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Enhancing Biological Control in Mating Disruption and Organic Pear Orchards by Understory Management,
by David Horton, USDA-ARS, Wapato, WA. May 1999.

FINAL REPORT

Project Title: Enhancing Biological Control in Mating Disruption and Organic Pear Orchards by Understory Management

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Summary:

The nature of the interaction between ground cover and the pear tree in low-pesticide and organic pear orchards is not well-understood, particularly with respect to whether ground cover is a valuable source of natural enemies in the orchard. The present study was done to determine whether mowing frequency affects natural enemy densities in the ground cover and pear trees of mating disruption and organic pear orchards. I showed that reduced frequency of mowing prompted large increases in densities of natural enemies in the ground cover, presumably in response to increased availability of pollen and nectar from flowering plants and to increased availability of small, soft-bodied prey such as aphids. Taxa showing the largest increases in densities included lacewing larvae, spiders, damselbugs (Nabidae), parasitoids, ladybug beetles, syrphid flies, and minute pirate bugs. Ground-dwelling predators such as ground beetles, harvestmen ("daddy-long legs"), and certain spiders were much less affected by mowing frequency, and if anything showed some slight reduction in numbers in the less frequently mowed plots. In the pear tree, counts of spiders and parasitoids were higher in less frequently mowed plots. For pest species, densities of spider mites in the tree and in the ground cover were higher in the less frequently mowed plots than in the frequently mowed plots. Virtually no spider mites were observed in the ground cover of the weekly mowed plots. *Lygus* spp. and stinkbugs associated with the ground cover increased in abundance as mowing frequency decreased. However, neither pest was recovered in damaging numbers on beat tray samples taken in the pear tree. Finally, for certain taxa (ground beetles, harvestmen, earwigs), there were extremely large density differences between blocks within orchards that easily swamped the much smaller differences within blocks caused by the different mowing treatments. Observations suggest that tree age (canopy openness?) and block location (i.e., nearness to non-agricultural habitats) dramatically affected densities of these specific predators.

Although it is clear from this study that mowing frequency had striking effects on densities of natural enemies in the orchard, it remains unclear just what impact this has on orchard pests. I monitored parasitism rates of pear psylla nymphs in all three mowing regimes, but showed no affects of mowing treatment. However, parasitism rates were atypically very low (<<10%) all season, and the study should be repeated when rates are at more typical levels. I also estimated predation rates of codling moth larvae by monitoring disappearance of larvae from cardboard strips stapled to the trunk of the pear tree. I failed to show any effects of mowing frequency on predation rates. However, strips were left in the orchards for only 48 hours (due to concerns about larvae migrating from strips to trees), and predation rates were thus fairly low. There was a positive correlation between disappearance rates and densities of earwigs in the plot, suggesting that earwigs are predaceous upon codling moth larvae. The impact portion of the study will be repeated next year at the same locations and using the same mowing treatments, but efforts will be made to improve methods and to increase sample sizes.

Background and Rationale

Habitat management to enhance biological control in cultivated crops is an increasingly common method of pest control in both annual and perennial cropping systems. Examples of this approach include use of windbreaks or hedge rows to prompt build-up of natural enemies around crop edges, planting of insectary seed mixes as cover crops in perennial crops, or management of natural ground cover (e.g., via mowing frequency, strip mowing, or selective herbicide use) to enhance build-up of natural enemies. For all of these approaches, the idea is to provide predators and parasites with alternative sources of habitat, food, or hosts, with hopes that the natural enemies will eventually move into the crop and prevent pest damage. The alternative food sources may include pollen or nectar associated with flowering plants, or arthropods that feed on the non-crop host plants. Ideally, these alternative habitats should not also act as a source of pest insects or diseases, although this can be difficult to attain in practice.

Past-reliance on broad-spectrum insecticides in pear orchards makes it unclear what role the ground cover plays in affecting insect numbers in the orchard. Growers differ in how they manage the ground cover (e.g., in mowing frequency, tilling, herbicide use, tolerance of weeds), and farms differ in the species' composition of ground cover (e.g., in dominance of broad-leaf weeds vs. orchard grass). With heavy use of insecticides, these grower or farm differences are probably inconsequential in affecting insect communities in the orchard. However, with reduced insecticide use, grower differences in ground cover management or farm differences in ground cover make-up potentially have very large effects on the types and numbers of insects occurring in the orchard. These effects may be negative or positive, in that ground cover provides habitat for both beneficial and pest insects.

Objectives of Project

(1) Determine effects of mowing frequency on density and diversity of pest and beneficial arthropods on the orchard floor, in the ground cover, and on the pear tree (summer 1998; results reported here).

(2) Estimate impact of beneficials on pear pests in each mowing regime (i.e., parasitism and predation rates). Some preliminary information provided here; more extensive research on this topic to be conducted in 1999.

Methods

Orchards and experimental design. In the summer of 1998, mowing frequency was varied to manipulate ground cover composition and associated insect communities at two orchards, a mating disruption pear block located in Hood River, Oregon and an experimental organic orchard located in Moxee, Washington (owned by USDA-ARS). Chemical controls for pests at the mating disruption orchard consisted only of a single application of an insect growth regulator (Confirm) directed at leafroller, and a post-harvest application of sulfur to control rust mite. No insecticides or herbicides were used at the organic orchard.

Three mowing frequencies were established at both orchards: (1) weekly (7-10 days); (2) monthly; (3) mowed once in early spring (hereafter referred to as unmowed). These treatments were selected to provide a full range of mowing frequencies, and are not necessarily meant to be adopted in practice by growers. At both orchards, the experiment was set out in a completely randomized block design, with 3 replicates per treatment at both orchards. At the larger orchard (mating disruption orchard), blocks were each 15-21 tree rows wide (= 5-7 tree rows per treatment plot) by 100-200 feet long. At the smaller, organic orchard, blocks were 9-12 tree rows wide (= 3-4 tree rows per treatment) x 80 feet long. At both locations, perimeter tree rows were used as buffer rows, and sampling was restricted as much as possible to interior tree rows.

Sampling. Arthropods were sampled every 3 weeks beginning in April and ending in late August. Several sampling methods were used: pitfall traps (for ground-dwelling arthropods); sweep nets and whole plant samples (for ground cover arthropods); and, beat trays and leaf samples (for arthropods on the pear tree). Total leaf area per plot of ground cover plants was estimated using point-intercept methods.

Some brief mention of the experimental design is warranted here, due to some unexpected trends in insect densities at the two sites. Our results showed extremely high block-to-block variation in densities of certain insect taxa at both sites, indicating that populations of certain species were distributed extremely patchily within the orchard. Indeed, for some specific natural enemies (see below), block-to-block differences in population densities were substantially larger than any effects produced by mowing frequency. Blocks differed from one another at both sites in a number of characteristics, including tree age (and, thus, openness of canopy), pear variety, soil type, aspect, slope, and distance to native (non-agricultural) habitats. Some brief comments about these results will be included below, as our sampling efforts in these different blocks may eventually allow us to sort out just what habitat factors lead to high densities of some natural enemy taxa in the orchard.

Impact of beneficials on pests. I anticipated large changes in the natural enemy community associated with the different mowing treatments. However, to determine whether these community changes translate into net benefits for the grower requires some measures of impact on pests. I quantified two sources of impact: parasitism of pear psylla nymphs; and, predation of late instar codling moth larvae.

Psylla nymphs were collected from the organic orchard only, as densities were too low at the disruption orchard to provide decent sample sizes. Nymphs were dissected under a microscope to determine presence of eggs or larvae of the parasitoid *Trechnitespsyllae.* Predation of codling moth larvae was quantified by monitoring disappearance rates of larvae from cardboard strips (containing larvae) stapled to the trunk of the pear tree. Strips and larvae were obtained from a laboratory culture. Strips were left in the field only 48 hours due to concerns that larvae might migrate from the strips to the trees. Control strips were placed in screened buckets and the buckets placed in the field for the same interval of time (to determine natural disappearance rates from strips due to migration).

Results

Unless otherwise indicated, results described in the following sections refer to the combined results for the two orchards.

Ground cover composition in the three mowing regimes. Season-long total leaf area of broad-leaf plants and grasses at the Hood River site was highest in the unmowed plots, intermediate in the monthly-mowed plots, and lowest in the weekly-mowed plots (Figure 1). These trends were repeated at the Moxee site (data not shown). Broadleaf species comprised about 15% of total leaf area in all three mowing regimes, and were dominated by dandelion, clovers, mallow, dock, and knapweed (Hood River site), or by dandelion and clovers (Moxee site).

Arthropod communities [beneficials] - seasonal averages. In percentage terms, taxonomic composition of the natural enemy community was similar among the three mowing treatments (Figures 2-4). (Note: all the data presented in this section refer to seasonally averaged results for the most abundant taxa; seasonal changes in densities will be presented in a following section). Beneficial taxa in the pitfall samples (Figure 2) were dominated by ground beetles (60% of the common arthropods), spiders (I 5%), staphylinid beetles (5%), and harvestmen ("daddy long legs"; 5%). As noted above, these percentages did not differ among the different mowing treatments. Sweep net samples of beneficials (Figure 3) were dominated by parasitoids (60%), spiders (15%), and damselbugs (Nabidae; 5%); again, these percentages were statistically similar among mowing treatments. Beat tray samples of beneficial arthropods (Figure

4) were dominated by spiders (60%), parasitoids (20%), earwigs (10%), *and Deraeocoris brevis* (a predatory bug; 5%), and again the various percentages were not affected by mowing.

Mowing frequency had a larger effect on absolute numbers of insects (Figures 5-8). In pitfall traps (Figure 5), decreased mowing frequency was accompanied by slight reductions in numbers of harvestmen, earwigs, spiders, and ground beetles (based upon season-long averages for each taxon). The opposite effect occurred in ground cover (sweep net) samples, in that reduced mowing frequency prompted very large increases in densities of several beneficials; i.e., counts of lacewings, spiders, damselbugs, parasitoids, syrphid flies, ladybug beetles, big-eyed bugs *(Geocoris* spp.), and minute pirate bugs *(Orius tristicolor)* were considerably larger in unmowed and monthly mowed plots than in weekly mowed plots (Figures 6 and 7). This build-up in densities of natural enemies was apparently due to increased availability of flowers in unmowed plots (source of nectar and pollen) and to increased densities of potential prey (aphids were especially abundant in the unmowed plots). The increased densities of natural enemies in the less frequently mowed plots were accompanied by similar increases in numbers on the pear tree for two major taxa: spiders and parasitoids (Figure 8). The lack of effects for other taxa may suggest that many ground cover inhabitants were not especially likely to move into the tree, that our sampling methods were inefficient at counting beneficial insects in the pear tree, or that predators moving from the ground cover into the tree did not necessarily colonize the trees occurring in the immediate area of the ground cover source (see also **Conclusions,** below).

Arthropod communities [beneficials] - seasonal frendsfor specific taxa. There were often large differences among natural enemy taxa in phenology, such that different groups of predators peaked in densities at different times of the year (Figures 9-1 1; data reported in this section refer to the Hood River site). These population trends are important to note, as they tell us when certain natural enemy taxa are likely to be most vulnerable to insecticide applications should they be used. For the ground dwelling predators (Figure 9), spiders peaked very early in the season, ground beetles and staphylinid beetles peaked in late July, and harvestmen peaked in mid-August (although common most of the summer). Arthropods associated with the ground cover tended to peak in early-July (Figure 10). Those taxa that feed extensively on aphids (including damselbugs and lacewings) showed sharp drops in numbers in mid-July (Figure 10), coinciding with a crash in the aphid populations occurring in the ground cover (aphids were very abundant on the 5th sampling date and almost nonexistent on the 6th date). On beat trays (i.e., in the pear tree), spiders and parasitoids were more abundant in late summer than early summer (Figure 11).

Block-to-block variation in densities of natural enemies. For several ground-dwelling taxa, population densities differed more among blocks within orchards than among mowing treatments within blocks. Densities of ground beetles at the Hood River orchard differed by 5-fold between the block having the highest densities of beetles and the block having the lowest densities. (Conversely, densities differed by only 1.2-fold among mowing treatments). Densities of ground beetles were extremely high in a block of very young trees (thus, an area of the orchard having relatively open canopy), and were much lower in a block having older trees- the young block was also bordered on one side by native vegetation. Earwigs (from pitfall samples) were 8fold more common in this same block than in a second block of older trees located just northwest of and adjacent to the original block. Again, these location effects dwarfed any mowing effects (1.3-fold difference only between mowing treatments). Other taxa showing high block-to-block variation included harvestmen (4-fold differences), ants (5-fold differences), and ladybug beetles (5-fold differences). These patchy distributions merit research, as the answers to that research may assist us in determining what sort of broad habitat or orchard characteristics lead to high densities of specific natural enemies.

Pest densities. Spider mite densities in pear at Hood River (the Moxee site was not sampled for this pest because of time constraints) were higher in the unmowed and monthly mowed plots than in the weekly mowed plots (Figure 12), although densities never reached damaging levels. Densities of mites on ground cover plants (particularly on mallow) were also significantly higher in the less frequently mowed plots (Figure 13). Spider n-tites were almost never observed in the ground cover of the weekly mowed plots. Pear psylla populations were not affected by mowing frequency (Figure 12). Psylla counts on beat trays were low all year at both orchards. In the ground cover, there were significant increases in densities of *Lygus* and stinkbugs in the umowed and monthly mowed plots compared to the weekly mowed plots (Figure 14). However, *Lygus* was never picked up in the beat tray samples, so it is not evident that these insects were moving between the ground cover and the pear tree. Stinkbugs were occasionally picked up on trays, but densities in the pear tree were similar in the three mowing treatments. Codling moth was not sampled, being extremely rare at the Hood River site and extremely abundant (I 00% of fruit damaged) at the Moxee site where it was not managed.

Impact of beneficials on pests. Psylla parasitism rates were atypically low most of the year (<<IO% in all plots), thus I made no attempts to compare mowing treatments for effects on parasitism rate. Generally, parasitism rates at this orchard are much higher than observed in 1998 (often >50%), and I will conduct this study again next summer when rates hopefully are high enough to allow conclusions to be made regarding the effects of mowing. The predation study involving codling moth larvae was done in August at both orchards. Disappearance rates of larvae from strips (presumably due to predation) was 10-20% per strip in 48 hours (rates adjusted for disappearance from control strips), and no relationship was noted between disappearance rate and mowing frequency. I also ran a number of correlation analyses to determine whether disappearance rates were related to densities of natural enemies. Surprisingly, there was no relationship between density of ground beetles (estimated by pitfall sampling) and disappearance rates of codling moth ($r < 0.\ 1$). However, there was a significant relationship between numbers of earwigs recovered in strips and numbers of codling moth disappearing from strips ($r = 0.80$), suggesting that earwigs are predators of codling moth. These studies will be repeated in 1999.

Conclusions

(1). Reduced mowing prompted large increases in densities of certain natural enemy taxa, suggesting that mowing frequency may be used as a means of affecting or enhancing biological control in orchards.

(2). However, of the various natural enemy taxa affected by mowing, only spiders and parasitoids showed the same population trends in the pear tree (i.e., had higher densities in the less frequently mowed plots). These results suggest: (a) that many taxa encountered in the ground cover do not move into the pear tree in appreciable numbers; or (b), that my sampling methods in the pear tree failed to adequately sample these taxa; or (c), that the insects did indeed colonize the pear trees, but that they did not colonize those trees immediately above the ground cover from which they dispersed (thus diluting any mowing effects). If this latter explanation is correct (and, I am inclined to favor this explanation over the first two explanations), larger plots than used in this study may be necessary to adequately demonstrate the effects of mowing frequency on densities of predators in the pear tree.

(3). Several common generalist predators on the orchard floor or in the ground cover (ground beetles, harvestmen, earwigs) were only marginally affected by mowing frequency. Those treatment effects that were demonstrated tended to suggest that a decrease in mowing frequency had a slightly negative effect on these taxa. For several of these arthropods, differences among blocks were much larger than differences among mowing treatments. These results suggest that population densities of these ground dwellers may be affected more by factors such as soil type, aspect, slope, tree age and openness of canopy, or surrounding habitats (i.e., nearness to non-orchard habitats) than by mowing frequency.

(4). Certain taxa were exceptionally abundant on the ground but were never collected from the pear tree (ground beetles, harvestmen). Thus, these species were unlikely to have had any direct impact on pear pests other than upon those pests that also occur near ground level at some stage of their life cycle (e.g., cutworms, late instar or diapausing codling moth larvae). Note that ground beetles and harvestmen are both thought to be effective natural enemies of codling moth, thus their presence in the orchard should be conserved as much as possible.

(5). Certain predatory taxa that are known to be effective predators of pear psylla *(Anthocoris spp., Deraeocoris brevis)* were occasionally abundant in the pear tree but were never encountered in the ground cover. This result suggests that mowing frequency or ground cover management is unlikely to have significant direct effects on densities of these important predators.

(6). Regular and frequent mowing kept broad-leaf weeds virtually free of spider mites.

(7). 1 still have a poor feel for whether changes in ground cover communities actually translate into impact on pests in the orchards. Attempts at measuring impact in 1999 were not notably successful, and I will repeat these studies (on a larger scale) in 1999 at the same orchards and incorporating the same mowing treatments.

Figure Captions

Figure 1. Seasonal change in total leaf area for grasses and broad-leaf plants in each of 3 mowing regimes. Hood River site. Data express total number of touches or "hits" along a thin rod held perpendicular to the orchard floor. Thus, data points provide crude indices of total leaf area.

Figures 2-4. Percentage composition of most common natural enemy taxa as determined by pitfall sampling (orchard floor arthropods; Fig. 2), sweep net sampling (ground cover arthropods; Fig. 3), and beat tray sampling (pear tree arthropods; Fig. 4). Each 'slice' of the pie depicts percentage of total predator/parasitoid specimens composed of that particular taxon. Results shown for dominant taxa only. Sites combined.

Figures 5-8. Densities of arthropods in monthly-mowed and unmowed plots expressed as proportion of the density found in the weekly-mowed plots. Bars ending to left of dashed line indicate that densities were higher in the weekly-mowed plots; bars ending to the fight of the dashed line indicate that densities were lower in the weekly-mowed plots. Results shown for pitfall traps (Fig. 5), sweep net samples (Figs. 6-7), and beat tray samples (Fig. 8) for the most common taxa. Sites combined.

Figures 9-1 1. Seasonal changes in densities of common natural enemy taxa as determined by pitfall samples (Fig. 9), sweep net samples (Fig. IO), or beat tray samples (Fig. I 1). Hood River site. Data averaged across mowing treatments and blocks.

Figure 12. Effects of mowing frequency on densities of spider mites (from leaf samples) and pear psylla (from beat tray samples) occurring on the pear tree. Bars ending to the fight of the dashed line indicate densities were higher in the monthly-mowed or unmowed plots than in the weekly mowed plots (treatment effects not statistically significant for pear psylla). Spider rnite data from
Hood River site- pear psylla data from both sites combined.

Figure 13. Effects of mowing frequency on densities of spider mites in the ground cover
(expressed as number per g of plant tissue [dry weight]). Whole plant samples. Hood River site.

Figure 14. Effects of mowing frequency on densities of aphids, stinkbugs, and *Lygus spp.* obtained in sweep net samples. Bars ending to fight of the dashed line indicate that densities were higher in the monthly-mowed or unmowed plots than in the weekly-mowed plots. Both sites combined.

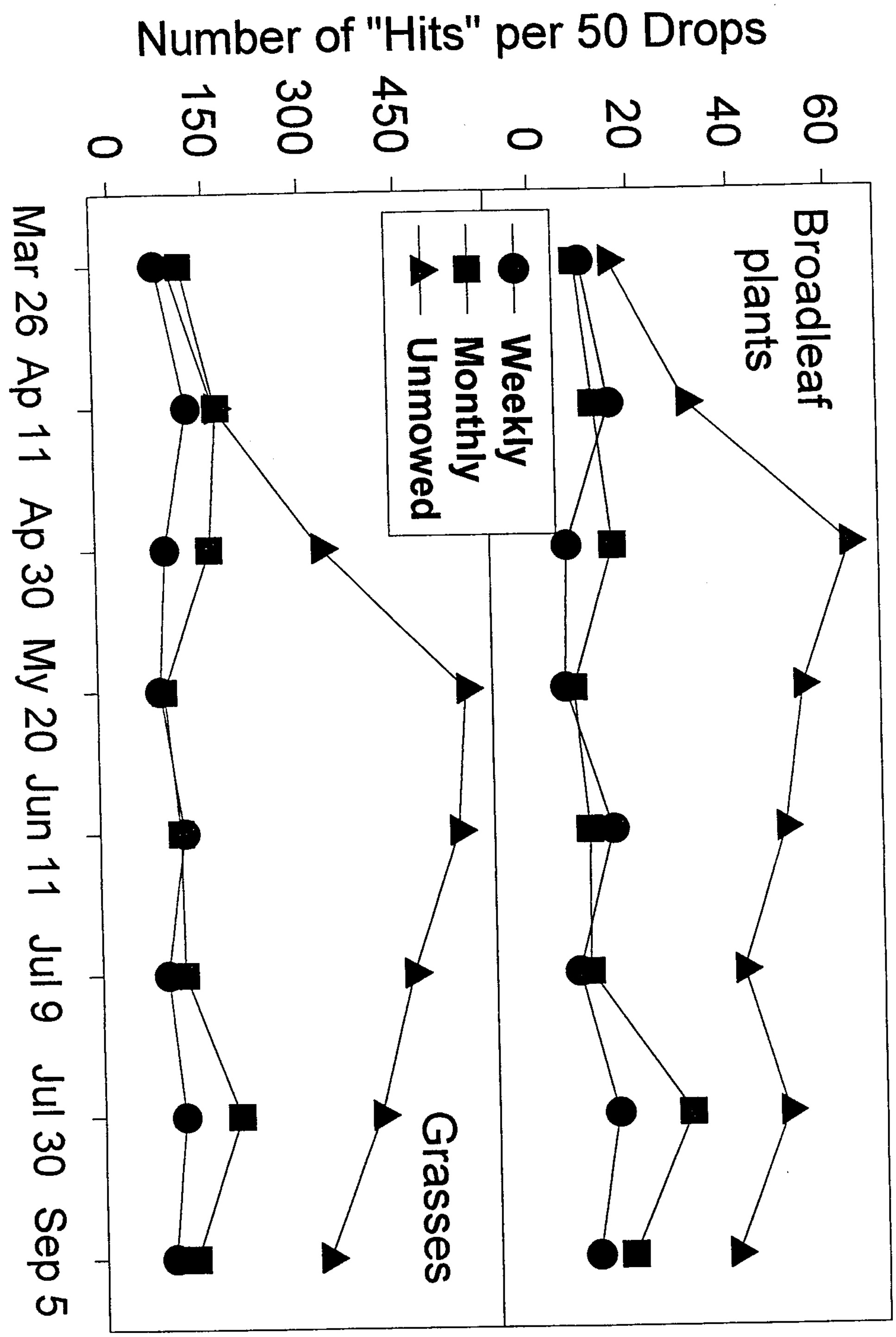

Number of "Hits" per 50 Drops
Broadleaf plants
Grasses
Weekly
Monthly
Unmowed
0
20
40
60
0
150
300
450
Mar 26
Ap 11
Ap 30
My 20
Jun 11
Jul 9
Jul 30
Sep 5

Figure 1.

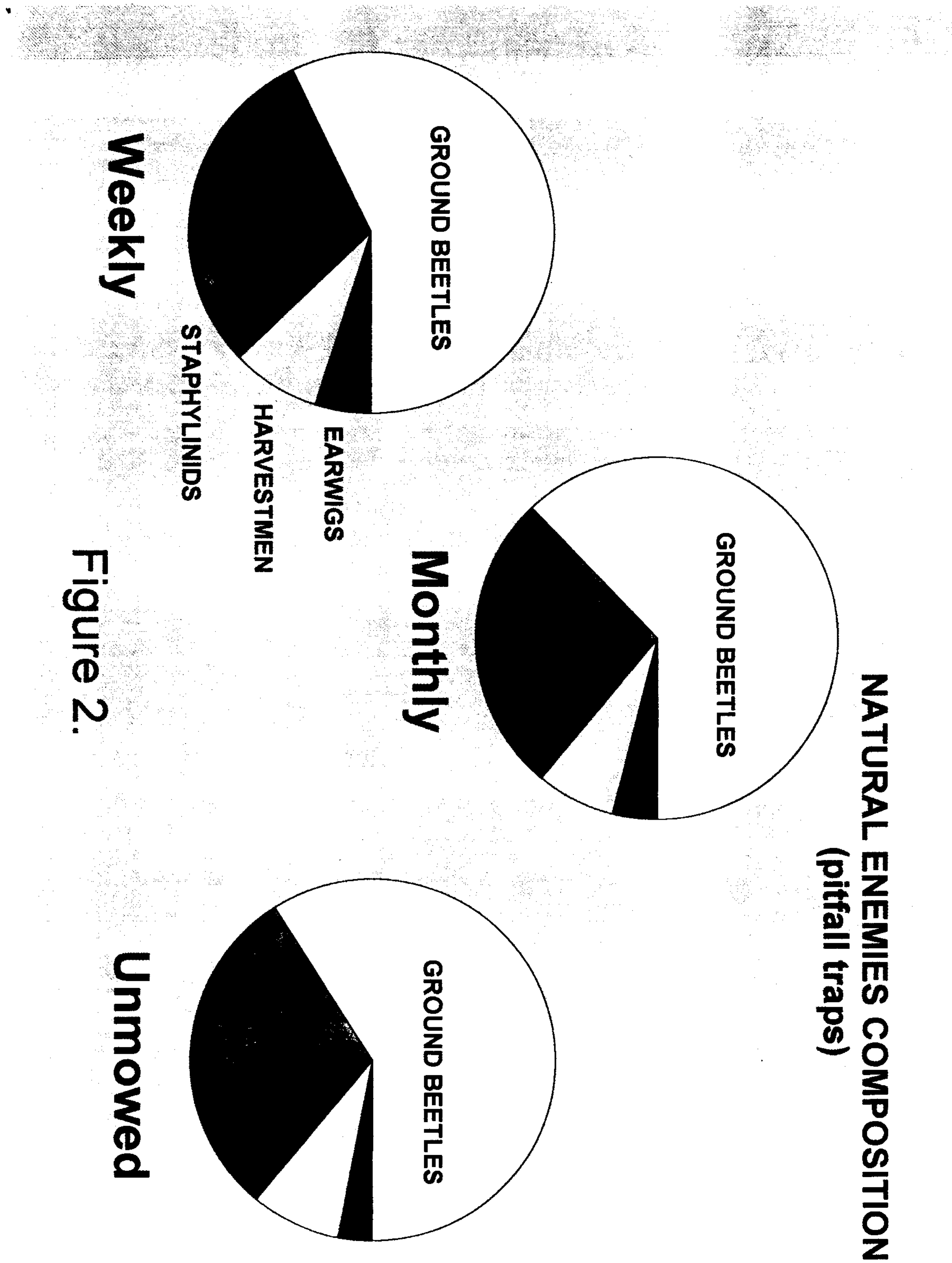

NATURAL ENEMIES COMPOSITION
(pitfall traps)
GROUND BEETLES
Weekly
STAPHYLINIDS
HARVESTMEN
EARWIGS
GROUND BEETLES
Monthly
GROUND BEETLES
Unmowed

Figure 2.

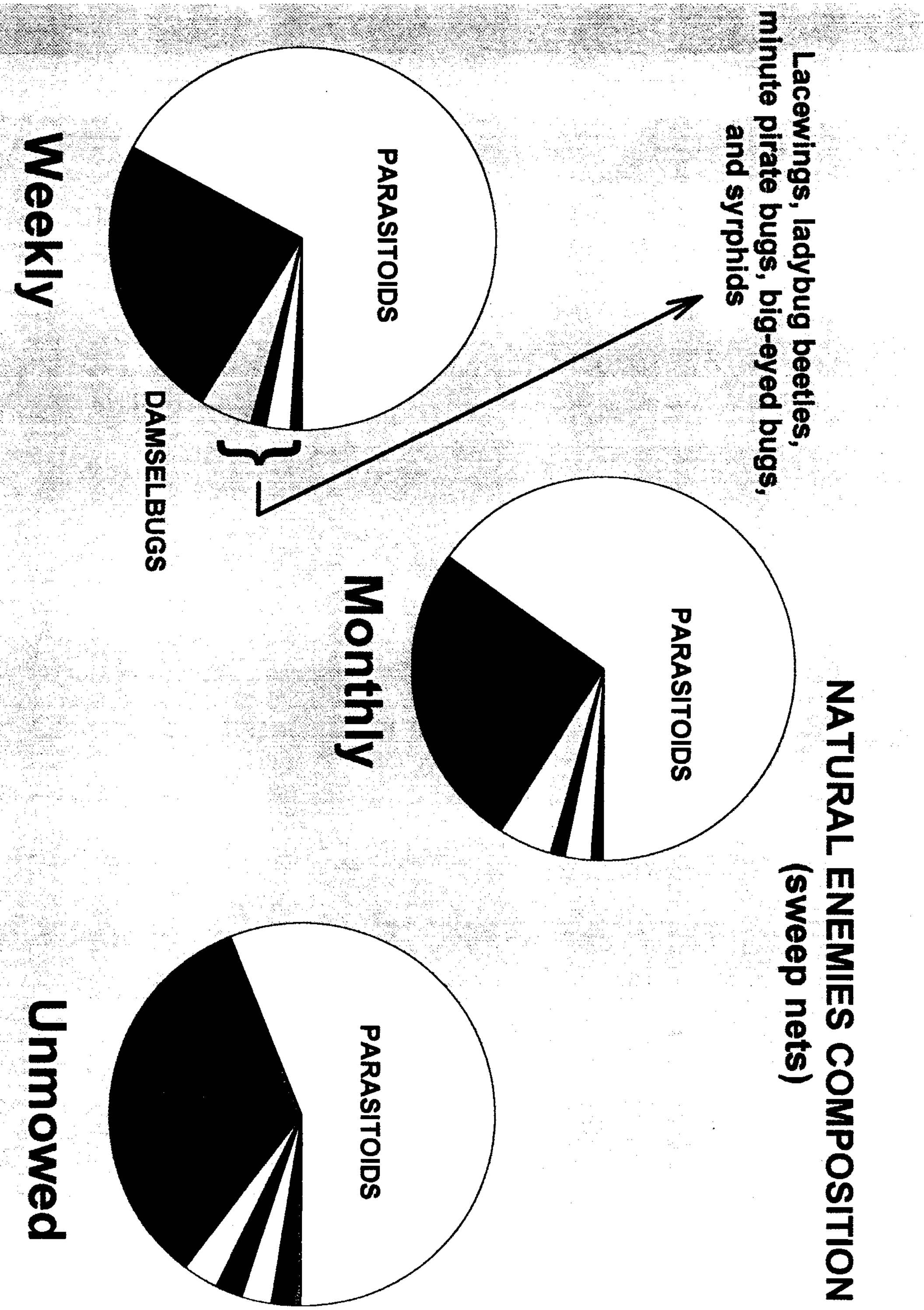

NATURAL ENEMIES COMPOSITION
(sweep nets)
Lacewings, ladybug beetles,
minute pirate bugs, big-eyed bugs,
and syrphids
PARASITOIDS
DAMSELBUGS
Weekly
PARASITOIDS
Monthly
PARASITOIDS
Unmowed

Figure 3.

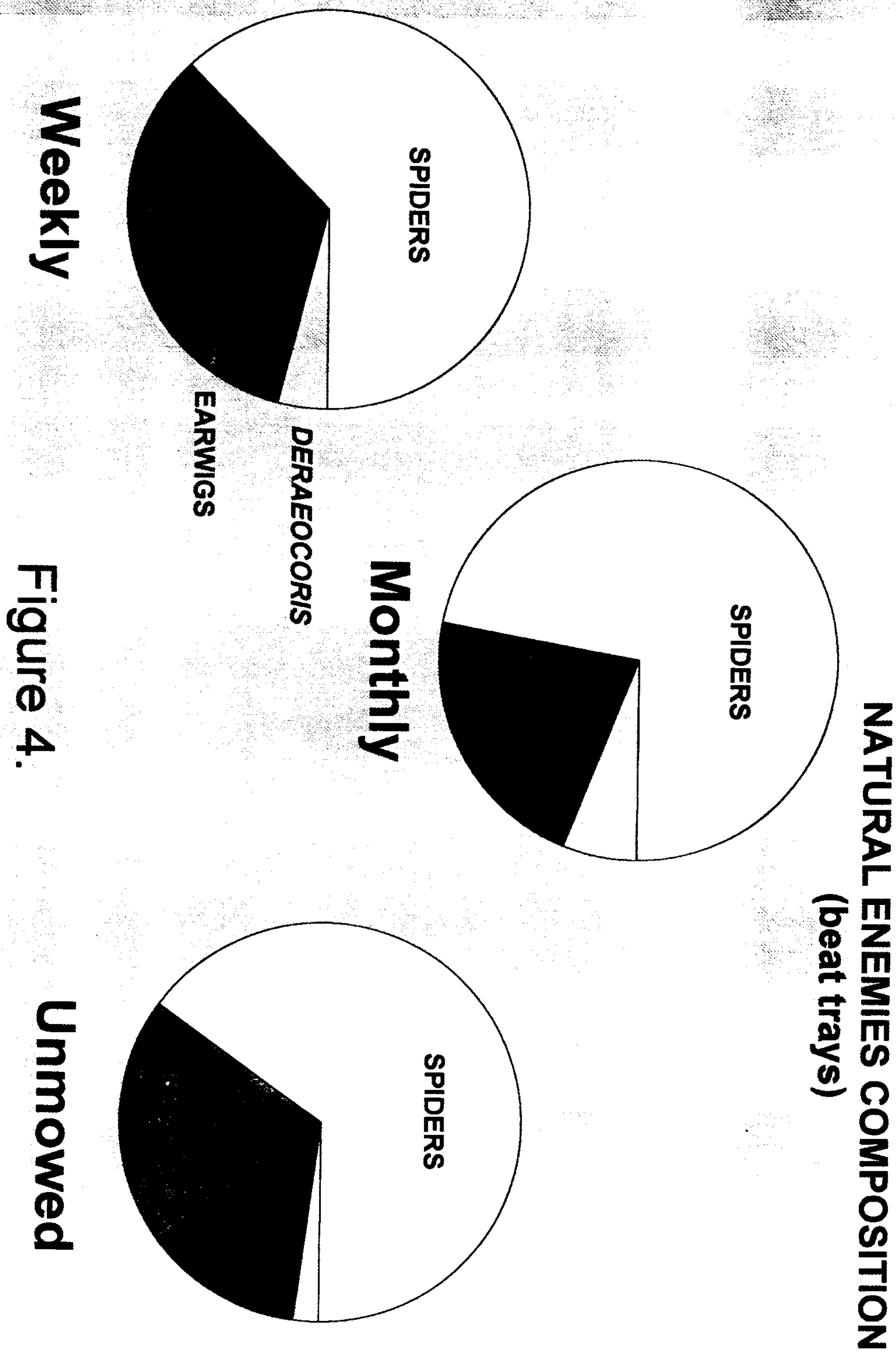

NATURAL ENEMIES COMPOSITION
(beat trays)
Weekly
SPIDERS
EARWIGS
DERAEOCORIS
Monthly
SPIDERS
Unmowed
SPIDERS

Figure 4.

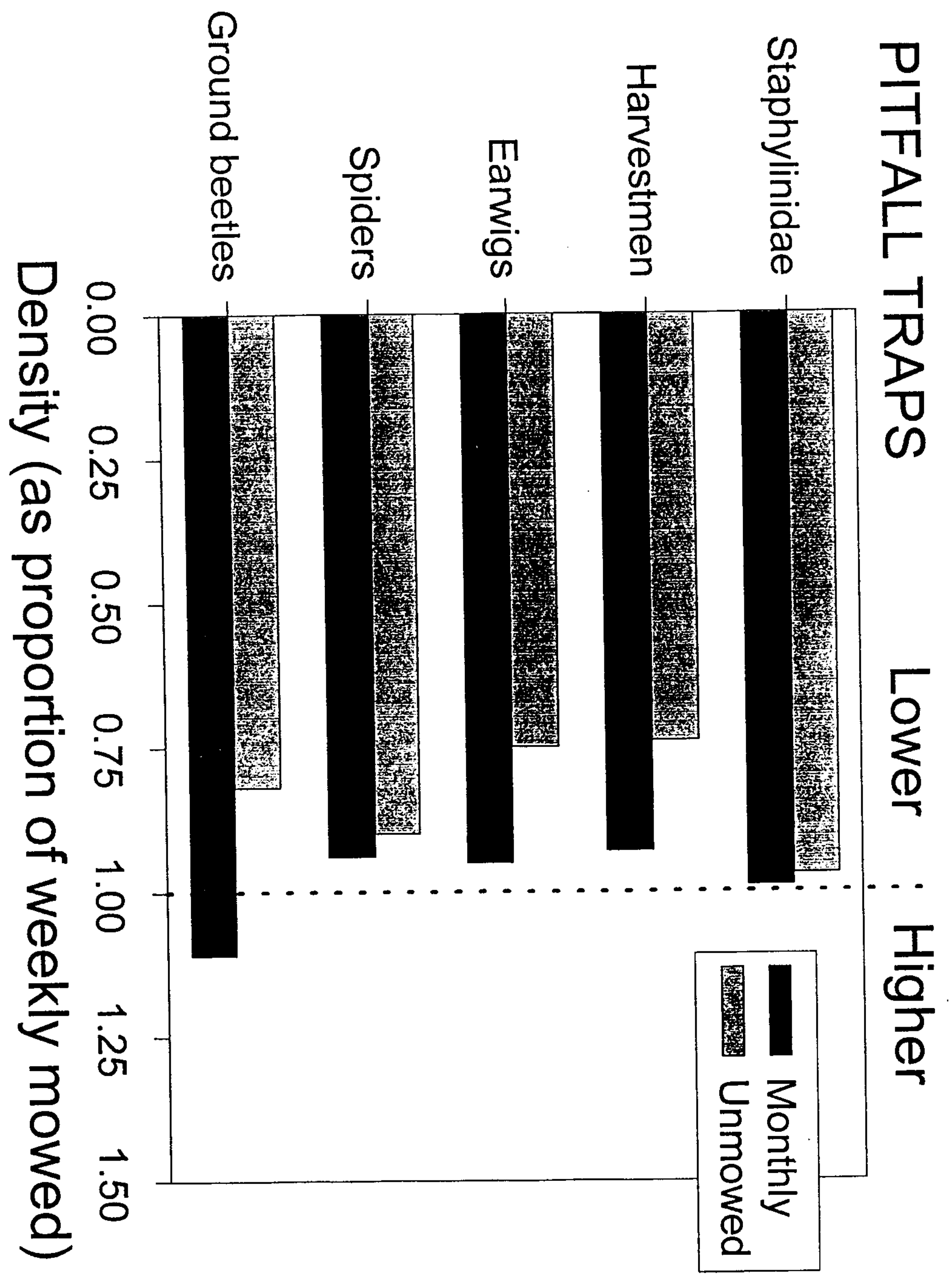

PITFALL TRAPS
Lower
Higher
Staphylinidae
Harvestmen
Earwigs
Spiders
Ground beetles
Monthly
Unmowed
0.00
0.25
0.50
0.75
1.00
1.25
1.50
Density (as proportion of weekly mowed)

Figure 5.

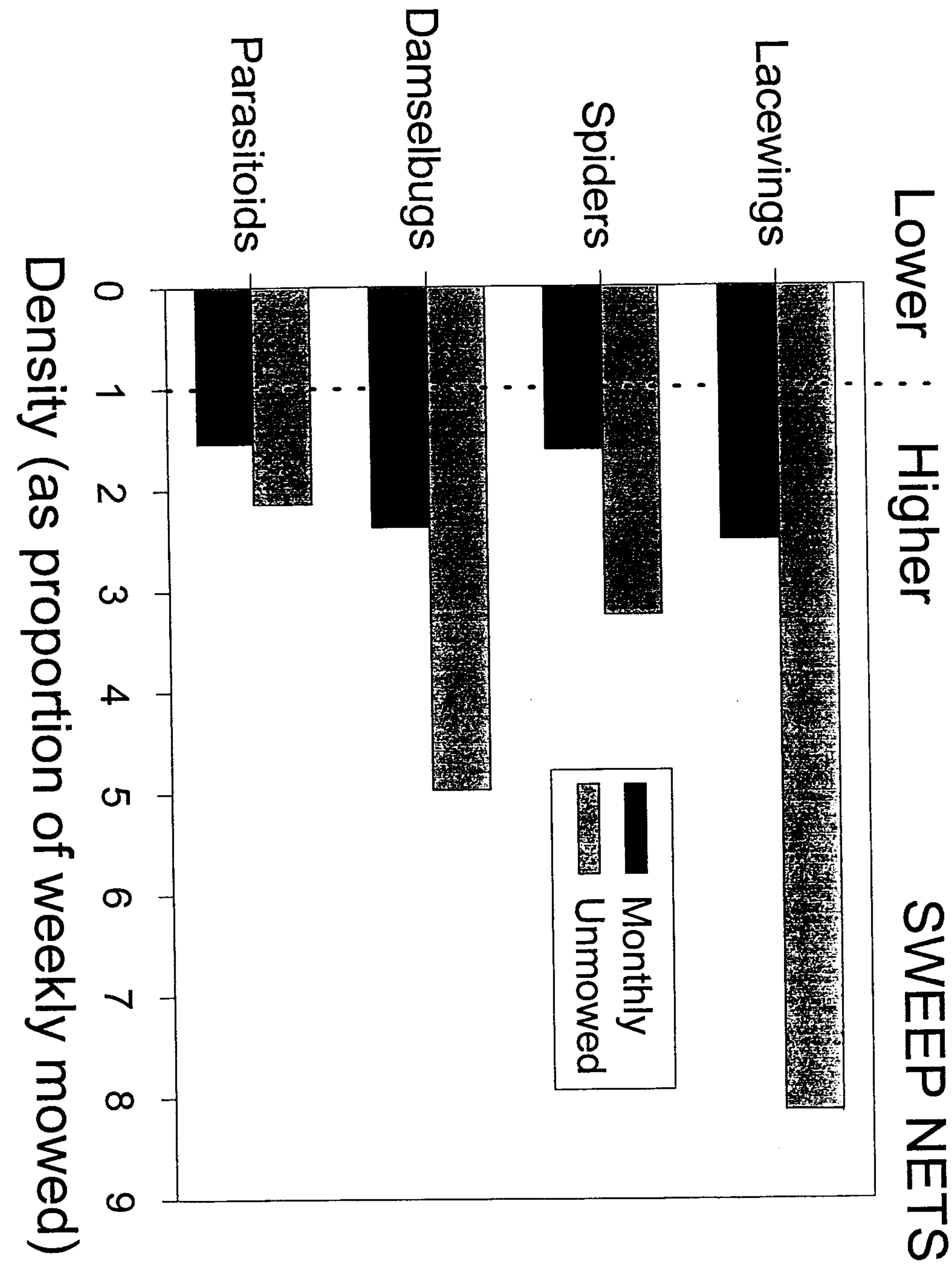

SWEEP NETS
Lower : Higher
Lacewings
Spiders
Damselbugs
Parasitoids
Monthly
Unmowed
0
1
2
3
4
5
6
7
8
9
Density (as proportion of weekly mowed)

Figure 6.

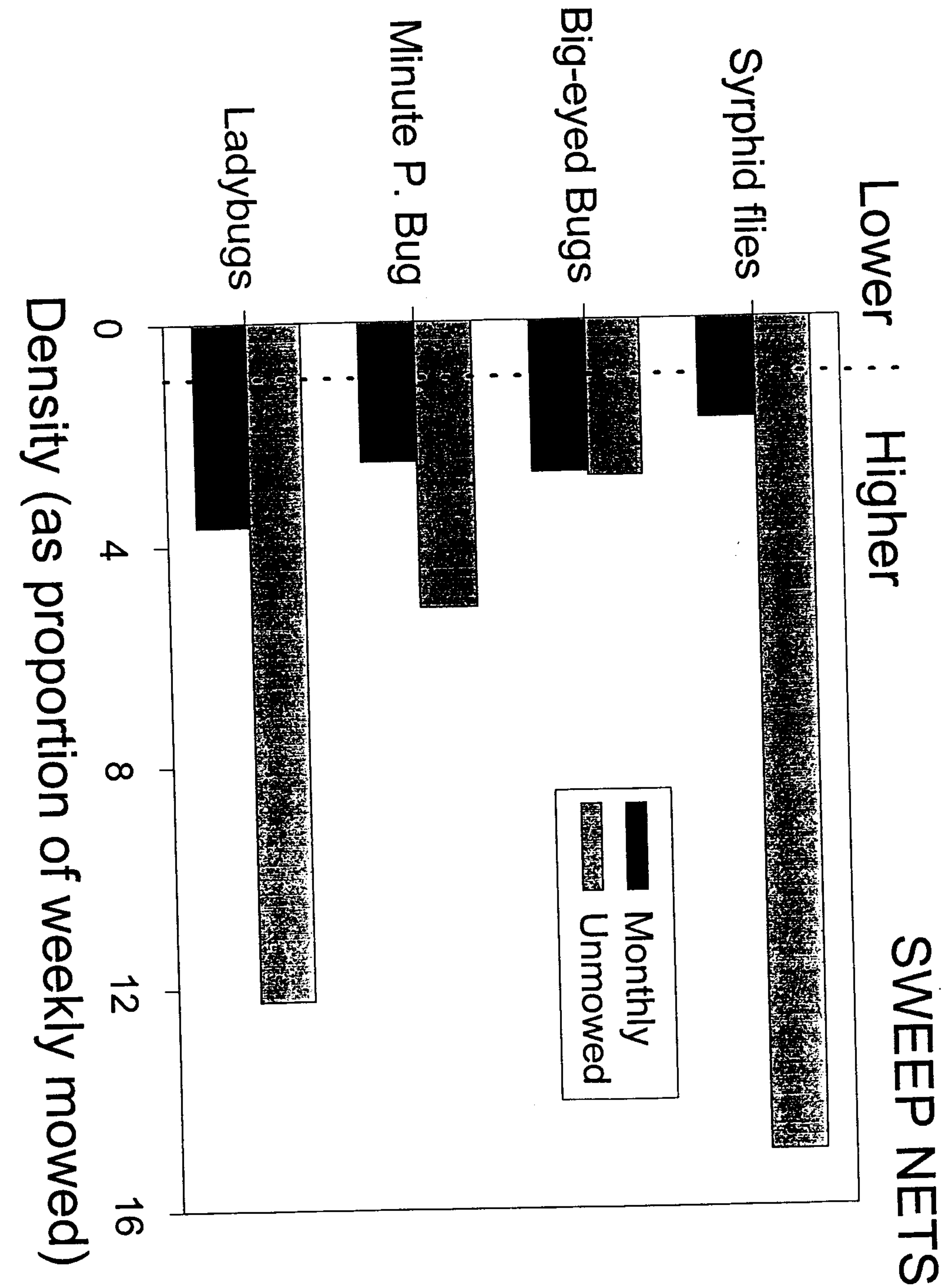

SWEEP NETS
Lower
Higher
Syrphid flies
Big-eyed Bugs
Minute P. Bug
Ladybugs
Monthly
Unmowed
0
4
8
12
16
Density (as proportion of weekly mowed)

Figure 7.

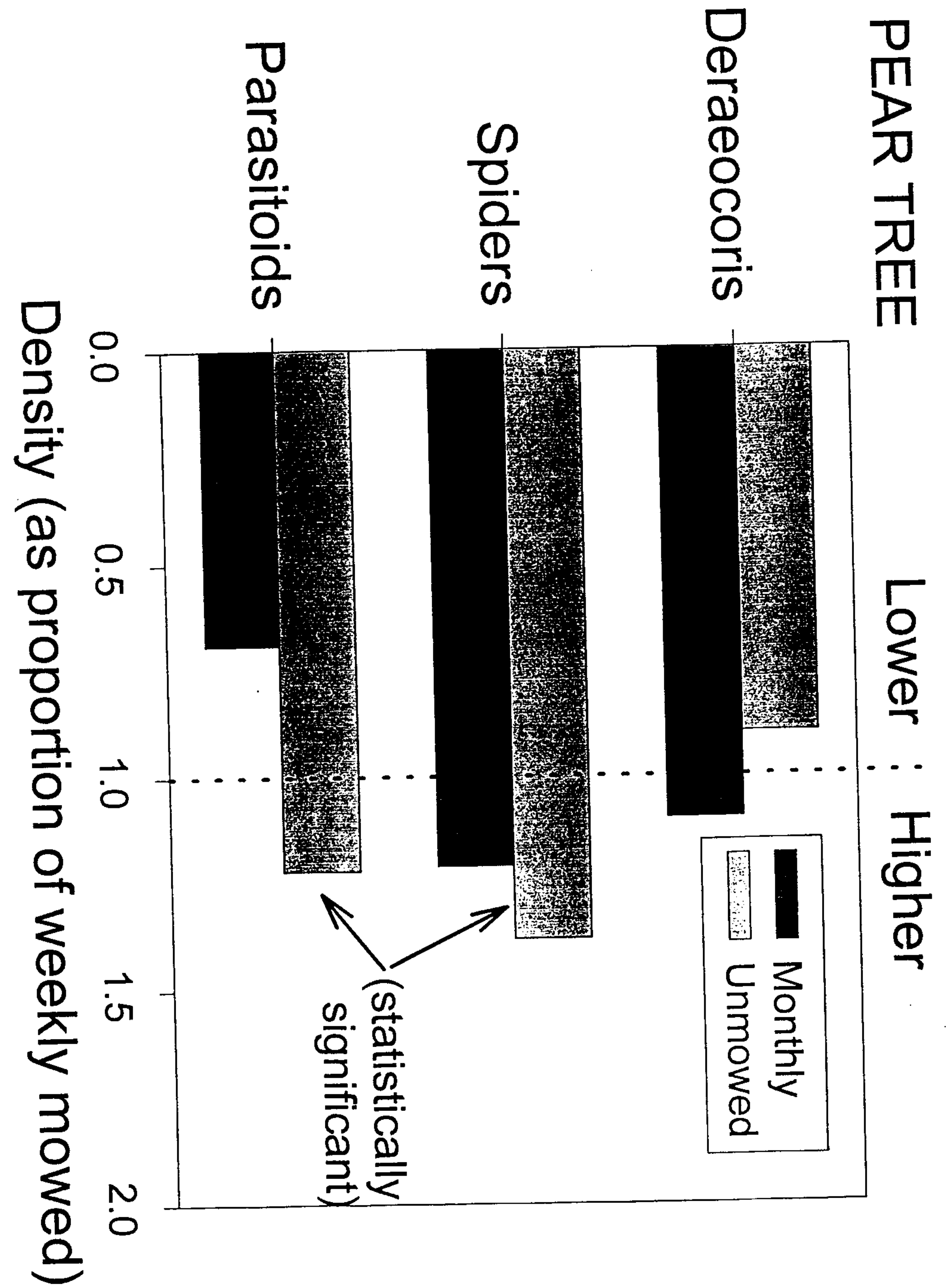

PEAR TREE
Deraeocoris
Spiders
Parasitoids
Lower
Higher
Monthly
Unmowed
(statistically significant)
0.0
0.5
1.0
1.5
2.0
Density (as proportion of weekly mowed)

Figure 8.

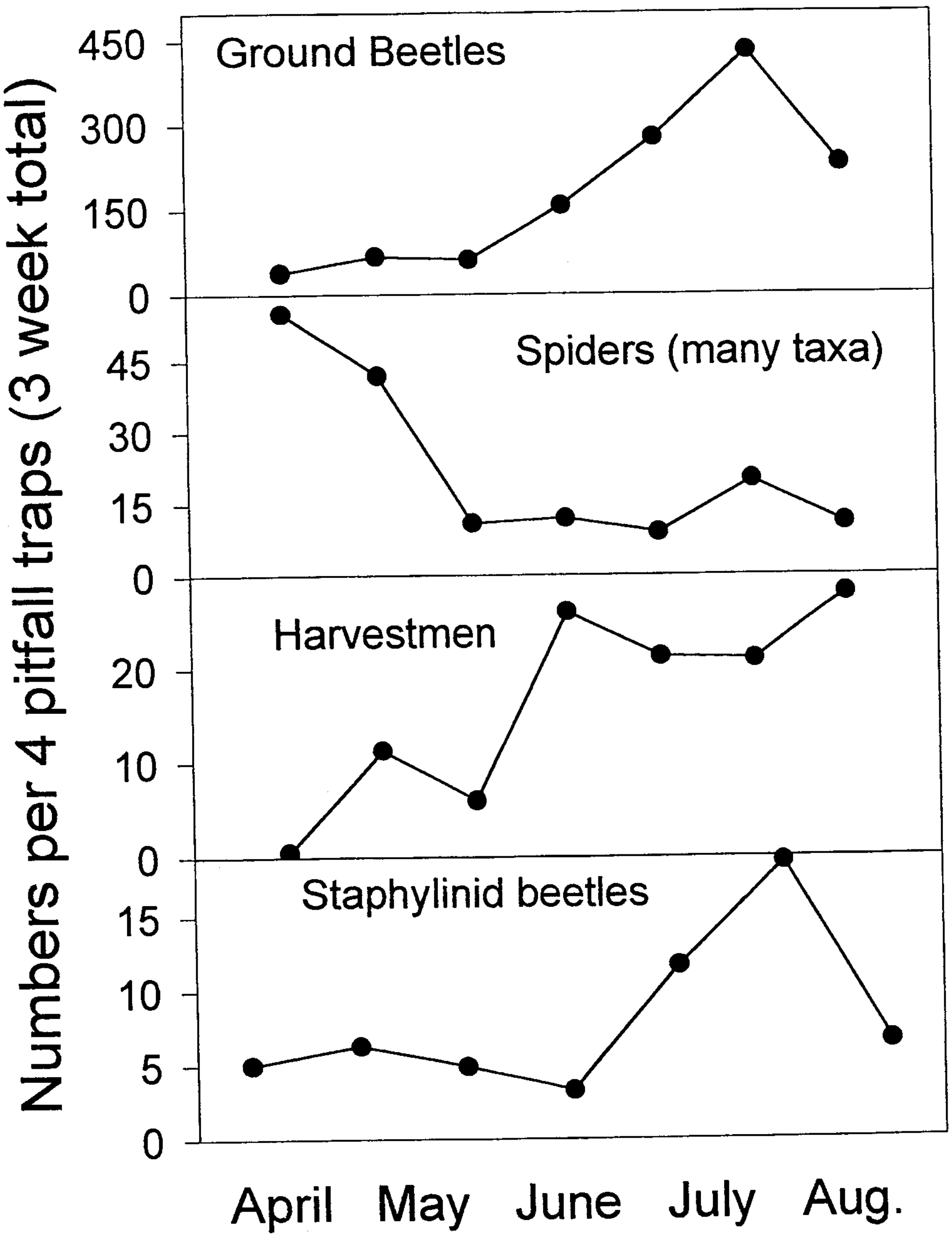

Numbers per 4 pitfall traps (3 week total)
Ground Beetles
450
300
150
0
Spiders (many taxa)
45
30
15
0
Harvestmen
20
10
0
Staphylinid beetles
15
10
5
0
April
May
June
July
Aug.

Figure 9.

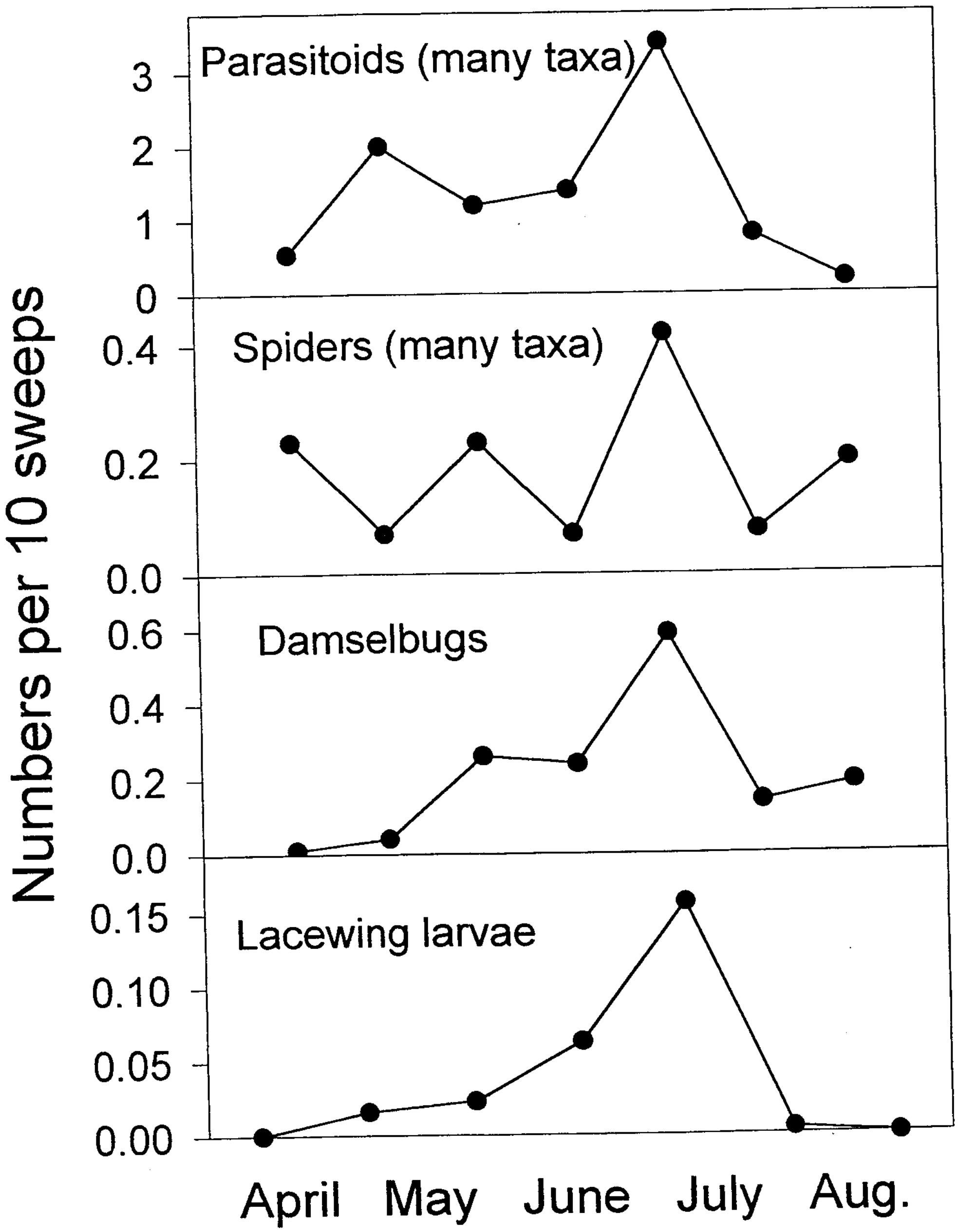

Parasitoids (many taxa)
3
2
1
0
Spiders (many taxa)
0.4
0.2
0.0
Damselbugs
0.6
0.4
0.2
0.0
Lacewing larvae
0.15
0.10
0.05
0.00
Numbers per 10 sweeps
April
May
June
July
Aug.

Figure 10.

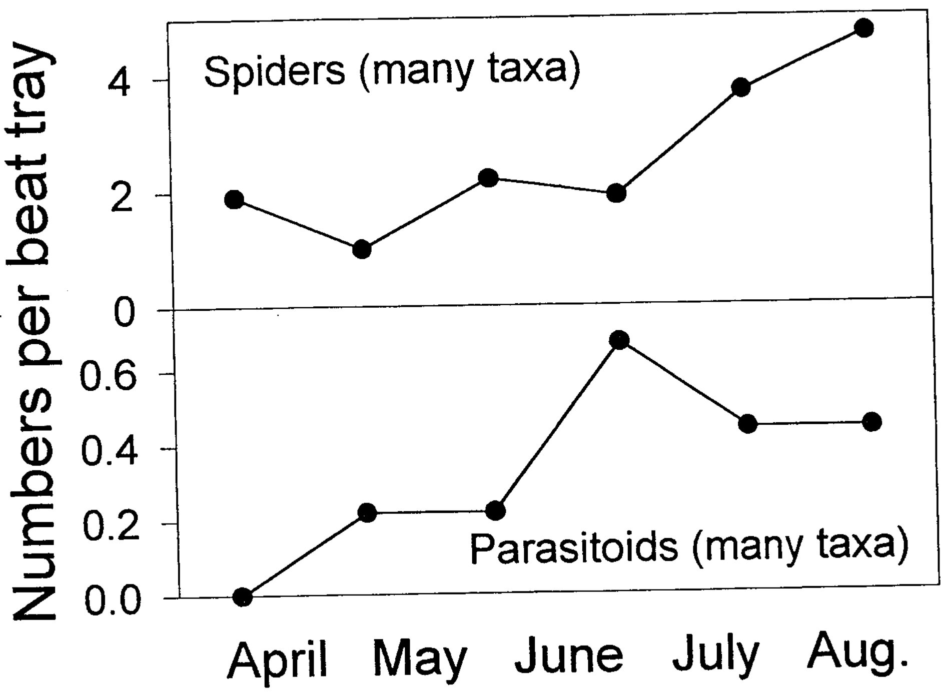
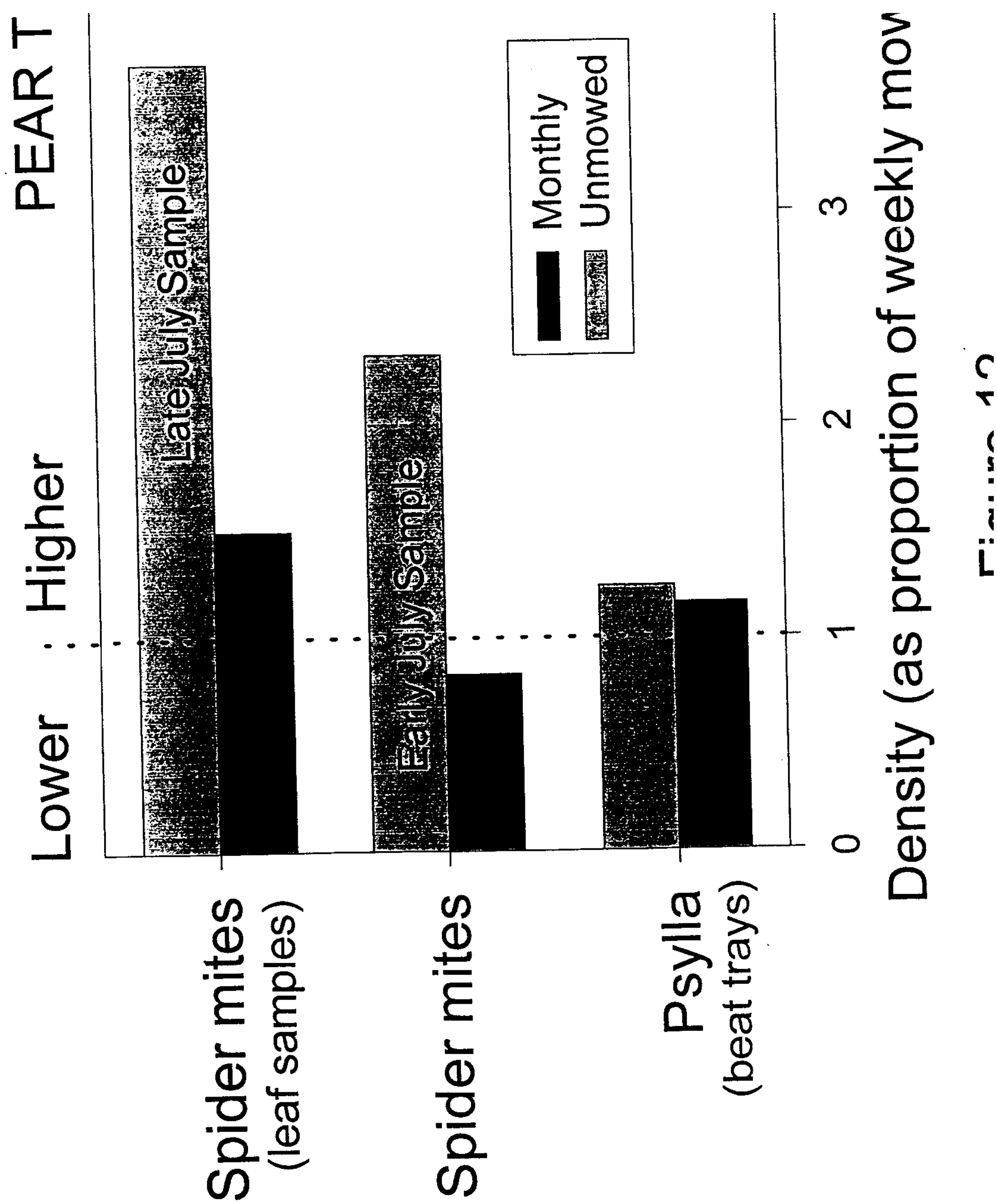

Spiders (many taxa)
Parasitoids (many taxa)
Numbers per beat tray
4
2
0
0.6
0.4
0.2
0.0
April
May
June
July
Aug.

Figure 11.


PEAR T
Lower
Higher
Late July Sample
Early July Sample
Monthly
Unmowed
0
1
2
3
Density (as proportion of weekly mov
Spider mites
(leaf samples)
Spider mites
Psylla
(beat trays)