c	2 cb c	3 cb c	4 cb c	5 cb c	1 cb c	2 cb c	3 cb c	4 cb c	5 cb c	1 cb c	2 cb c	3 cb c	4 cb c	5 cb c
1	0 1	5 0	0 1	0 2	0 0	0 1	0 1	0 0	0 0	0 1	5 0	0 0	5 3	5 0	5 2
2	0 2	0 3	0 2	0 5	5 9	0 0	0 1	5 2	5 0	0 1	0 1	5 0	0 2	5 0	0 0
3	0 0	0 6	0 4	0 0	0 1	0 1	0 1	0 2	0 0	0 0	0 1	0 0	5 0	0 1	0 0
4	0 0	0 1	0 0	5 8	0 2	0 2	0 2	0 0	0 5	0 0	0 0	0 0	0 0	0 0	0 1
5	0 1	5 1	0 1	5 0	5 2	0 0	0 2	5 4	0 2	5 11	0 0	0 0	0 1	0 0	0 0
6	5 2	5 3	5 0	5 1	5 0	5 1	0 0	0 0	0 1	0 1	0 0	0 2	0 2	5 2	0 1
7	5 2	5 2	5 3	0 0	0 7						0 1	0 1	0 0	0 0	0 1
8	0 0	0 1	5 0	0 0	0 1						0 3	0 1	5 3	0 2	0 3
9	0 1	0 5	0 0	0 0	0 0						5 0	0 2	0 1	5 2	5 3
10	0 3	5 3	5 1	5 1	0 3						5 0	0 1	5 2	0 2	0 2
11	0 1	0 3	0 0	0 1	5 1										
12	0 1	5 0	5 1	5 0	5 1										
13	5 1	0 1	0 0	5 0	0 1										

random distribution ($< 1/\text{tree}$) throughout the plantation as adults died. When high and low adult coccinellid populations were compared to high and low chrysomelid egg deposition, the coccinellid population remained evenly distributed within the plantation but was clumped in areas of high egg numbers, suggesting that short distance migration occurs to utilise food sources as they become available. In the absence of predation, there should be a direct relationship between egg deposition and subsequent larval populations of the host species.

High egg populations early in the season accompanied by large adult coccinellid populations present on the same trees resulted in low host egg survival and, subsequently, a low larval population. However, a later host egg-deposition peak was accompanied by low adult and larval ladybird populations and resulted in high host egg survival and subsequent high larval populations causing severe defoliation (Table 3). Pre-overwintering feeding by newly emerging *C. bimaculata* adults in late summer also caused severe damage.

Potential predation of *C. bimaculata* eggs by ladybird adults and larvae was estimated using results from the laboratory studies by Elliott and de Little (1980) (Table 3).

Ladybirds on *Eucalyptus nitens*

Adult ladybirds of both species were recorded as foraging mainly on the lower branches of *E. nitens* carrying either juvenile or mature foliage. There were more *Cleobora mellyi* than *Harmonia conformis* and both species showed a preference for mature foliage (Figure 3). It should be noted that large numbers of juvenile shoots were occupied by egg batches and larvae of *Chrysophtharta agricola* whilst a smaller proportion of mature shoots carried *C. bimaculata* eggs and larvae. Coccinellid predation of *C. agricola* eggs was rarely seen. Coccinellid larvae and eggs were often found on the older foliage closer to the main stem.

Discussion

This preliminary study has shown that mid- or late-season chrysomelid egg laying suffers low levels of predation compared to egg laying that occurs early in the season. Similar patterns of egg predation to those found in this study (i.e. high predation by ladybirds of early season egg peaks and lower predation of late season peaks have been noted by N. Beveridge (pers. comm.).

Introduction of *Cleobora mellyi* adults, previously fed on an artificial diet containing

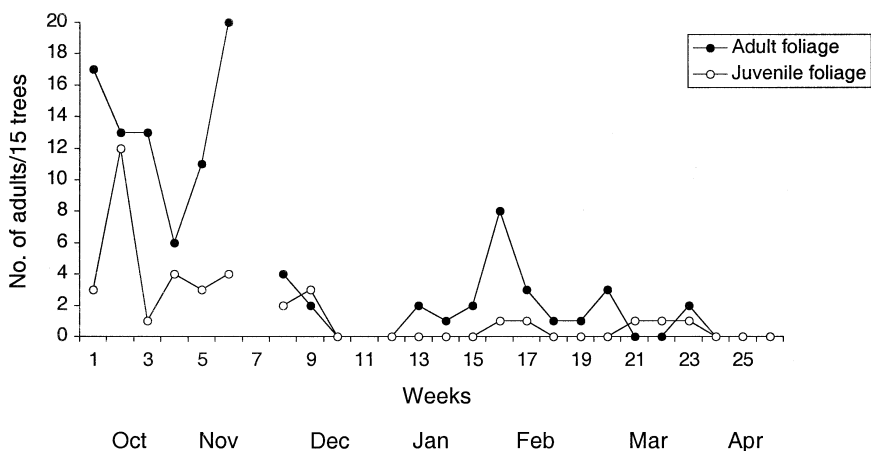


Figure 3. Numbers of coccinellid adults on *Eucalyptus nitens* during the sampling period.

Table 2. Spatial distribution of coccinellids in relation to prey egg numbers for different population ratios (coccinellids:eggs).

Ratio of coccinellids to prey eggs	Week	Block	Mean	Var	Var/Mean	SE
High/high	6	1	4.30	22.45	5.22	0.61
		2	3.53	13.48	3.82	0.55
		3	2.44	19.66	8.04	0.66
		plantation	3.65	21.25	5.82	0.39
High/low	8	1	0.60	0.87	1.45	0.12
		2	1.03	3.14	3.04	0.32
		3	0.58	0.70	1.20	0.12
		plantation	0.67	1.28	1.91	0.08
Low/high	9	1	1.10	1.72	1.56	0.17
		2	0.49	0.66	1.36	0.12
		3	0.30	0.42	1.39	0.09
		plantation	0.69	1.11	1.61	0.11
Low/low	12	1	0.22	0.21	0.97	0.06
		2	0.09	0.08	0.94	0.05
		3	0.03	0.03	1.00	0.03
		plantation	0.14	0.13	0.97	0.04

Table 3. Estimated predation of *Chrysophtharta bimaculata* eggs by coccinellid adults and larvae, based on the means of 100 trees and 28 eggs per batch.

Egg predation

<i>Chrysophtharta bimaculata</i> eggs laid in first peak	68 152
Number of <i>C. bimaculata</i> larvae surviving	18 536
Total consumption of eggs	49 616
Percentage egg predation for first peak	72.8%
Total number of <i>C. bimaculata</i> eggs laid in second peak	71 036
Number of <i>C. bimaculata</i> larvae surviving	50 148
Total consumption of eggs	20 888
Percentage egg predation for second peak	29.4%

Potential predation of *C. bimaculata* eggs by native coccinellid population (Based on consumption rates given by Elliott and de Little 1980)

<i>Harmonia conformis</i> adults	32 294
<i>Cleobora mellyi</i> adults	123 816
Coccinellid larvae	7 920
Potential consumption	164 030
Actual consumption (from first and second peaks)	70 504

psyllids for a short period and then weaned onto leaf beetle eggs, at a rate of approximately two adults per tree in high egg density sites, may be sufficient to reduce the potential larval population and subsequent defoliation levels to sub-economic levels. Release levels would be approximately two to three adults per tree (1333 stems/ha for eucalypt plantations) depending on existing coccinellid populations and the number of high egg density sites within a compartment.

The use of 'special diets' containing 'natural' food (i.e. psyllids) has been used to mass-rear other species of ladybirds to prevent migration on release (Hoffmann and Frodsham 1993). Diets for the mass production of both *Cleobora mellyi* and *Harmonia conformis* have been developed in New Zealand (Bain *et al.* 1984). Mass production of coccinellid species for weed control is conducted at Biocontrol Services Victoria and there are several commercial producers in Australia.

This study indicates that there is some potential for augmentative release of the coccinellid *Cleobora mellyi* in high value eucalypt plantations as an alternative to aerial applications of chemical or bioinsecticides. Field trials involving the release of large numbers of *C. mellyi* collected from overwintering sites should proceed to determine the viability of inundative releases at the time of low natural populations. However, the continued collection of overwintering adults is not an option as it removes populations which are exerting considerable levels of control of local leaf beetle populations. The collection technique is also destructive of the overwintering habitat and there is anecdotal evidence that the same overwintering sites are utilised for many years (N. Denny, pers. comm.). Michels *et al.* (1997) and Bain and Kay (1989) have attempted the use of artificial overwintering cages with some degree of success. The sampling methodology to measure reductions in field prey populations following augmentative releases by ladybird beetles is well documented by Luck *et al.* (1988) and techniques for marking beetles

prior to release using immuno-labelling or the conventional florescent dust are detailed by Hagler (1997).

The technique of augmentative release has been used in commercial agricultural situations for many years. Dreistadt and Flint (1996) found releases of *Hippodamia covergens*, a predator of melon aphid on chrysanthemum, dispersed up to 40 m from the release point and significantly reduced melon aphid populations by up to 84%. There was a density-dependent functional response in predation, with ladybirds consuming more aphids when released in sites of higher aphid densities. Release of adults collected from overwintering sites has not been effective except where a degree of conditioning has been included by providing diets containing the proposed prey (Hoffman and Frodsham 1993; DeBach and Hagen 1964; Hagen 1974; Obrycki and Kring 1998). An alternative method suggested by many researchers (Mensah and Madden 1994; DeBach and Rosen 1991; Ehler *et al.* 1997; Evans and Richards 1997) of supplementary feeding by spraying an attractive diet supplement to concentrate populations of existing ladybird beetles at sites of high prey density has also been tried commercially (Mensah 1997) with some success. Other predaceous species have been used in augmentative releases such as a pentatomid bug against the chrysomelid *Leptinotarsa decemlineata*, a major pest of potatoes in the Northern Hemisphere (Cloutier and Baudin 1995).

The questions to be answered in trial augmentative releases of pre-conditioned ladybird beetles are:

- Will the ladybirds disperse within the plantation, feed and reproduce?
- If suitable artificial overwintering sites are available, will ladybirds released into new plantations carrying low *C. bimaculata* populations remain in the plantation area in subsequent seasons?
- What are the ecological effects of enhancing native ladybird populations?

A recent study by Baker (1998) has shown that conditioned ladybirds released into a plantation significantly reduced chrysomelid egg numbers up to 70 m from the release point.

A cost-benefit analysis should be conducted, especially in terms of labour requirements associated with monitoring and mass-rearing. If augmentation cannot be shown to be cost-

effective, then plantation managers will not readily adopt it.

Acknowledgements

My thanks to Steve Candy for his statistical expertise and Neil Denny for interesting discussions which preceded this project. Bill Brown took the photographs of the ladybirds.

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Appendix 1. Weekly population counts of *Chrysophtharta bimaculata*, *Harmonia conformis* and *Cleobora mellyi* at the Castra plantation.

Date	Trees sampled	<i>Harmonia</i> adults	<i>Cleobora</i> adults	<i>Chrysophtharta</i> adults	<i>Chrysophtharta</i> egg batches	<i>Chrysophtharta</i> larvae	Coccinellid larvae
17/10/96	120	51	149	100	0	0	0
24/10/96	125	86	152	395	1	0	0
31/10/96	135	109	389	610	13	0	0
6/11/96	140	71	512	1230	434	0	0
14/11/96	145	26	342	900	1021	0	0
19/11/96	150	66	527	1055	1466	0	0
4/12/96	140	62	106	414	542	192	30
12/12/96	145	94	99	225	65	185	33
20/12/96	155	47	103	1205	1084	48	87
3/1/97	140	20	28	495	422	512	94
7/1/97	125	7	22	315	450	477	75
14/1/97	125	1	16	220	87	789	27
23/1/97	135	3	26	330	321	508	35
30/1/97	140	6	37	560	112	597	31
2/2/97	145	3	36	285	66	548	24
14/2/97	140	2	20	560	254	55	13
21/2/97	145	6	29	255	143	115	6
28/2/97	140	4	20	450	542	274	4
6/3/97	150	7	30	970	148	401	2
13/3/97	140	1	25	1085	9	255	1
20/3/97	145	4	20	940	2	226	0
28/3/97	135	1	16	685	0	86	0
4/4/97	140	3	16	455	0	4	0
11/4/97	135	1	5	270	0	2	0

Adjusted per 100 trees

17/10/96	43	124	83	0	0	0
24/10/96	69	122	316	0.8	0	0
31/10/96	81	288	452	9.6	0	0
6/11/96	51	366	879	310	0	0
14/11/96	18	236	627	704	0	0
19/11/96	44	351	703	977	0	0
4/12/96	44	76	296	387	137	21
12/12/96	65	68	155	45	128	23
20/12/96	30	66	777	669	31	56
3/1/97	14	20	354	301	366	67
7/1/97	6	18	252	360	381	60
14/1/97	1	13	176	70	631	22
23/1/97	2	19	244	238	376	26
30/1/97	4	26	400	80	426	22
2/2/97	2	25	197	46	378	17
14/2/97	1	14	400	181	39	9
21/2/97	4	20	176	99	79	4
28/2/97	3	14	321	387	196	3
6/3/97	5	20	647	99	267	1
13/3/97	1	18	775	6	182	1
20/3/97	3	14	648	1	156	0
28/3/97	1	12	507	0	64	0
4/4/97	2	11	325	0	3	0
11/4/97	1	4	200	0	1	0