Habitat Creation Through Farmland Stewardship:
Insect and Weed Colonization of Habitats Created through Farmland Stewardship and the Potential Impact on Agricultural Crops

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Background:

The lower Fraser River delta is an osasis to the 1.5 million migrating birds that stop over on their journey between breeding areas in the Arctic and wintering grounds in the southern United States, Central and South America (Butler and Campbell 1987). The biologically rich delta supports the largest wintering population of shore birds, water fowl and birds of prey in Canada, as well as breeding populations of neotropical songbirds in the summer. The birds and other wildlife which are reliant on the delta, are however, in competition with man who relies on the rich alluvial soils and long frost-free growing season to maintain one of Canada's most productive agricultural areas.

The Delta Farmland and Wildlife Trust (DF&WT) is committed to establishing wildlife habitat in perpetuity by farmland stewardship. This includes the planting of grassland set-asides, hedgerows and grass margins to provide habitat for ground nesting birds, song birds, birds of prey, small mammals and insects. The financial support of Environment Canada's Action 21 Programme will complement existing DF&WT stewardship programmes by providing opportunities to create additional wildlife habitat and to monitor the effects of this habitat on wildlife and the agricultural community.

Farmer participation is essential and has been encouraged through incentive-driven stewardship programs. There has, however, been considerable concern by farmers over the potential of such habitats to attract pest species which may negatively impact crops. If the farm stewardship programs are to succeed, the DF&WT must be able to demonstrate that the establishment of these habitats do not significantly compromise agricultural production. On the other hand, it has been shown that some polyphagous arthropod predators which shelter in such habitats can be effective in reducing numbers of pests such as cereal aphids (Sotherton 1984). The Trust may, infact, be able to encourage greater farmer involvement if it is able to show that the programs enhance populations of such beneficial species.

E.S. Cropconsult Ltd. has been involved in the evaluation of hedgerows, grass margins and grassland set-asides established by the DF&WT. The study focuses on the impact on crops of insects and weeds which colonize these habitats. We were particularly interested in populations of beneficial predators such as ground beetles, syrphid flies and parasitic wasps and pests such as thrips, wireworm, and plant-feeding bugs.

Hymenoptera (wasps, bees and ants)

Parasitic and predatory wasps can be of great value to the farmer. But as more wildlife habitat is taken up by monoculture crops, many indigenous predators, largely hymenoptera which depend on a diversity of plants to support their prey, are eliminated (van Emden 1965, 1981 as cited in Thomas *et al.* 1991.) Predatory hymenoptera have been found to be uniformly distributed in fields of naturally developed vegetation and in sown fields (Gathmann *et al.* 1994). Plant food availability apparently does not influence their numbers.

The decrease in pollen and nectar-bearing plants as a result of land clearing for agricultural expansion has resulted in a sharp decline in populations of honey bees and bumble bees (Corbet 1987). When pollination fails, crops such as clover and field beans decline. In Europe the typical response to such declines has been to switch over to cereal crops which do not rely on pollinators for propagation. Such crops, however, do not offer nectar or nesting sites to bees resulting in a further decline in pollinator populations. In Canada the leaf-cutter bee, *Megachile rotundata*, was introduced into alfalfa fields and found to significantly enhance the yield of seeds. Bumble bees are also attractive as pollinators and work faster, for longer hours and in worse weather than honey bees. They carry more pollen and often visit crops that honey bees will avoid. Yields of the field bean, *Vicia faba*, have been shown to triple when visited by bumble bees though the plant does not require pollination by insects to produce seeds.

Providing flowering plants in hedgerows and grass fields may significantly benefit the yield of crops requiring pollination by bees. Habitats with great floral diversity, such as old meadows with naturally developed vegetation, offer better and richer food sources to pollinating bees than do new meadows (Gathmann *et al.* 1994). In contrast, some bee species which colonized early-successional fields took twice as long to provision cells due to the low plant species richness of these habitats. Management by mowing, however, greatly increases plant richness in early-successional set-asides, doubling species richness of bees. Older set-asides showed the greatest plant and thus insect diversity when both mown and unmown areas were present together.

The collecting methods used in this study were not specific for pollinators and thus very few were collected though their presence was often observed. Due to the importance of this group of insects, it would be interesting to include methods for pollinator collection in future seasons.

Coleoptera (beetles)

Many European studies have looked at the distribution and abundance of ground beetles (Coleoptera: *Carabidae*) and rove beetles (Coleoptera: *Staphylinidae*) due to their potential to control pests such as cereal crop aphids (Sotherton 1984). Staphylinids were found in consistently higher abundances in shelter belts with a thick deciduous leaf base than in hedgerows, grassbanks and grass strips (Sotherton 1984). Carabids, predaceous both as adults and larvae (Borror *et al.* 1989), were found in higher abundances in hedgerows than in other field boundaries. To maximize land the removal of hedgerows to accomodate large machinery, or the failure to plant them, means less overwintering sites available to carabids which, in turn, greatly limits their potential to feed on crop pests the following spring. Although they rarely travel long distances from their habitat in search of prey, they are important predators in the areas in which they are found.

It has often been observed that carabid and staphylinid abundances between similar areas and in different years are not always similar (Sotherton 1984). Thiele (1964) postulated that sensitivity to microclimate, particularly temperature and humidity, may influence the distribution of polyphagous predators.

Wireworms (larval click beetles) are polyphagous pests which can be extremely injurious to crops (Jones 1964). They are most abundant in the soil under permanent grassland and only come to the surface when the soil is exceptionally wet. Damage to crops often escalates when grassland is ploughed and wireworms turn to arable crops for food. Adult wireworms, or click beetles, are found scurrying over the soil surface and through the grass from April to July. Mating and oviposition are completed by July and both males and females die.

There are 2 active feeding periods each year, one in the spring which coincides with the seedling stage of many crops, and one in the fall, when crops are mature. Damage is often greatest in the second year of the 4-5 year life cycle. Potato tubers may become riddled with feeding holes though much of this damage is purely aesthetic. Early potatoes, harvested early, can often be saved from the fall feeding period but late potatoes are often scarred and downgraded as a result of wireworm damage. In recent years in Florida up to 45% of the total potato harvest was downgraded due to this damage (Jansson and Lecrone 1991).

Mechanical and chemical control of wireworm is very difficult due to the very small size of the larvae in the first 2 years of the life cycle and due to the mass of soil protecting the larvae below (Jones 1964). It has been suggested that damage to potato tubers can be reduced by removing the cover crop by fallowing fields (McSorley et al. 1987). A positive correlation was found between potato tuber damage and number of days that the cover crop was present during the summer. Others studies showed that potatoes that followed early-planted cover crops in April and June had more wireworm and more damage than those that followed late-planted cover crops in July (Jansson and Lecrone 1991).

Weeds:

Weeds often invade crops with such vigour that they rob the soil of nutrients essential for optimal crop yields. In the grass margin and established setaside sites, different grass species were chosen to compare effectiveness against weed invasion, as well as benefit to wildlife.

Objectives:

Summer, 1996:

1) to determine the diversity and relative abundances of insect and weed species which colonize grassland setasides, grass margins, hedgerows and crops.
2) to determine if pest and beneficial insect populations are significantly different in locations within and between sites.

Long term:

1) to determine if a correlation exists between the abundance of certain beneficials and pests within and between years.
2) to monitor insect and weed density changes over the growing season.
3) to determine if the introduced habitats above increase, decrease or have no effect on pest and beneficial insect populations in the adjacent crops.

General Sampling Methods:

Insects were collected at each site over three sampling periods between July 31 and September 17, 1996. Methods of collection were pitfall trapping, sticky card trapping and sweep-netting.

Pitfall traps were made from 500 ml plastic containers which were set in the ground flush with the surface. Approximately 2 cm of water was put into each trap in order to drown insects, thus preventing predation of and by other insects in the trap.

In the hedgerows sticky cards (4x6", Pherotech® Inc.) were wired to inside branches approximately 5 ft from the ground. In the grass margin study site, sticky cards were wired to stakes approximately 4 ft from the ground. All other cards in all other sites were set on stakes approximately 30 cm from the ground. Pitfall traps and sticky cards were set for 7 days for each sample period.

Each sweep net sample consisted of ten sweeps. Standardization of hedgerow sweeps was often difficult due to the inability to sweep through blackberry brambles and hawthorn. Hedgerows were beaten, therefore, to lift insects from foliage, and swept as closely as possible.

Two weed surveys were conducted on Aug 7 and Aug 27. For the first survey a sample of each weed was collected along a 12 m transect. This, however, was not sufficient to represent all weeds present in a site. For the second survey, abundances of dominant weed species were estimated for each site. Voucher samples were collected, pressed and filed for reference.

Site Description

A: Set-asides:

i) *Established Setasides:*

Two mature grass setasides were selected for study (Appendix A). Each was 3 years old and seeded with timothy (*Phleum pratense* L.), tall fescue (*Festuca arundinacea*) and orchard grass (*Dactylis glomerata*). Two paired 20 x 20 m blocks of each grass species were selected, one block of each pair was "cut" and the other "uncut". Uncut blocks were 1 - 1.5 m in height. The cut blocks at Set-aside Site 1 (hereafter referred to as SA-1) on Brunswick Point were cut in July before the first sample and again in late August before the last sample. The cut blocks at SA-2 (Fig. 1b), on 34th St., were last cut in 1995 and were indiscernible in height from the uncut blocks.

One pitfall trap and one sticky card were set in the centre of each block in both the cut and uncut sections. One sweep net sample was taken in each of the cut and uncut blocks for each grass species. Samples were collected on Aug 7, Aug 26 and Sept 17.

ii) *Newly-planted Setaside:*

One newly-planted setaside was selected for study (Appendix A). This setaside, SA-3, was seeded in late June, 1996 with the DF&WT setaside mix (Appendix B). Each treatment block in the field was treated with a different concentration of turkey manure; recommended dose (Treatment 1), double the recommended dose (Treatment 2) and no manure (Treatment 3). Five pitfall traps and 5 sticky cards were set within each treatment block.

B: Grass Margin:

The single grass margin study site, GM, was adjacent to SA-1, separated by a ditch (Appendix A). On the other side of the grass margin was a potato field. The margin was composed of 10 m x 3 m blocks, seeded with different grass species. Three blocks of creeping red fescue (*Festuca rubra rubra*) and 3 blocks of chewings fescue (*Festuca rubra commutata)* were selected for study. One pitfall trap and one sticky card were set in each block in 3 locations; in the grass margin, 2 m into the crop and 10 m into the crop.

C: Crop Margin:

The single crop margin study site, CM, was a stretch of unseeded dirt adjacent to a potato crop (Appendix A). There was no hedgerow or grass margin present. The crop margin was largely dominated by weeds such as red root pigweed, green smartweed and lady's thumb. This relatively barren site was selected to compare the insect diversity and abundance with those found in crop edges with grass margins and/or hedgerows. Five pitfall traps and 5 sticky cards were set along the margin and 5 were set at approximately 10 m into the crop. The potato crop was top-killed prior to the last sample.

D: Hedgerows:

Four established hedgerows and one newly-planted hedgerow were selected for study (Appendix A). Two of the established hedgerows were considered "medium" and 2 were considered "large" based on a height classification developed by Mike Short (1995). One medium and one large hedgerow had an adjacent grass margin. In hedgerow sites adjacent to crops, traps were set in the grass margin, if present, at 2 m and at 10 m into the crop to monitor insect movement into the crop from the hedgerow.

i) *Medium Hedgerows:*

Both hedgerows are both composed mainly of hardhack, Himalayan blackberry and hawthorn with occasional mountain ash, bitter cherry and crab apple trees along the length. The grass margin at Hedgerow Site1, HR-1, was composed mainly of perennial rye and Canada bluegrass and an occasional red-osier dogwood. This hedgerow and grass margin was adjacent to SA-3. The hedgerow at HR-2, without a grass margin, divided two pesticide-treated potato fields.

ii) *Large Hedgerows:*

Both hedgerows were composed mainly of hardhack, Himalayan blackberry, hawthorn, and poplar. HR-3, with no grass margin, was adjacent to a pesticide-treated potato field. HR-4, with a grass margin, was adjacent to an organic bean field. The grass margin was composed mainly of velvet grass, rye grass and bentgrass with lamb's quarter, curled dock, Canada thistle and bull thistle.

iii) *Newly-planted Hedgerow:*

This single new hedgerow, HR-5, was planted by the DF&WT in November, 1996. The maple and red cedar saplings were spaced evenly along a pasture edge approximately 150 m long. Most of the cedar saplings did not establish well due to harsh weather conditions shortly after planting and therefore, died before the 1996 sampling season. These saplings were, however, replaced in the Fall, 1996.

The hedgerow, which more closely resembled a grass margin at this stage, was composed mainly of bentgrass, timothy, rye grass, and orchard grass (Table 1). Other weeds growing in the hedgerow were hemp nettle, Canada thistle, buttercup, purple-leafed willow herb, curled dock, barnyard grass, red clover, stinking chamomile and sowthistle.

Table 1. Hedgerow site characteristics

Site	Boundary type	Height (m)	Width (m)	Main tree/shrub or grass cover
1	hedgerow	3	3	hardhack, blackberry, hawthorn
1	grass margin	1	2	perrenial rye, Canada bluegrass
2	hedgerow	3	3	hardhack, blackberry, hawthorn
3	hedgerow	5-6	4	hardhack, blackberry, hawthorn, poplar
4	grass margin	0.5-1	2	velvet, rye, bent grasses
4	hedgerow	5-6	5	hardhack, blackberry, hawthorn, poplar
5	hedgerow	2	1.5	timothy, rye, bent, orchard grasses, red cedar and maple saplings

Statistical Analysis

As is typical of catch data, the data collected in this study were highly variable and could not be normalized using standard transformations. The data were analysed, therefore, non-parametrically using Friedman's 2-Way ANOVA ($\alpha = 0.05$) where traps were paired and the Kruskal-Wallis 1-Way ANOVA ($\alpha = 0.05$) where data were not paired. Insects were grouped into guilds as either "pests", "beneficials" or "total", including all insects, to facilitate easier manipulation of the data.

It is important to note that Friedman's 2-Way ANOVA and the Kruskal-Wallis 1-Way ANOVA test statistics are derived from rank sums and do not account for the magnitude of differences often encountered in the data.

The Simpson's Diversity Index (Brower *et al.* 1989) was calculated for each site and for locations within sites that were shown to be significantly different (Appendix C). The diversity indices reflect eveness of species numbers as well as species richness, the number of species present. A system with a high number of species and high abundances will have a high diversity index and a high species richness. Likewise, a system with few species and uneven abundances of each species will have a relatively low diversity index and a low species richness.

Similarity Indices were calculated to determine similarities in species composition between sites and in different locations within sites. The Simpson's diversity value and the similarity value are both presented as proportions of one, the higher proportions indicating greater diversity and similarity, respectively.

Results and Discussion

In the interest of simplicity, beneficial arthropods in the following bargraphs have been grouped by order; Arachnida, Coleoptera (ground beetles, rove beetles and ladybird beetles), Homoptera (damsel bugs, minute pirate bugs, and seed bugs), Hymenoptera and Other (damsel flies, syrphid flies and lacewings). Similarly, pest insects have been grouped as Homoptera (aphids, leafhoppers, plantbugs and froghoppers), Coleoptera (weevils and flea beetles), Thysanoptera (thrips) and Other (grasshoppers and lepidoptera). This grouping was based on general characteristics of each order but is not exact. Some species of plantbugs and froghoppers, for example, are predators of pests but generally, this is not the case. Bargraphs of insect abundances at different locations show only the most abundant beneficials and pests.

A: Set-asides:

i) *Established Set-asides:*

Studies have shown a positive correlation between ground beetle numbers and the densely tussocked orchard grass, *D. glomerata* (Thomas *et al.* 1991, Luff 1966). It has been suggested that carabids favour the less variable temperatures provided by grass matts and tussocks. Further, the less variable temperatures may reduce the effect of mortality in over-wintering carabids (Desender 1982). Densities of ground beetles in this study were not, however, found to be higher in orchard grass than tall fescue and timothy. Factors such as aspect, exposure and drainage appeared to be the same for each block. Perhaps the uniformity of the sample plots, each seeded with only one grass species, resulted in less temperature variability between the species, thereby making each grass species as attractive to carabids as the others.

Total insect catch sizes were not significantly different between the three grass species, timothy, tall fescue and orchard grass (Friedman's, $p = 0.076$, $n = 36$). Similarly, insect abundances were not significantly different between the two sites (Kruskal-Wallis, $p = 0.305$, $n = 72$). A significant difference was found, however, between pest abundances in the cut and uncut blocks in SA-1 (Fig. 1c,d) due to high numbers of weevils and aphids caught in the cut blocks at Sample 3 in mid-September (mean = 43 and 36/trap, respectively; Kruskal-Wallis, $p < 0.001$, $n = 72$). The weevils appeared to be attracted to the abundance of red clover which had sprung up vigorously after the block was cut the week before. Samples of the weevil will be sent to the Biosystematics Research Lab in Ottawa for identification. In SA-2, where the cut blocks were as tall as the uncut blocks, no differences in abundances were found (Fig. 2c,d).

In SA-2 the number of "pests" rose sharply from Sample 1 (early August) to Sample 2 (late August) due to very high thrips catches (total = 2094)(Fig. 2b). By Sample 3, thrips catch sizes dropped sharply to 406 but "total" insect catch sizes increased due to very high adundances of flies, predominantly midges and gnats which, in general, are neutral insects (Appendix C).

ii) *Newly planted Setaside:*

No significant difference was found between insect catch sizes in the setaside blocks treated with the recommended manure dose (Treatment 1), double the recommended dose (Treatment 2) or no manure (Treatment 3)(Kruskal-Wallis, $p = 0.936$, $n = 45$). There were, however, significantly more insects trapped in Sample 3 than in Samples 1 and 2 (Kruskal-Wallis, $p < 0.001$, $n = 45$). This is due mainly to very large catch sizes of thrips which increased from 1589 in Sample 1 to 8694 in Sample 3 (Fig. 3b). These high thrips counts were obtained despite the set-aside being cut the week prior to Sample 3 in mid September. The high catch sizes in September may be a reflection of emigration of thrips to new habitats as a result of the cutting. Another possible factor influencing higher catches in Sample 3 may have been the greatly increased sticky trap exposure after the site was cut. Prior to cutting many sticky traps were almost completely obscurred by red root pigweed and barnyard grass which had grown up vigorously around the stakes supporting the traps.

Abundances of pests between treatments are remarkably similar (Fig. 3d). Abundances of beneficials between treatments were relatively more variable though the small catch numbers make it difficult to determine any trends (Fig. 3c).

B. Grass Margin:

Catch sizes of total insects caught in blocks of creeping red fescue and chewings fescue were not significantly different (Friedman's, $p = 0.739$, $n = 9$). Upon pooling both grass species, however, there were significantly more insects caught in Sample 3 (Kruskal-Wallis, $p < 0.001$, $n = 54$). This difference is due to a sharp increase in the number of flies, increasing from a mean of 20 and 18 per trap in Samples 1 and 2 to

80 per trap in Sample 3. Most of the flies were male midges and fungus gnats. Often sticky cards placed within several metres of each other caught markedly different numbers of flies suggesting that groups of males looking for females encountered the sticky cards while swarming.

No difference was found between trap catch sizes of total insects and pests from the grass margin, 2 m into the crop or 10 m into the potato crop (Friedman's, p = 0.311, n = 6, for both guilds). There were, however, significantly more beneficials found in the grass margin than at 2 m and 10 m into the crop (Friedman's, p = 0.006, n = 6, Fig. 4c). Pitfall traps in the grass margin caught more ground beetles than those in the crops. Numbers of all beneficial beetles (ladybird beetles, rove beetles and ground beetles) climbed from 44 to 61 to 159 in Samples 1, 2 and 3, respectively. Numbers of spiders and, again, flies increased in Sample 3.

A dramatic increase in thrips catch sizes was observed in Sample 2 (Fig. 4b). At this point the potato crop was thriving. By Sample 3 the crop had been harvested and the number of thrips had dropped from 514 to 106 though it is not known whether this was the cause of the decrease as crop harvest in other sites appears to have had no effect on thrips numbers. Likely the absence of potatos in the field influenced lower thrips numbers.

The highest number of thrips were observed at 2m into the potato crop (mean = 24.1) and the lowest number in the grass margin (mean = 7.4)(Fig. 4d).

C: Crop Margin

At the time of the first sample, the crop margin was a bare strip of dirt with little weed cover. By Sample 2, red root pigweed, green smartweed and lady's thumb were growing vigorously along the margin and were up to 1 m high. In the week prior to the Sample 3, the adjacent potato crop had been top-killed. Insect abundances in the crop and on the weeds in the margin dropped dramatically as the plants died back. There were no differences found in total insects and pest abundances between the two locations (Friedman's, p= 0.128 and 0.612, respectively, n = 6, Fig. 5d). There were, however, more beneficials caught in the margin than in the crop (Friedman's, p = 0.028, n = 35), likely due to the greater diversity of plants and thus, prey species available there (Fig. 5c).

A very sudden increase in thrips was observed at Sample 2, rising to a mean of 1023/trap from 56.4/trap at Sample 1 (Fig. 5b). At this point the weeds and potato plants were most vigorous. Thrips abundances dropped just as dramatically to 40.0/trap by Sample 3. Numbers of beneficial beetles dropped in Samples 2 and 3 while hymenoptera doubled in number from 35 to 71 between the first and last samples.

D: Hedgerows

Trichogramma spp., a small hymenopteran egg parasitoid of many lepidopterous insects, was observed in very small numbers. Of the 11 wasps trapped on sticky cards, 9 were caught in hedgerows and 2 in the grass margin. All were caught in Sample 2.

No wireworms were collected this season, even in sites where they have previously been observed. This is likely because sampling did not begin this season until August by which time click beetle had mated, oviposited and died (Jones 1964). It is expected that click beetle adults will be trapped next season when sampling begins in the spring.

i) Established Hedgerows

No significant difference was observed in trap catch sizes of total insects collected in the 2 medium hedgerows (Kruskal-Wallis, $p = 0.869$, $n = 48$) or the 2 large hedgerows (Kruskal-Wallis, $p = 0.087$, $n = 48$). The catch sizes in pooled medium vs. pooled large hedgerows were then tested and, again, no significance was found.

In sites with both a hedgerow and a grass margin, more beneficials were usually caught in the grass margin than in the hedgerow or crop (Figs. 6 & 9). In sites with no grass margin, more beneficials were caught in the hedgerow than in the crop (Figs. 7 & 8). These results agree with findings by Lewis (1969) which showed that higher densities of beneficials are found near to hedgerows and grass margins due to the greater abundance of other insects on which they depend.

In general thrips were caught in increasing numbers in traps placed farthest into the crop. This is likely due to the lesser number of beneficials found in the centre of the field leaving pest populations to go relatively unchecked. Potato plants were flowering in late August at Sample 2 which may have influenced higher thrips numbers in thrips species which are attracted to flowers. Interestingly, however, the highest abundance of thrips in HR-1 (medium) was in mid September, after the potato plants had been top-killed.

In HR-1 the majority of beneficials were hymenoptera, almost exclusively parasitoids (Fig. 6a). This hedgerow included many hardhack bushes which were in bloom until late August. Many pests, particularly homoptera, were collected on the hardhack which, likely attracted the high numbers of parasitic hymenoptera. This was the only site in which high numbers of myrmicine ants were caught. In Samples 2 and 3, 888 and 452 ants, respectively, were trapped in the pitfalls whereas none were caught in Sample 1. It is curious that these ants were not found in the other hedgerows (except for HR-4 in which only 2 ants were caught), particularly HR-2 which is very similar to HR-1 in composition.

The pest beetles and homoptera in HR-1 were caught in similar abundances throughout the sampling season (Fig. 6b). Thrips numbers, however, increased dramatically with each sample though overall they were much less abundant than in the other established hedgerows.

The number of beneficials, excluding hymenoptera, trapped in HR-2 (medium) was relatively low throughout the season (Fig. 7a). The hymenoptera, on the other hand, increased sharply in abundance at each sample. Pest abundances were remarkably similar throughout the sampling season (Fig. 7b), except for thrips which showed a considerable increase from 1406 in Sample 1 to 19919 in Sample 2. At this time the adjacent potato crops were in full flower. Prior to Sample 3, the crop was top-killed. The potato plants and in-crop weeds wilted and died. Thrips numbers dropped to 1375 in Sample 3.

In HR-3 (large hedgerow) hymenopterans were the most abundant beneficial insects (Fig. 8a). Their numbers were consistent throughout the season despite the top-kill of the adjacent potato crop prior to the final sample. This suggests that hymenopteran fauna in the hedgerow, where the majority were trapped, is relatively unaffected by conditions in the crop. Pest abundances were relatively steady throughout the sampling period with the exception of thrips, which increased from 473 in Sample 1 to 12,605 and 548 in Samples 2 and 3, respectively (Fig. 8b). This pattern of pest abundances is very similar to that ot HR-2 which borders the same potato field (Fig. 7b).

Large hymenopteran catches were made in HR-4, the second large hedgerow, in Sample 1 (Fig. 9a). Although this number dropped in subsequent samples hymenoptera were more numerous than other beneficials. Again, thrips numbers peaked at Sample 2, just before harvest, though not as dramatically as in other sites. Total thrips numbers over the season were very similar between HR-3, adjacent to a pesticide-treated potato field and HR-4, adjacent to an organic bean field. Inspecting the bean plants visually revealed few signs of feeding damage by thrips or other pests yet there were relatively high numbers of homopterans, beetles and thrips present in the field.

It is worth noting that sticky cards, set approximately 30 m apart often yielded dramatically different catch sizes of thrips, differing as much as several thousand. Each card had optimal exposure and was not obscured by foliage. This uneveness in catches may be explained by swarming however this is not likely as the cards were set for one week intervals and should, therefore, all have had similar chances of encountering a swarm.

ii) Newly-planted Hedgerow

Overall abundance patterns of beneficials and pests in HR-5, the newly planted hedgerow, were not markedly different from the established hedgerow catch sizes (Fig. 10). Hymenopterans, peaking in Sample 1, made up the majority of the beneficials

though spiders, carabids and rove beetles were also important in this site. More rove beeltes were caught in HR-5 than in any of the established hedgerows, likely due to the thick grassy cover of the hedgerow which borders a pasture which was uncut for Samples 1 and 2. Thrips numbers were very low in HR-5 relative to the established sites. Other pest abundances were comparable to other sites.

Effect of hedgerows on flying insects

The effect of hedgerows on attracting populations of flying insects is of concern. Studies by Lewis have shown that populations of small weakly flying insects are often deposited in the lee of hedgerows while stronger flying insects congregate in areas of calmer air (1969, 1970). Typically, however, shelter effects do not extend more than ten times the hedge height into the crop on the leeward side and much less to the windward side (Pollard 1971). The data collected in this study suggests that hedgerows do not affect thrips as the highest densities were observed on traps placed farthest into the crop and thus, farthest from the hedgerow.

Another concern is that hedgerows provide overwintering sites for pests which then move into the crops the following summer. Hedgerows come into leaf early and have a very rapid period of growth at which time they support a very large invertebrate fauna peaking in May and June. This is before the arable crops are at their optimal growth. It is well known that some pests, such as aphids, alternate between perennial and annual plants, changing their food depending on its availability. What is less widely recognized, however, is the number of predators also take advantage of the changing food supply. Many beneficials, notable hover flies (Syrphidae), ladybird beetles (Coccinellidae) and lacewings (Neuroptera) produce an early generation in hedgerows and a later one or more, which feed on pests in the crops (Bombosch 1963).

The production of nectar and pollen early in the season is very important for predators such as syrphids for which pollen feeding is essential for maturation of the ovaries (Schneider 1948). Flower feeding is, however, important to both beneficials and pests. The flowering plants and shelter of the hedgerow may determine the pattern of infestation by pests in the field but pests populations may, similarly, be determined by populations of predators and parasites dependent on the hedgerow for overwintering sites, alternate hosts and food (Pollard 1971).

Diversity and Similarity Indices

The indices values were calculated on insects identified to family or order. It is important to note that the following calculations are not as sensitive as they would be if calculated on specimens identified to species level. Note also that the similarity index does not account for abundance within species; a group with only 1 individual carries as much weight in the calculation as a group with thousands of individuals.

A: Set-asides

The established set-asides, SA-1 and SA-2, had a higher insect diversity value than the new set-aside, SA-3 (Table 2). The value is derived from insect catch sizes in monoculture grass blocks. The plant diversity in SA-3 was much greater than in the older monoculture sites and yet, somewhat surprisingly, supported a lower diversity of insects. Interestingly, many homopterans, most of which feed on plant juices, were observed in the established set-asides late in the season when the grasses had dried and seeded. It is unclear what attracted them to these sites, seemingly barren of food.

A study by Gathmann *et al.* (1994) found that old fields with naturally developed vegetation had greater insect diversity than younger monoculture fields. This, together with the results of this study, suggests that insect diversity is more strongly influenced by setaside age than by diversity of plants.

The cut and uncut grass blocks in SA-2 were marginally less similar than those in SA-1 (Table 3). This is not surprising, however, as the uncut blocks in SA-2, are indistinguishable from the cut blocks, based on height. On the other hand, the species similarity between cut blocks in SA-1 and SA-2 is higher, albeit marginally, than the uncut blocks between the two sites. The occurrence of several groups with very few individuals in each group may be influencing a higher similarity value in the cut blocks.

B: Grass Margin

Despite the relatively large difference observed in numbers of insects trapped in the grass margin site and at the 2 m and 10 m locations, the diversity index values are similar (Table 2). This likely reflects a greater eveness in numbers of insects found in the crop than in the margin.

Trap catches in the grass margin and at the 2m location were less similar than trap catches at the grass margin and the 10 m location (Table 3).

C: Crop Margin

The diversity value of the bare crop margin is, not surprisingly, very low. Few weed species were collected here and accordingly, relatively few insect species were collected.

The crop margin and in-crop habitats were very similar in species composition (Table 3).

D: Hedgerows

HR-1 showed a relatively high diversity value which, likely, was influenced by the more moderate catch sizes of thrips. The largest out-lying group was the myrmicine ants which were caught in numbers in Sample 2 and 3.

The diversity indices of HR-2 and HR-3 were lower than that of HR-1 skewed greatly by very large thrips catches in those sites.

In HR-4 there was a significant difference in the number of insects caught in the hedgerow and grass margin, and in at the 2 m and 10 m locations, therefore 2 diversity values were calculated. The hedgerow/grass margin has a much higher insect diversity than the crop due to the relative eveness of species. The greatest outlier, thrips, are half as abundant as they are in the adjacent crop. The 2 m/10 m locations also had very high dipteran counts which, likely, along with high thrips counts, influenced a lower diversity value.

Table 2. Simpson's diversity indices by site*

Site	Locations**	Diversity value	No. spp.
SA-1	grassland set-aside	0.751	24
SA-2	grassland set-aside	0.640	21
SA-3	grassland set-aside	0.282	21
GM	grass margin	0.782	25
GM	2 m + 10 m	0.684	23
CM	margin + 10 m	0.244	23
HR-1	hedgerow + grass margin	0.556	25
HR-2	hedgerow + 2 m + 10 m	0.259	23
HR-3	hedgerow + 2 m + 10 m	0.278	21
HR-4	hedgerow + grass margin	0.608	23
HR-4	2 m + 10 m	0.359	22
HR-5	hedgerow	0.730	16

* Values are based on insect diversity only
**Locations in which insect abundances are not significantly different have been pooled.

Table 3. Similarity index by site, site factors and location

Site	No. spp.	No. common spp.	Similarity value
SA-1 cut/uncut	24/18	18	0.857
SA-2 cut/uncut	18/20	17	0.895
SA-1 cut/SA-2 cut	24/18	18	0.857
SA-1uncut/SA-2uncut	18/20	16	0.842
GM/2m	23/20	19	0.884
GM/10m	23/22	20	0.889
2m/10m	20/22	18	0.857
CM/crop	23/20	20	0.930
HR-1/HR-2	23/22	21	0.933
HR-3/HR-4	18/19	16	0.865
HR-2+HR-3 (HR)/ HR-2+HR-3 (2m)	22/22	19	0.864
HR-2+HR-3 (2m)/ HR-2+HR-3 (10m)	22/21	20	0.930
HR-2+HR-3 (HR)/ HR-2+HR-3 (10m)	22/21	20	0.930
HR-1 GM/HR-4 GM	22/22	20	0.909
HR-5/HR-4 GM	18/22	18	0.900

Weeds:

At the time of the first weed sample, most weeds were well established. Some had begun to seed and decline so it is not possible to chronicle weed invasion of different sites and locations for 1996. An inventory of weeds present within the sites in August and September , 1996 was compiled (Appendix E).

A: *Set-asides*

In cut timothy and orchard grass blocks of SA-1, mown twice this season, red clover covered an estimated 80% of the ground. Adjacent cut blocks of tall fescue were only 5% red clover. Weeds appeared unable to penetrate the densely matted tall fescue tussocks. In uncut blocks of all species red clover grew 2 - 3m into the block from the edge between the cut and uncut blocks. The timothy blocks had occasional bull thistles throughout.

The cut blocks in SA-2, last mown in 1995, had 15% white and red clover in the tall fescue, 10% Canada bluegrass in the timothy, and 25% red and white clover, with some bull thistle, in the orchard grass. In uncut blocks, no weeds were found in the tall fescue. Timothy had 25% Canada bluegrass and one block of orchard grass had 70% Canada bluegrass and 25% red clover while the other block had only the occasional Canada bluegrass.

The highest diversity of weed species in the set-asides was in SA-3 with different manure treatments. This field, however, is not typical and has always had a problem with invasive weeds. At Sample 1, the ground was bare, having been recently seeded. Three weeks later, at Sample 2, approximately 90-95% of ground cover in all treatment blocks was pigweed and barnyard grass, both up to 1 m high. There were dense patches of two-row barley, lamb's quarter and green smartweed. Other weeds included common groudsel, shepherd's purse, perennial rye and scarlett clover. At Sample 3 the set-aside had been mowed.

B: *Grass Margin*

Grass margins are often established to choke out annual weeds which would otherwise invade crops. Most weed species observed in the margins did not extend into the crops and those that did, did not invade very far. There appeared to be a definite demarcation of crop weeds (pigweed, lamb's quarters and smartweed) and margin weeds (thistles, clover, sowthistle, horsetail, willow herb).

At the grass margin site, across the ditch from SA-1, the margin was divided into 3 sections; along the ditch, the path, frequently used by walkers, and the crop margin at the edge of the potato field. In all blocks of creeping red fescue and chewings fescue, the dominant weed along the ditch was common horsetail (75%). Weeds along the track were few due to the heavy foot traffic. Along the margin, the dominant weeds were perennial rye-grass (25%) and common horsetail (10%). At 2m and 10m into the crop the only weeds were occasional lamb's quarters, lady's thumb and smartweed.

C: Crop Margin

This potato crop margin, bare at Sample 1, was overgrown with pigweed, green smartweed and lady's thumb by Sample 2. The same weeds were found farther into the crop than in other fields, perhaps because a grass margin was not in place to slow weed advance into the crop.

D: Hedgerows

Weeds within all the established hedgerows were minimal due to the density of growth and lack of light within the hedge. The grass margin adjacent to HR-1 was composed of perrenial rye and Canada bluegrass (75%) and Himalayan blackberry (15%) with occasional bull thistle, curled dock, bentgrass, common rush and deadly nightshade. Many of these weeds are found throughout the adjacent SA-3 and not just near the grass margin. Deadly nightshade is an important weed pest commonly found along crop margins. It's poisonous berries are the size and shape of peas and can be mechanically harvested with processing peas. Detection of a single berry will result in the disposal of the entire harvest.

HR-2 and HR-3 have no grass margin but on the edge between hedge and crop a thin strip of perennial rye, Canada blue grass and purple-leafed willow herb grow. At 2m and 10m into the crop occasional pigweed, perennial rye and barley grows and extends throughout the field. The hedge at HR-4 was not as dense as the other hedges which allowed for the invasion of velvet grass, bentgrass, native blackberry and horsetail. The adjacent grass margin was composed of velvet grass, Himalayan blackberry, bull and Canada thistles, lamb's quarter, curled dock and rye-grass. A greater diversity of weeds was found within the bean field at HR-4 but there were fewer individual plants than at other sites. In-crop weeds included lamb's quarter, barnyard grass, rye grass, pigweed, smartweed, barley, shepherd's purse, sowthistle and lady's thumb at 2m and 10m, and common horsetail at 2m. Weeds were controlled in this organic field by hand pulling only. No herbicides were applied as they were in crops adjacent to HR-2 and HR-3.

The newly-planted hedgerow, HR-5, which was more a grass margin than a hedge at this stage, was a fairly homogenous mixture of bentgrass, timothy, rye-grass, orchard grass, hemp nettle, Canada thistle, buttercup, purple-leafed willow herb, curled dock, barnyard grass, red clover, stinking chamomile, and sowthistle. When the cedar and maple trees grow up, many of these weeds will be shaded out.

Suggestions for Future Study

Due to late confirmation of funding, sampling began late in the season this year. Successive years of sampling will begin in early spring with crop planting and continue through until harvest. This will enable us to monitor insect abundances and crop damage simultaneously and to determine whether a correlation between the two exists. This will also allow us to follow the establishment and invasion of weeds in setasides, crop margins and crops throughout the season.

It is suggested that sticky cards be set on taller stakes in the setasides so that they are are approximately the same height as the grass, where most of the insect activity occurs. Similarly, sticky cards on the grass margin site should be set lower, again to be roughly the same height as the grass. It is also important that the cards be oriented in the same direction so as to avoid differences in wind and sun exposure. Finally the cards should be fastened at both ends to avoid spinning in the wind.

It was found that decay in the pitfall traps advanced quickly, attracting unrepresentative numbers of carrion beetles and some mite species. Decay was accelerated by the heat and number of insects in each trap. It is suggested, therefore, that a preservative be added to the water in the traps and/or the traps be changed twice rather than once a week.

The counting of thrips on the sticky cards was extremely time consuming. Sticky cards were, however, very useful for recording thrips activity and presence of many microhymenoptera, such as *Trichogramma spp*. It is suggested, however, that the number of sticky cards can be reduced without compromising the quality of the data. Further, in the interest of facilitating statistical analysis, it is suggested that the number of pitfall traps, sticky cards and sweep net samples be equal in number.

All samples for the 1996 season have been preserved in ethyl alcohol and labelled. This required much time and may not be necessary in future years though it proved a useful method of familiarization of insects that were caught. The samples remain, however, should there be any need to go through them again to identify speciment to the genus or species levels.

No attempt has been made in this report to determine correlations between specific pests and beneficials and their host plants. Sampling did not begin until the first week of August by which time many insects had completed oviposition and many of the host plants on which they feed and oviposit had finished flowering and were in decline. Future work will, however, begin with sampling in early spring and monitor plant and insect activity throughout the season.

It is suggested that, where possible, traps be set on the leeward and windward sides of hedges to account for variation in insect abundances which may result from differences in exposure to wind and sun.

Due to the great potential of pollinators to increase crop yields, it is suggested that sampling include methods that are specific to pollinators. This might include pollinator counts conducted visually and sweep-netting pollin and nectar producing shrubs, trees and crops.

Summary

Setasides:

- No difference was found in insect diversity between grass species.
- Insect diversity was greatest in the established setasides.

- Weed were prominant in cut blocks of established setasides but were very few in uncut blocks. In cut blocks that were one year post cutting, invasion of weeds was similar to that in uncut blocks.
- No difference was found in insect diversity in setaside blocks treated with different concentrations of manure.
- Weeds were extremely prevalent in newly-planted set-aside.

Grass Margin:

- No difference was found in insect diversity between grass species.
- More beneficials were found in the grass margin than in the adjacent potato crop.
- The grass margin supported many weeds which did not occur in the crop but suppressed a number of in-crop weeds. In-crop weeds were mainly pigweed, smartweed and barley.

Crop Margin:

- The bare crop margin supported a low diversity of insects and weeds.
- Pigweed and smartweed dominated the margin.
- The lack of a grass margin appeared to have aided the spread of weeds further into the crop than in fields with a grass margin.

Hedgerows:

- More beneficials, particularly hymenoptera and carabids, were trapped in the hedgerow and adjacent grass margins than in the crops.
- More pests, particularly thrips, were trapped in the crop than in the hedgerow. Numbers increased with distance into the crop.
- Thrips abundances dropped in September after crops were top-killed.

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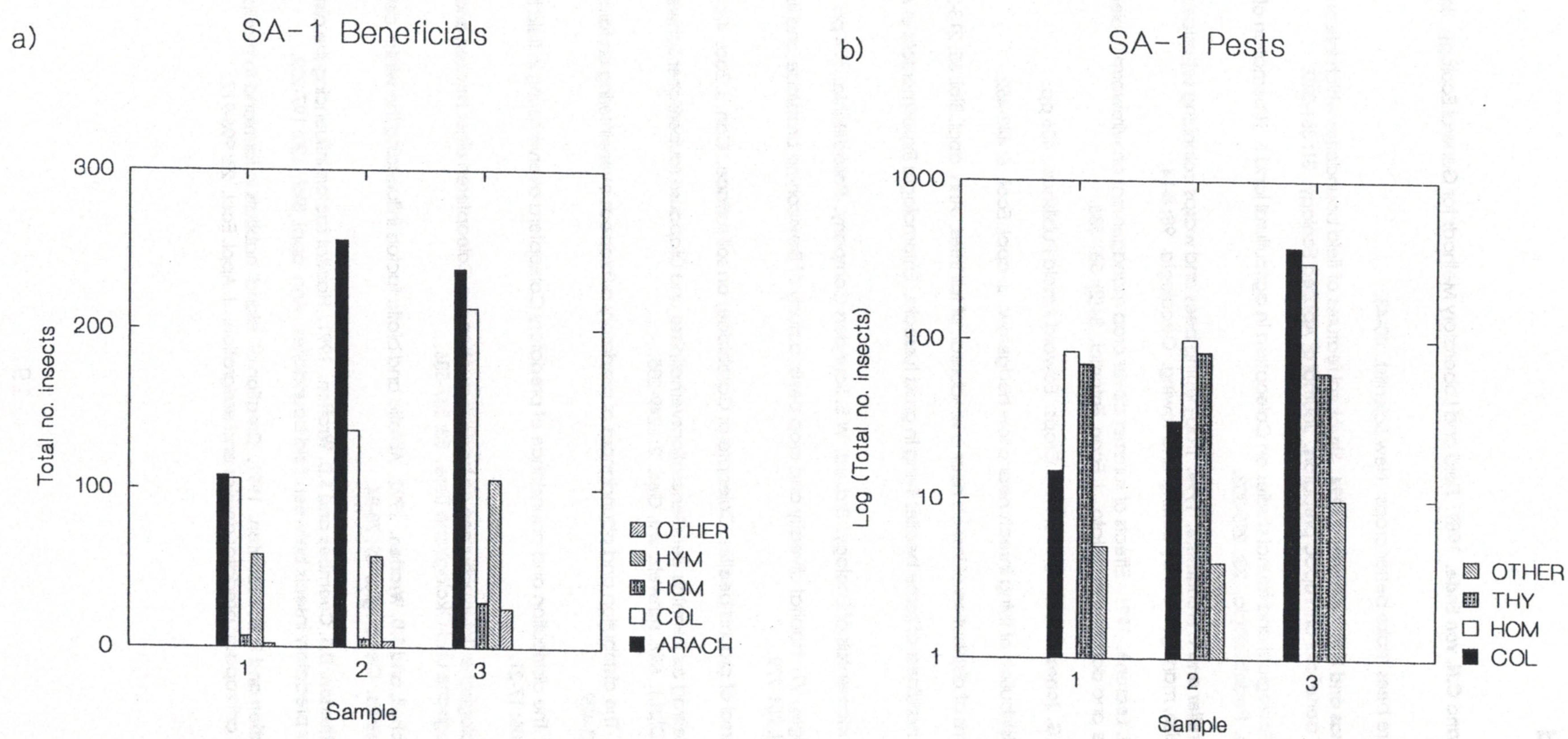

Fig 1. Total catch sizes of most abundant economically important insects in established set-aside site, SA-1, where Sample = 1 (early August), 2 (late August) and 3 (mid-September, 1996). Beneficials are a) Arach(nida) = spiders, Col(eoptera) = ladybird beetles, ground beetles and rove beetles, Hom(optera) = damsel bugs, minute pirate bugs and seed bugs, Hym(enoptera) = parasitic and predatory wasps, and Other = lacewings, syrphid flies and damsel flies. Pests are b) Col(eoptera) = flea beetles and weevils, Hom(optera) = leafhoppers, plantbugs and froghoppers, Thy(sanoptera) = thrips and Other = grasshoppers and moths.

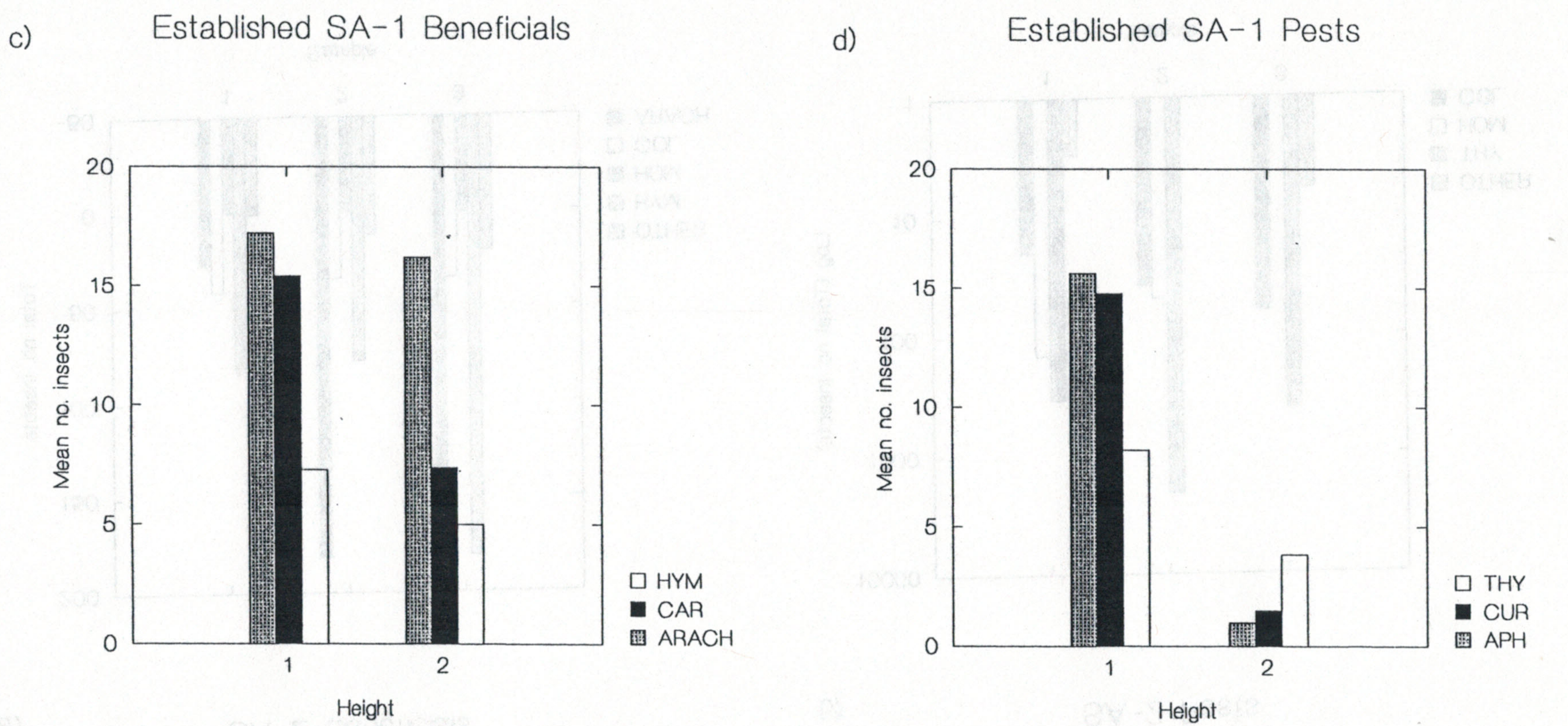

Fig 1 cont. Mean catch sizes of most abundant economically important insects in established set-aside site, SA-1, where Height = 1 (cut) and 2 (uncut). Beneficials are c) Arach(nida) = spiders, Car(abidae) = ground beetles and Hym(enoptera) = parasitic and predatory wasps. Pests are d) Aph(idae) = aphids, Cur(culionidae) = weevils and Thy(sanoptera) = thrips.

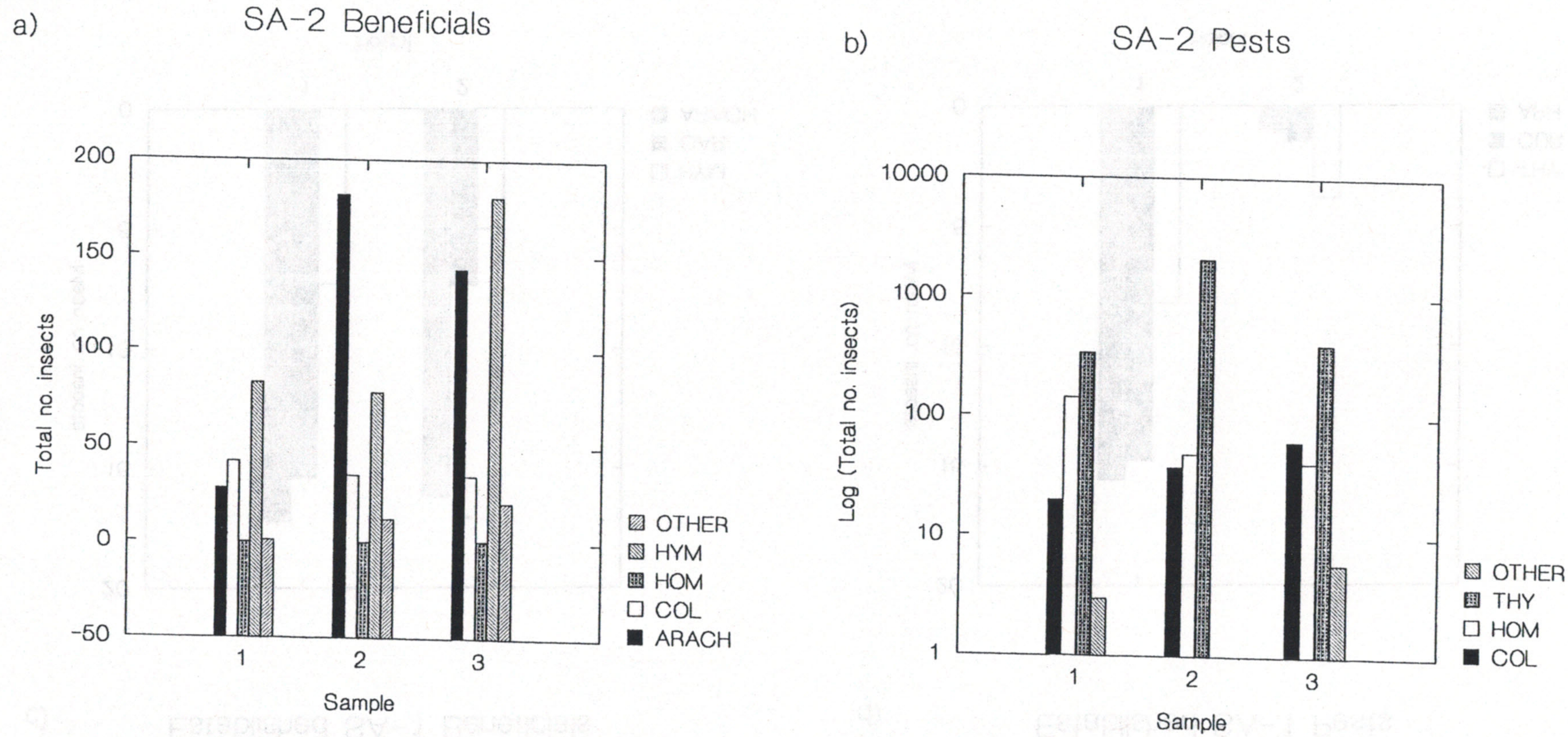

Fig 2. Total catch sizes of most abundant economically important insects in established set-aside site, SA-2, where Sample = 1 (early August), 2 (late August) and 3 (mid-September, 1996). Beneficials are a) Arach(nida) = spiders, Col(eoptera) = ladybird beetles, ground beetles and rove beetles, Hom(optera) = damsel bugs, minute pirate bugs and seed bugs, Hym(enoptera) = parasitic and predatory wasps, and Other = lacewings, syrphid flies and damsel flies. Pests are b) Col(eoptera) = flea beetles and weevils, Hom(optera) = leafhoppers, plantbugs abd froghoppers, Thy(sanoptera) = thrips and Other = grasshoppers and moths.

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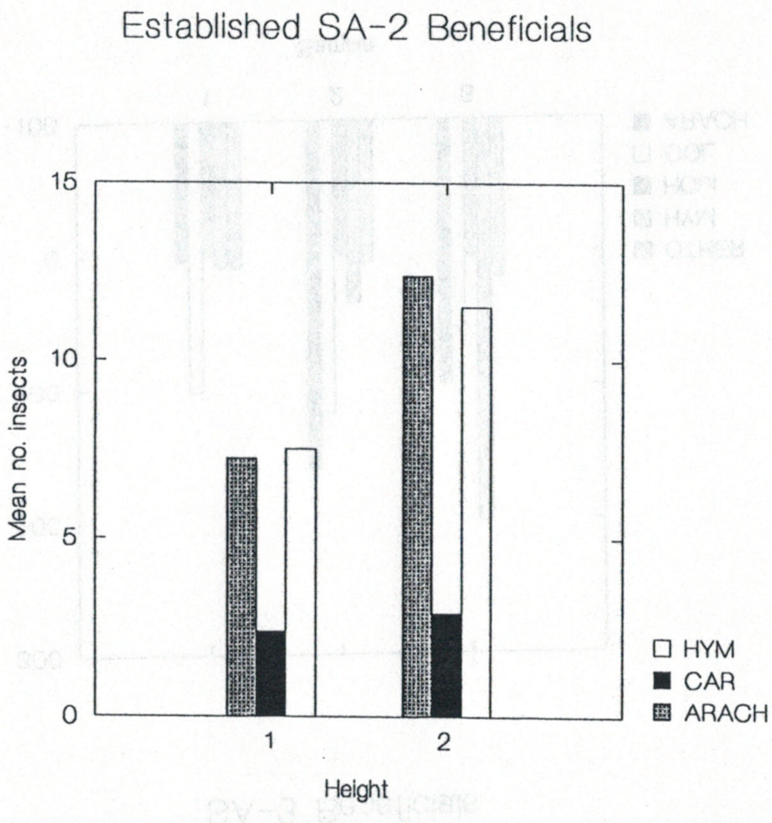

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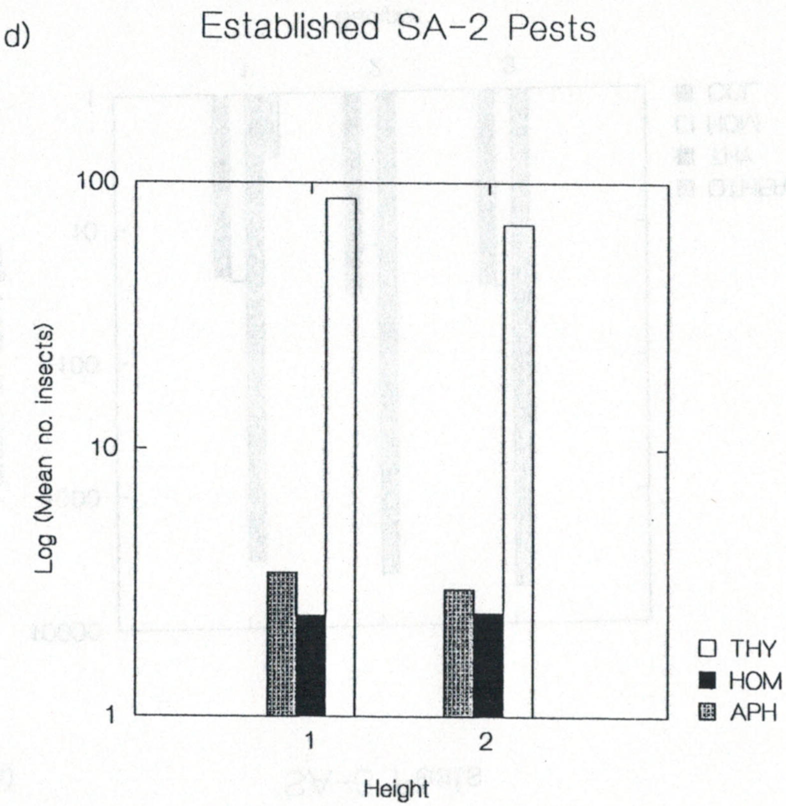

Fig 2 cont. Mean catch sizes of most abundant economically important insects in established set-aside site, SA-2, where Height = 1 (cut) and 2 (uncut). Beneficials are c) Arach(nida) = spiders, Car(abidae) = ground beetles and Hym(enoptera) = parasitic and predatory wasps. Pests are d) Aph(idae) = aphids, Hom(optera) = leafhoppers, plantbugs and froghoppers, and Thy(sanoptera) = thrips.

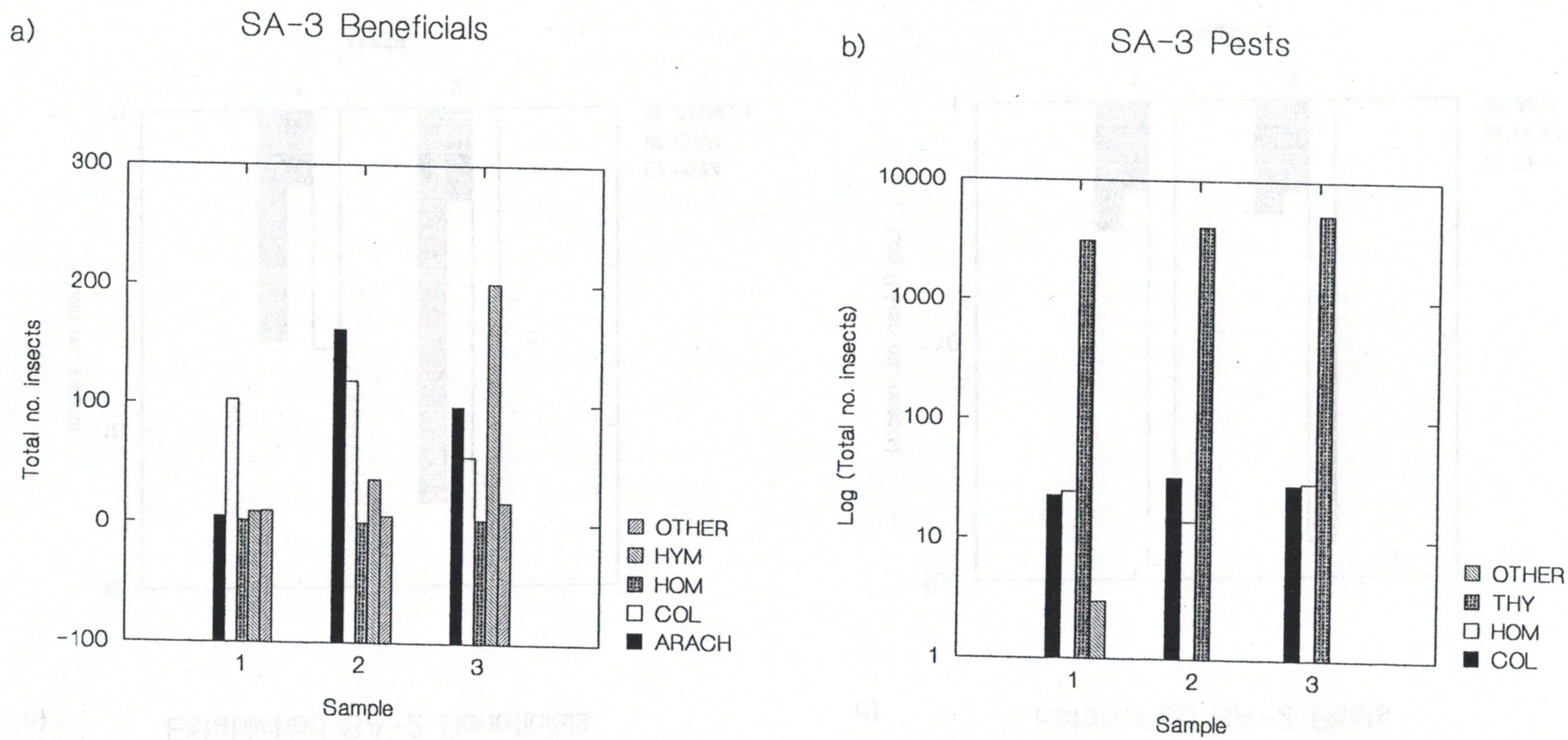

Fig 3. Total catch sizes of most abundant economically important insects in newly-planted set-aside site, SA-3, where Sample = 1 (early August), 2 (late August) and 3 (mid-September, 1996). Beneficials are a) Arach(nida) = spiders, Col(eoptera) = ladybird beetles, ground beetles and rove beetles, Hom(optera) = damsel bugs, minute pirate bugs and seed bugs, Hym(enoptera) = parasitic and predatory wasps, and Other = lacewings, syrphid flies and damsel flies. Pests are b) Col(eoptera) = flea beetles and weevils, Hom(optera) = leafhoppers, plantbugs abd froghoppers, Thy(sanoptera) = thrips and Other = grasshoppers and moths.

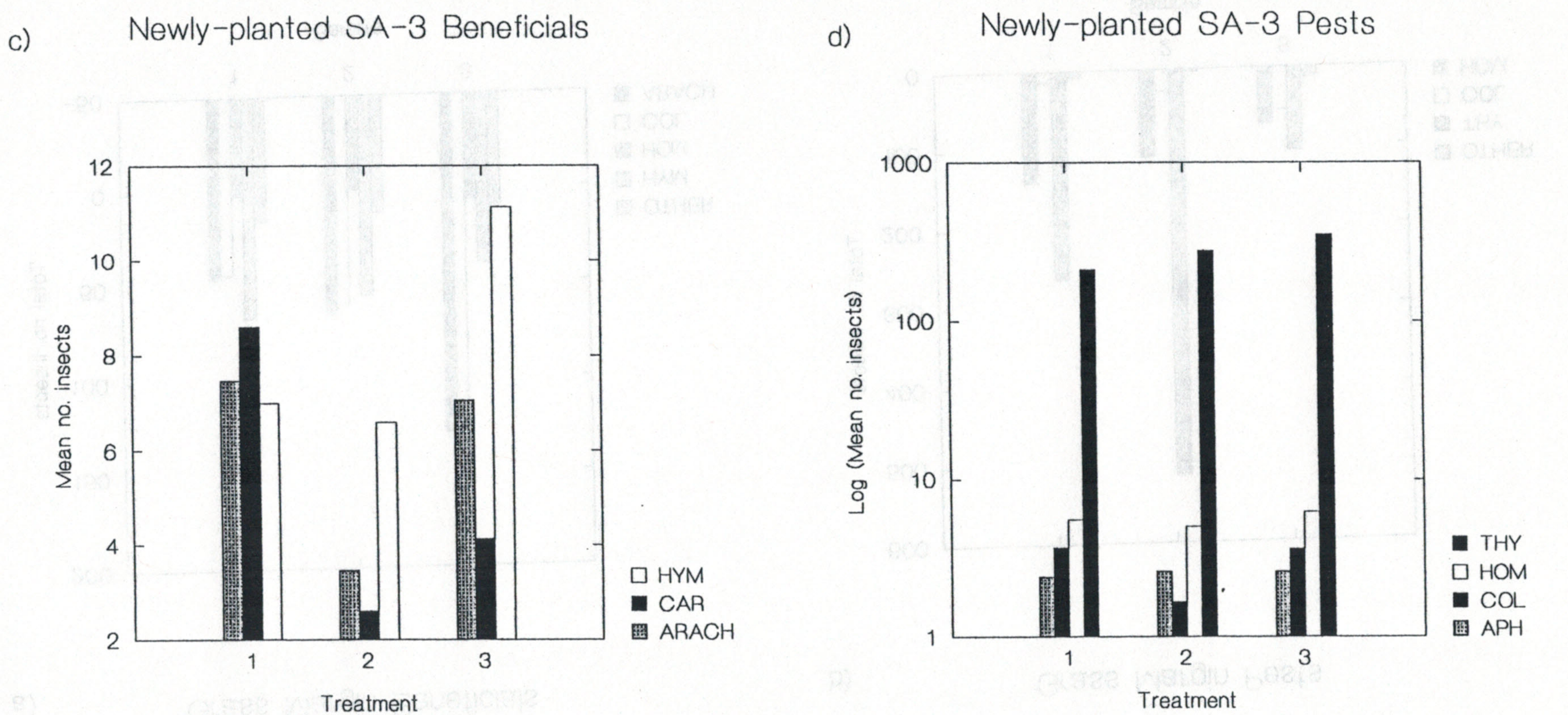

Fig 3 cont. Mean catch sizes of most abundant economically important insects in newly-planted set-aside site, SA-3, where Treatment = 1 (recommended manure concentration), Treatment = 2 (double recommended manure concentration) and Treatment = 3 (no manure applied). Beneficials are c) Arach(nida) = spiders, Car(abidae) = ground beetles and Hym(enoptera) = parasitic and predatory wasps. Pests are d) Aph(idae) = aphids, Col(eoptera) = flea beetles and weevils, Hom(optera) = leafhoppers, plantbugs abd froghoppers, Thy(sanoptera) = thrips.

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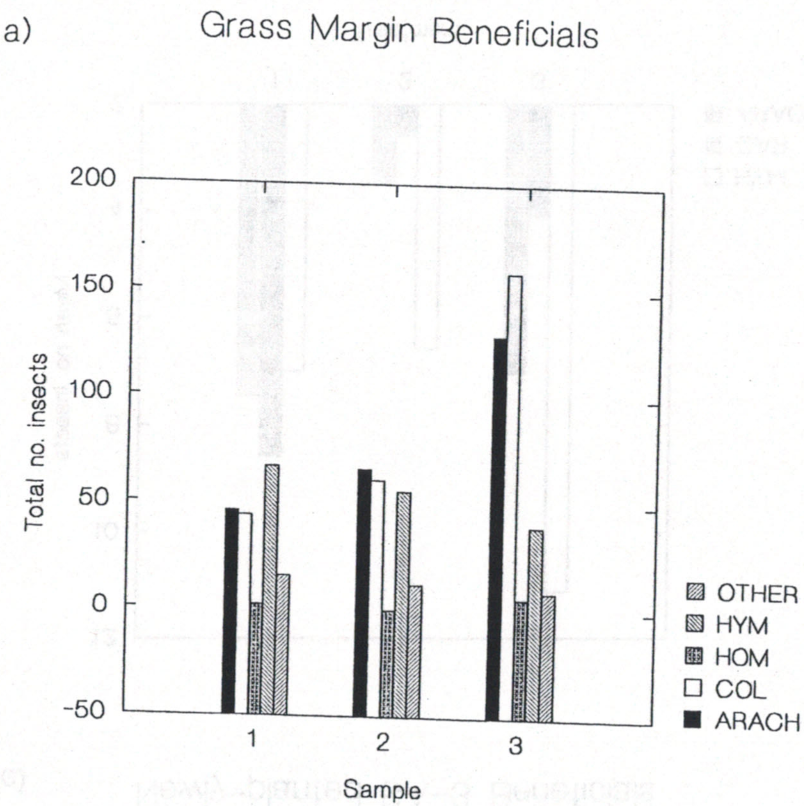

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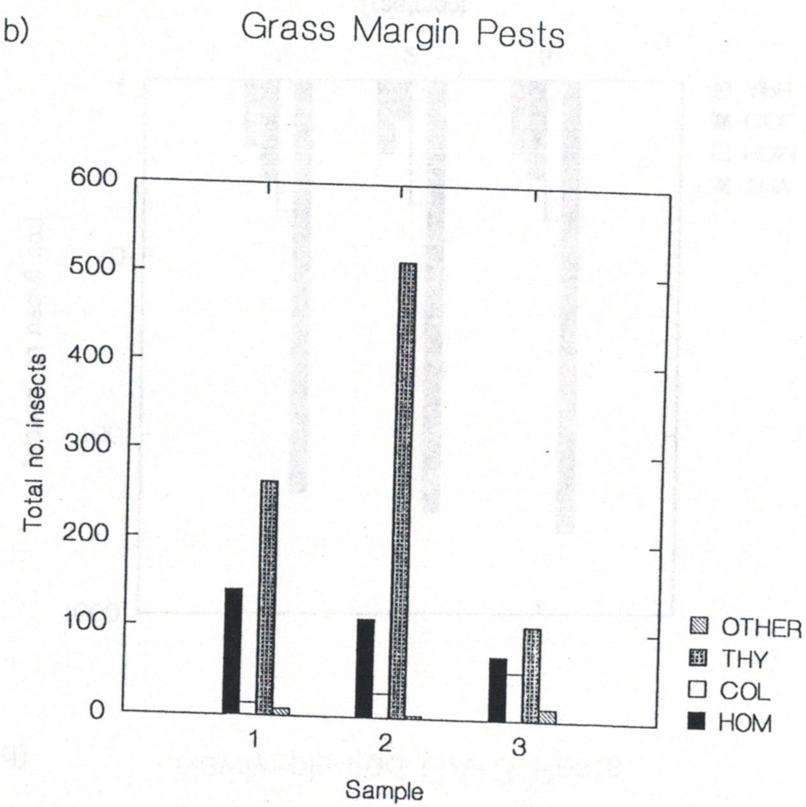

Fig 4. Total catch sizes of most abundant economically important insects in grass margin site, GM, seeded with blocks of creeping red fescue, *Festuca rubra rubra*, and chewings fescue, *Festuca rubra commutata*, where Sample = 1 (early August), 2 (late August) and 3 (mid-September, 1996). Beneficials are a) Arach(nida) = spiders, Col(eoptera) = ladybird beetles, ground beetles and rove beetles, Hom(optera) = damsel bugs, minute pirate bugs and seed bugs, Hym(enoptera) = parasitic and predatory wasps, and Other = lacewings, syrphid flies and damsel flies. Pests are b) Col(eoptera) = flea beetles and weevils, Hom(optera) = leafhoppers, plantbugs and froghoppers, Thy(sanoptera) = thrips and Other = grasshoppers and moths.

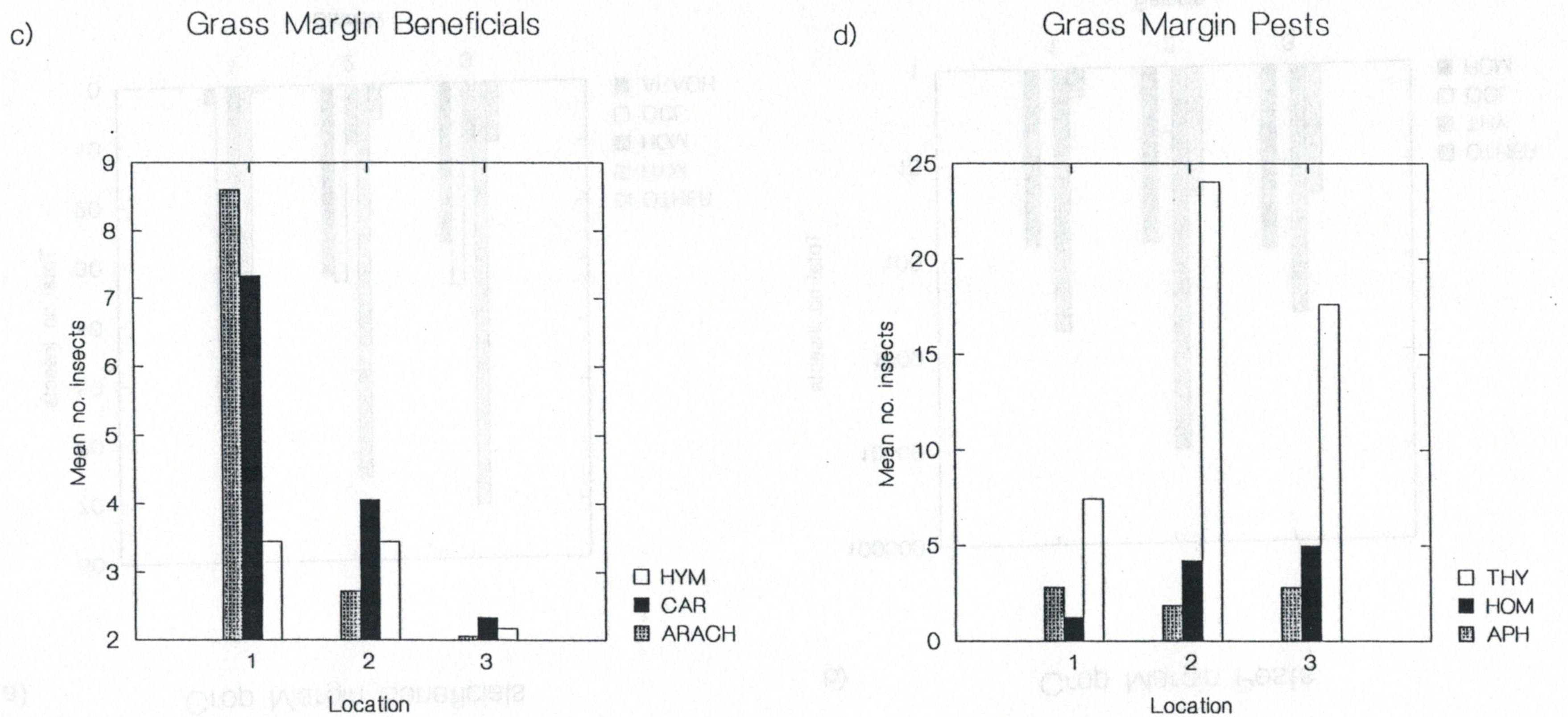

Fig 4 cont. Mean catch sizes of most abundant economically important insects in grass margin site, GM, where Location 1 = grass margin, 2 = 2m into adjacent potato crop and 3 = 10m into adjacent potato crop. Beneficials are c) Arach(nida) = spiders, Car(abidae) = ground beetles and Hym(enoptera) = parasitic and predatory wasps. Pests are d) Aph(idae) = aphids, Col(eoptera) = flea beetles and weevils, Hom(optera) = leafhoppers, plantbugs and froghoppers, Thy(sanoptera) = thrips.

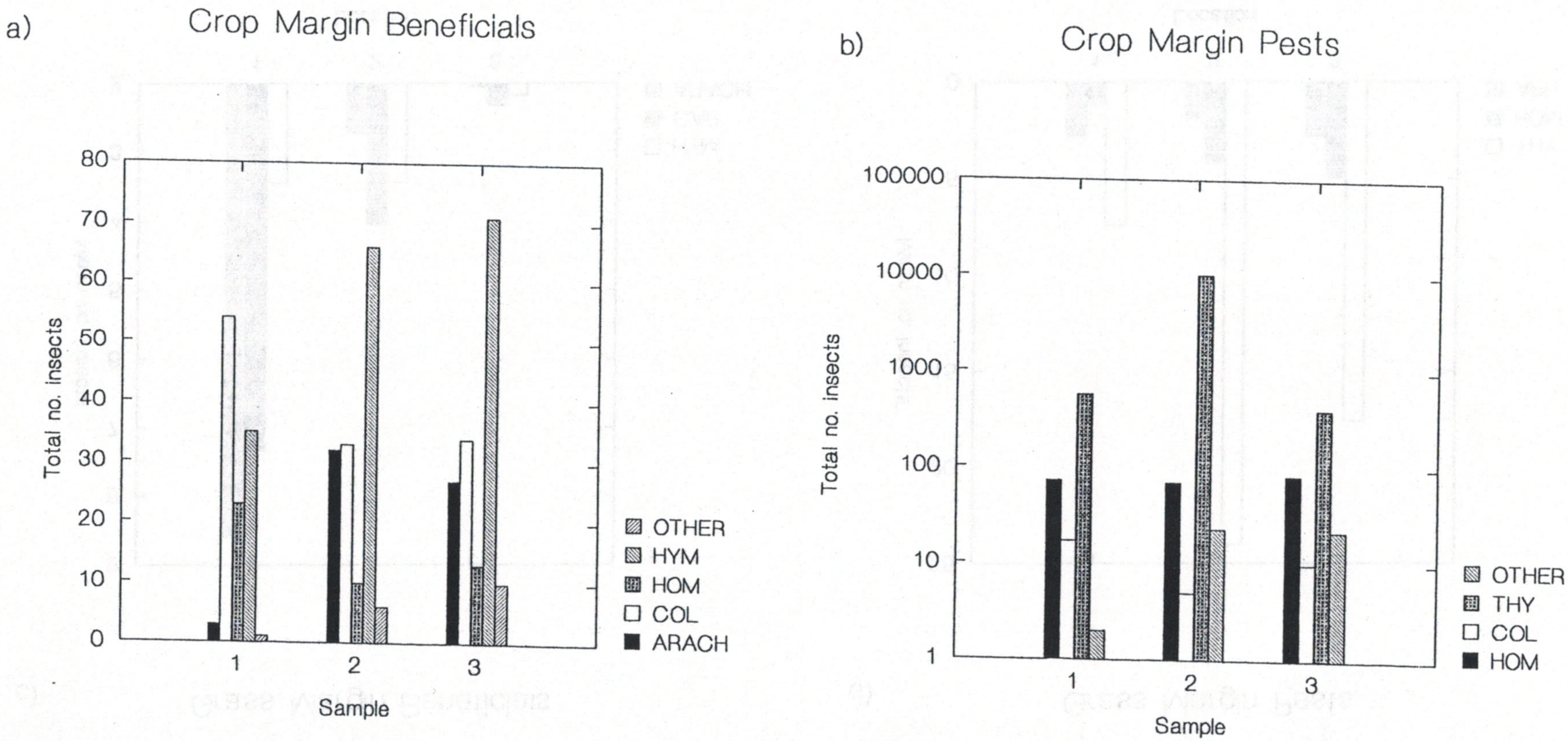

Fig 5. Total catch sizes of most abundant economically important insects in crop margin site, CM, where Sample = 1 (early August), 2 (late August) and 3 (mid-September, 1996). Beneficials are a) Arach(nida) = spiders, Col(eoptera) = ladybird beetles, ground beetles and rove beetles, Hom(optera) = damsel bugs, minute pirate bugs and seed bugs, Hym(enoptera) = parasitic and predatory wasps, and Other = lacewings, syrphid flies and damsel flies. Pests are b) Col(eoptera) = flea beetles and weevils, Hom(optera) = leafhoppers, plantbugs and froghoppers, Thy(sanoptera) = thrips and Other = grasshoppers and moths.

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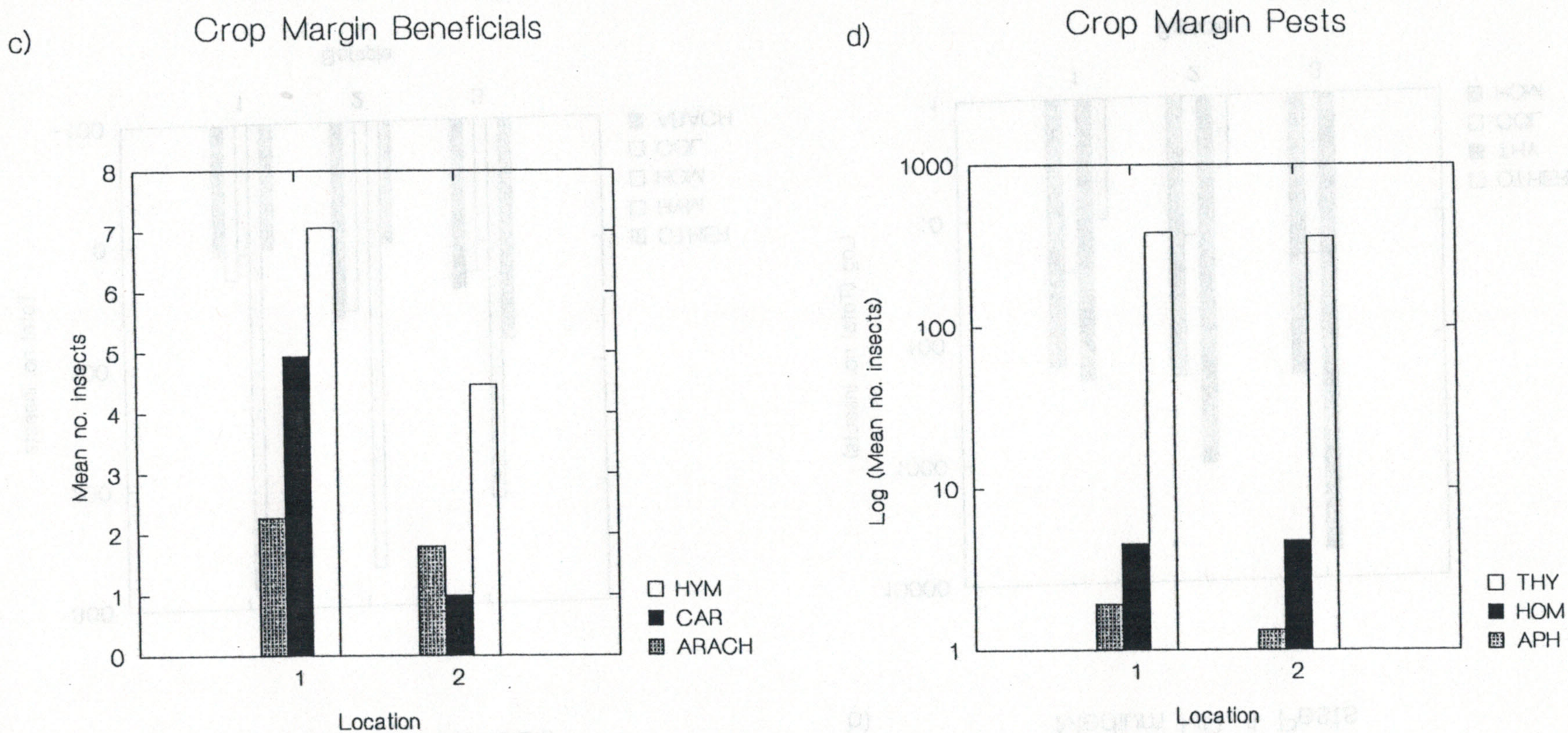

Fig 5 cont. Mean catch sizes of most abundant economically important insects in crop margin site, CM, where Location 1 = crop margin and 2 = in adjacent potato crop. Beneficials are c) Arach(nida) = spiders, Car(abidae) = ground beetles and Hym(enoptera) = parasitic and predatory wasps. Pests are d) Aph(idae) = aphids, Col(eoptera) = flea beetles and weevils, Hom(optera) = leafhoppers, plantbugs and froghoppers, Thy(sanoptera) = thrips.

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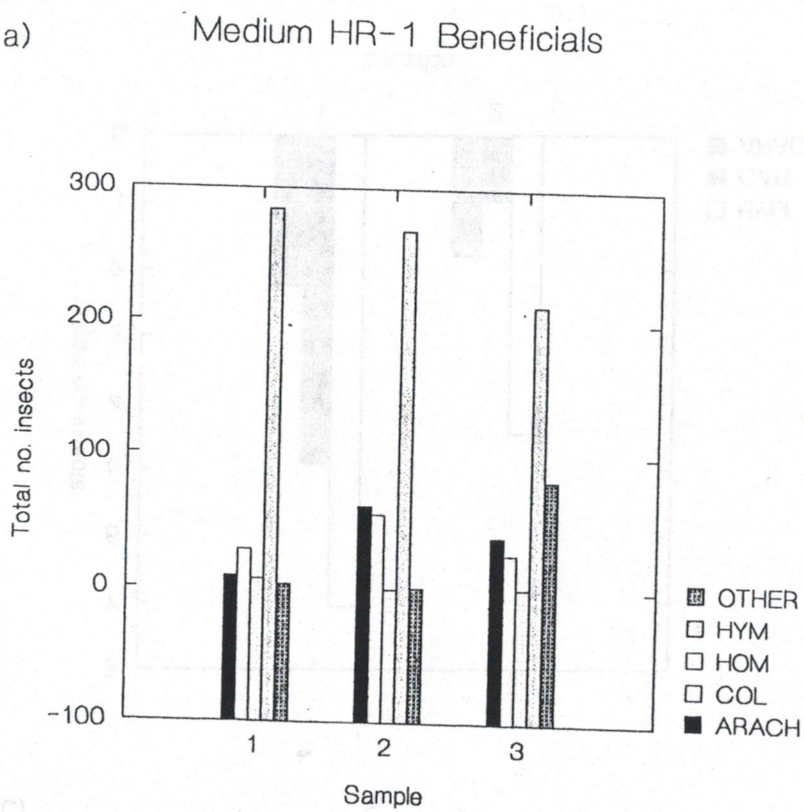

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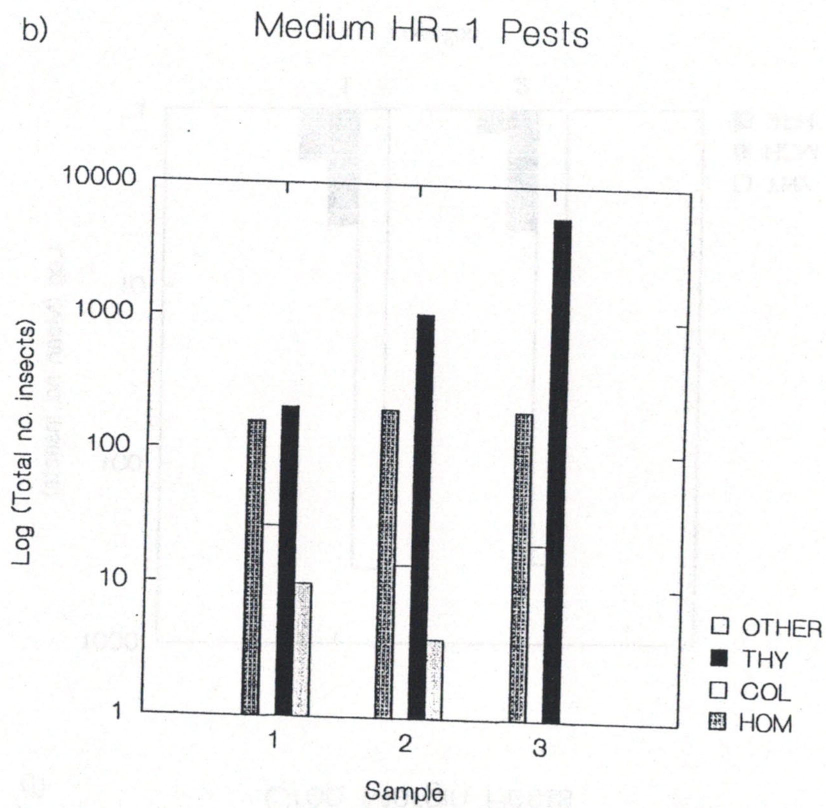


Fig 6. Total catch sizes of most abundant economically important insects in medium established hedgerow site, HR-1, where Sample = 1 (early August), 2 (late August) and 3 (mid-September, 1996). Beneficials are a) Arach(nida) = spiders, Col(eoptera) = ladybird beetles, ground beetles and rove beetles, Hom(optera) = damsel bugs, minute pirate bugs and seed bugs, Hym(enoptera) = parasitic and predatory wasps, and Other = lacewings, syrphid flies and damsel flies. Pests are b) Col(eoptera) = flea beetles and weevils, Hom(optera) = leafhoppers, plantbugs and froghoppers, Thy(sanoptera) = thrips and Other = grasshoppers and moths.

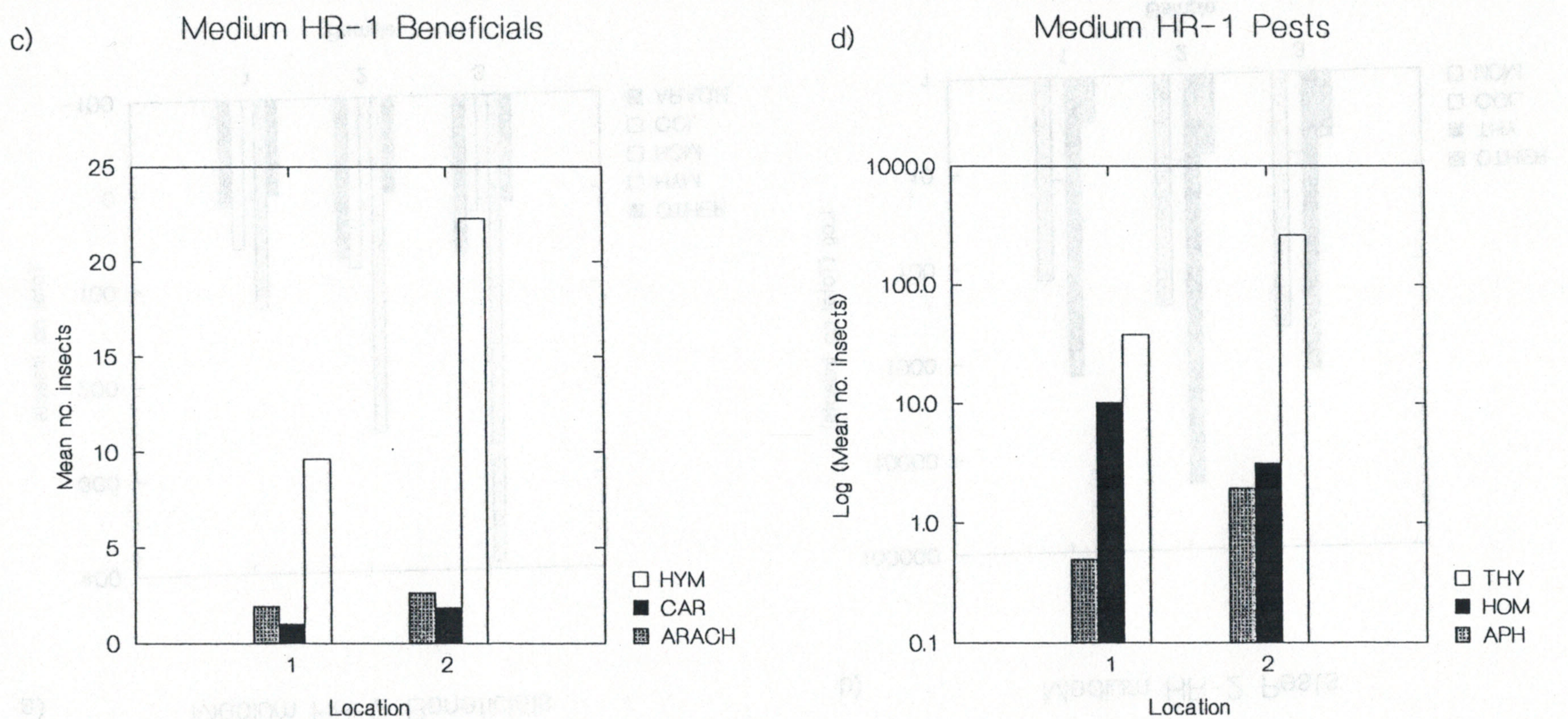
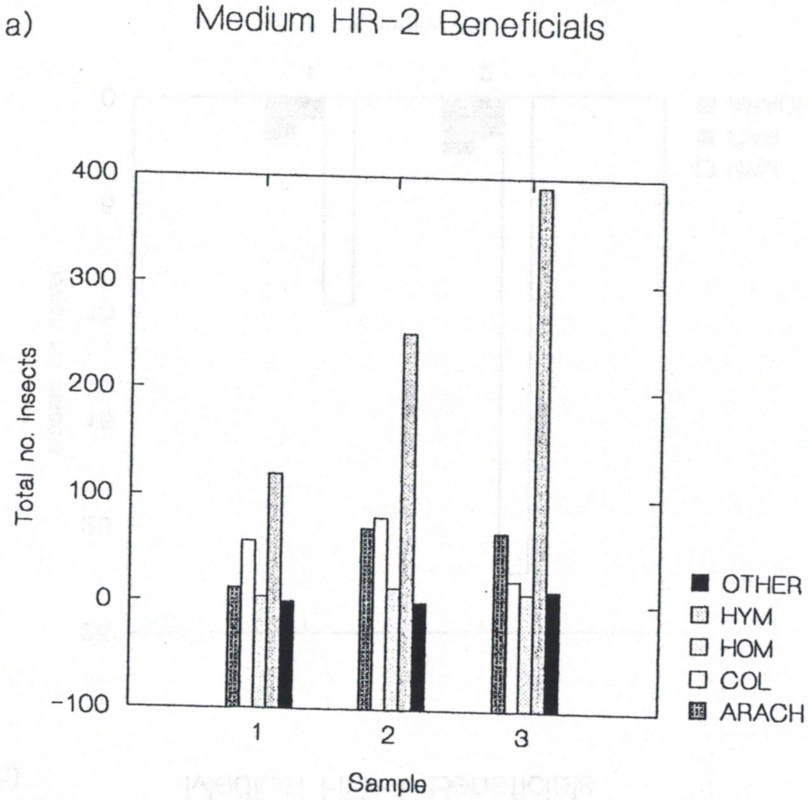


Fig 6 cont. Mean catch sizes of most abundant economically important insects in medium established hedgerow site, HR-1, where Location 1 = hedgerow and 2 = grass margin. Beneficials are c) Arach(nida) = spiders, Car(abidae) = ground beetles and Hym(enoptera) = parasitic and predatory wasps. Pests are d) Aph(idae) = aphids, Hom(optera) = leafhoppers, plantbugs and froghoppers, Thy(sanoptera) = thrips.



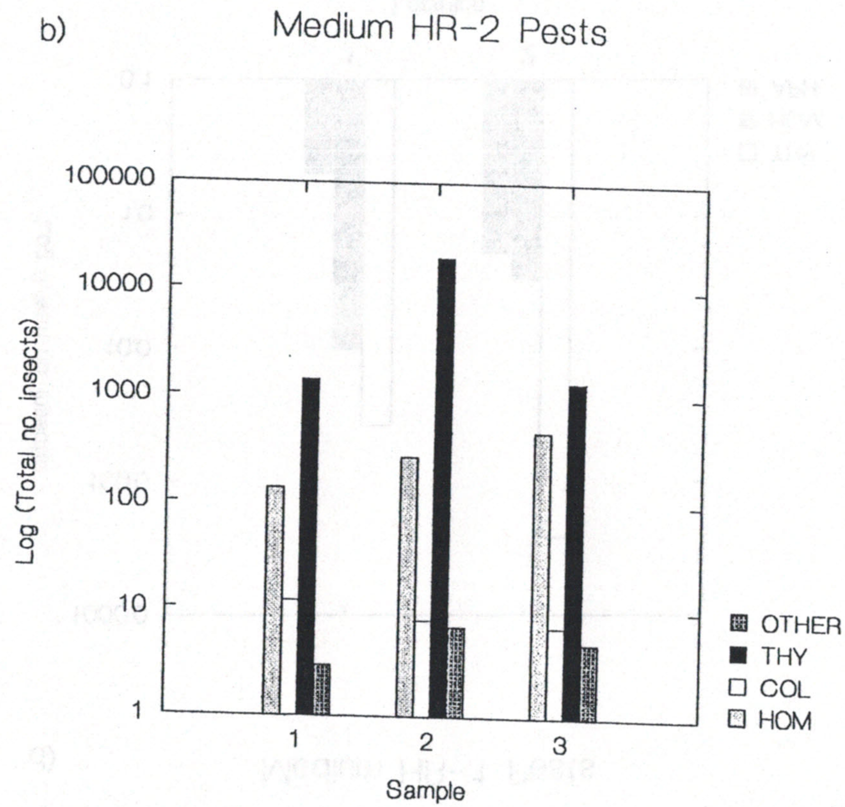
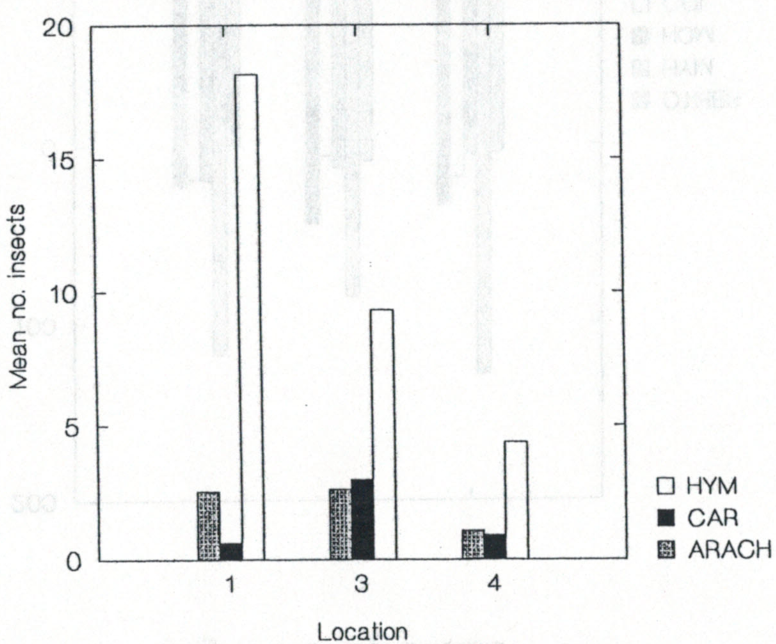


Fig 7. Total catch sizes of most abundant economically important insects in medium established hedgerow site, HR-2, where Sample = 1 (early August), 2 (late August) and 3 (mid-September, 1996). Beneficials are a) Arach(nida) = spiders, Col(eoptera) = ladybird beetles, ground beetles and rove beetles, Hom(optera) = damsel bugs, minute pirate bugs and seed bugs, Hym(enoptera) = parasitic and predatory wasps, and Other = lacewings, syrphid flies and damsel flies. Pests are b) Col(eoptera) = flea beetles and weevils, Hom(optera) = leafhoppers, plantbugs and froghoppers, Thy(sanoptera) = thrips and Other = grasshoppers and moths.

c) Medium HR-2 Beneficials



d) Medium HR-2 Pests

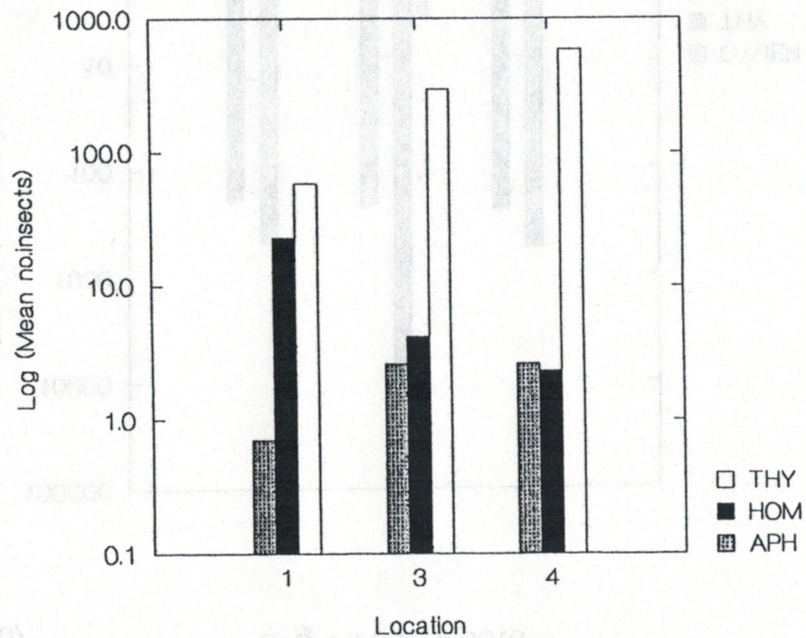
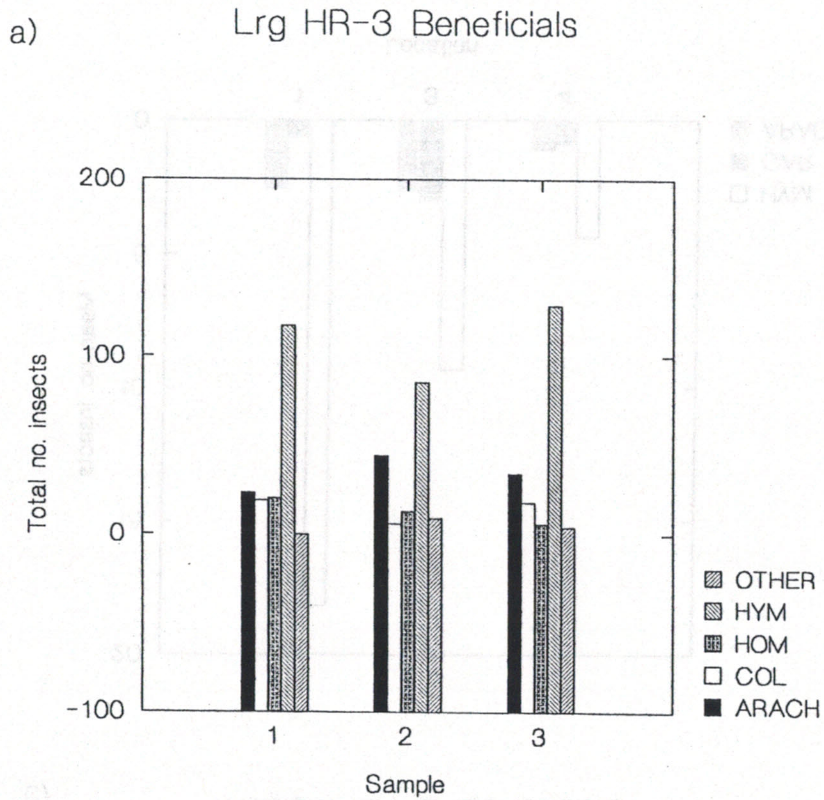


Fig 7 cont. Mean catch sizes of most abundant economically important insects in medium established hedgerow site, HR-2, where Location 1 = hedgerow , 3 = 2m into adjacent potato crop and 4 = 10m into adjacent potato crop. Beneficials are c) Arach(nida) = spiders, Car(abidae) = ground beetles and Hym(enoptera) = parasitic and predatory wasps. Pests are d) Aph(idae) = aphids, Hom(optera) = leafhoppers, plantbugs and froghoppers, Thy(sanoptera) = thrips.



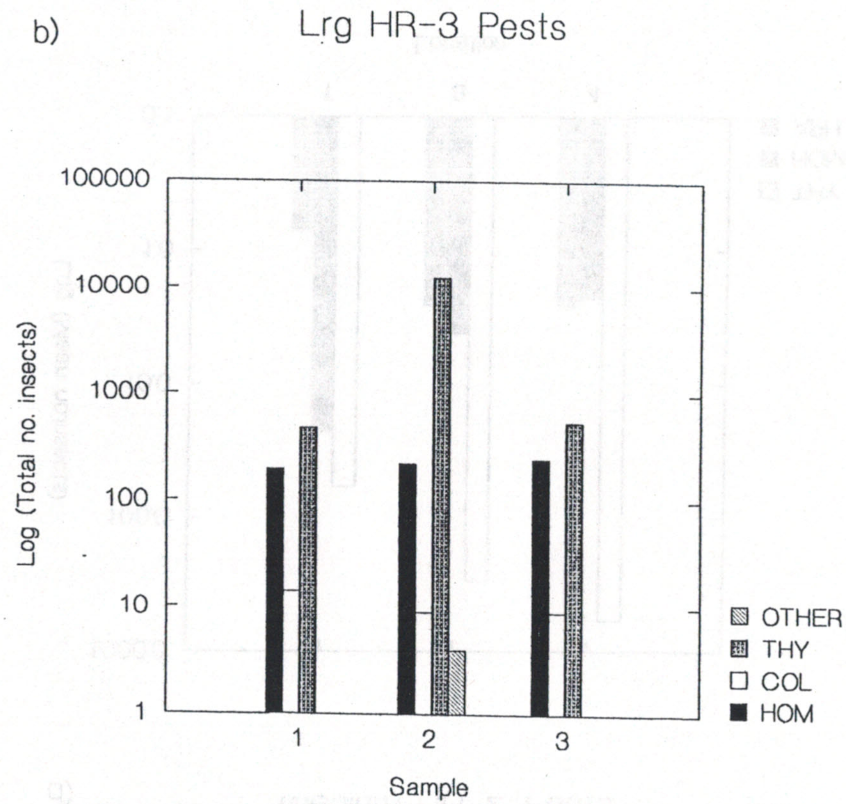


Fig 8. Total catch sizes of most abundant economically important insects in large established hedgerow site, HR-3, where Sample = 1 (early August), 2 (late August) and 3 (mid-September, 1996). Beneficials are a) Arach(nida) = spiders, Col(eoptera) = ladybird beetles, ground beetles and rove beetles, Hom(optera) = damsel bugs, minute pirate bugs and seed bugs, Hym(enoptera) = parasitic and predatory wasps, and Other = lacewings, syrphid flies and damsel flies. Pests are b) Col(eoptera) = flea beetles and weevils, Hom(optera) = leafhoppers, plantbugs and froghoppers, Thy(sanoptera) = thrips and Other = grasshoppers and moths.

c)

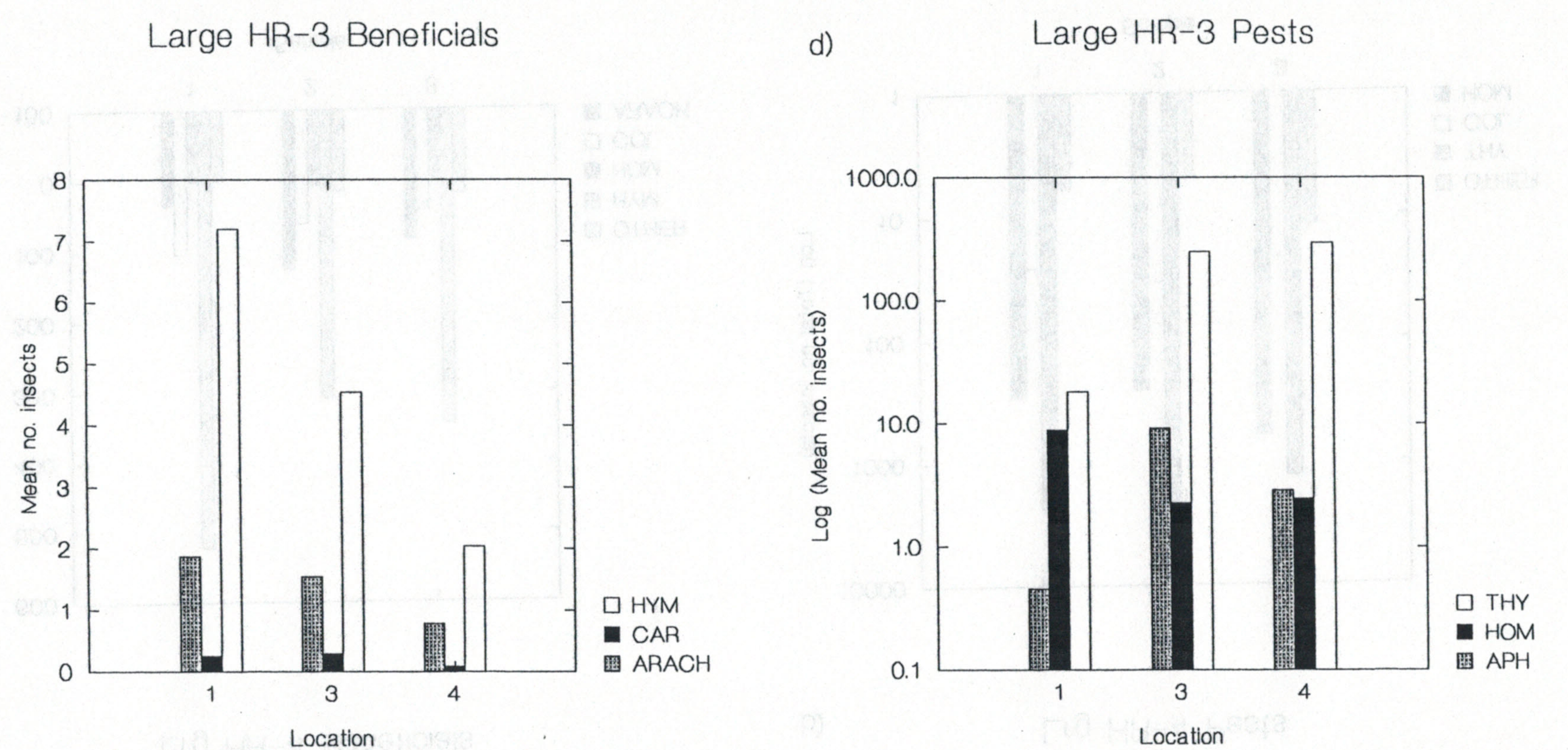


Fig 8 cont. Mean catch sizes of most abundant economically important insects in large established hedgerow site, HR-3, where Location 1 = hedgerow , 3 = 2m into adjacent potato crop and 4 = 10m into adjacent potato crop. Beneficials are c) Arach(nida) = spiders, Car(abidae) = ground beetles and Hym(enoptera) = parasitic and predatory wasps. Pests are d) Aph(idae) = aphids, Hom(optera) = leafhoppers, plantbugs and froghoppers, Thy(sanoptera) = thrips.

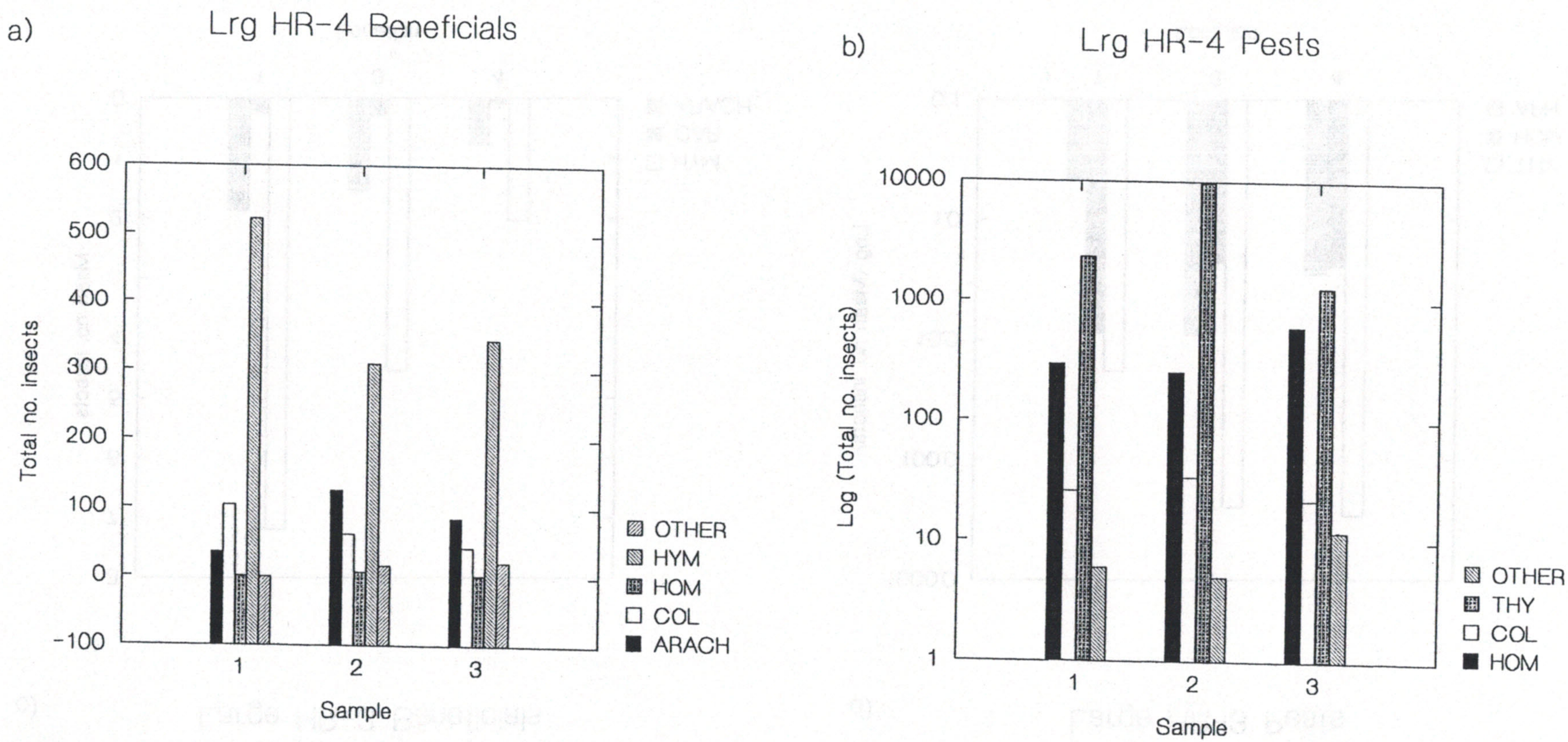
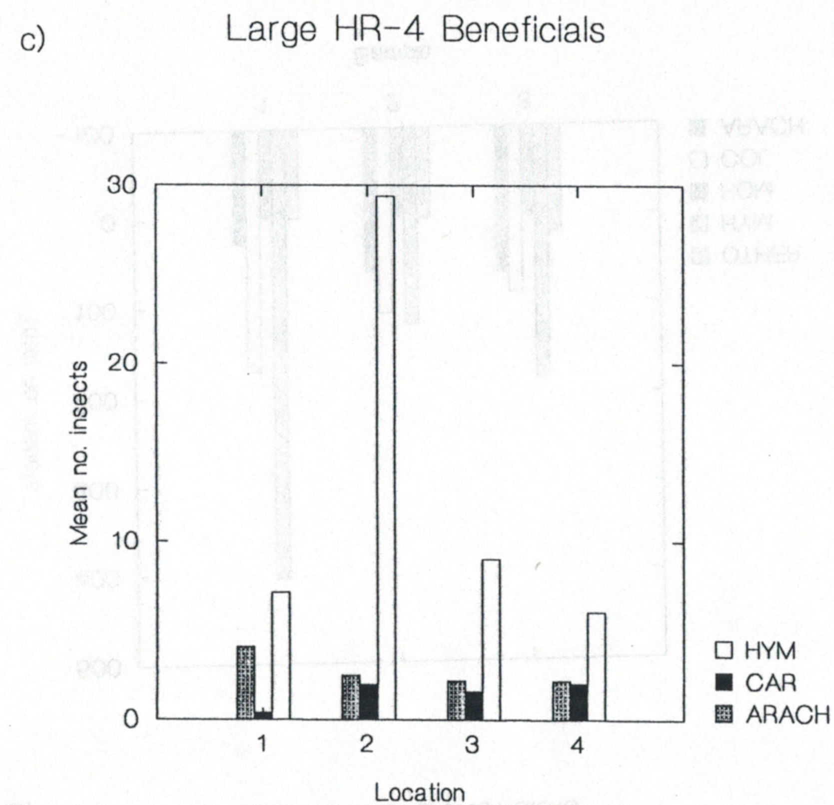


Fig 9. Total catch sizes of most abundant economically important insects in large established hedgerow site, HR-4, where Sample = 1 (early August), 2 (late August) and 3 (mid-September, 1996). Beneficials are a) Arach(nida) = spiders, Col(eoptera) = ladybird beetles, ground beetles and rove beetles, Hom(optera) = damsel bugs, minute pirate bugs and seed bugs, Hym(enoptera) = parasitic and predatory wasps, and Other = lacewings, syrphid flies and damsel flies. Pests are b) Col(eoptera) = flea beetles and weevils, Hom(optera) = leafhoppers, plantbugs and froghoppers, Thy(sanoptera) = thrips and Other = grasshoppers and moths.



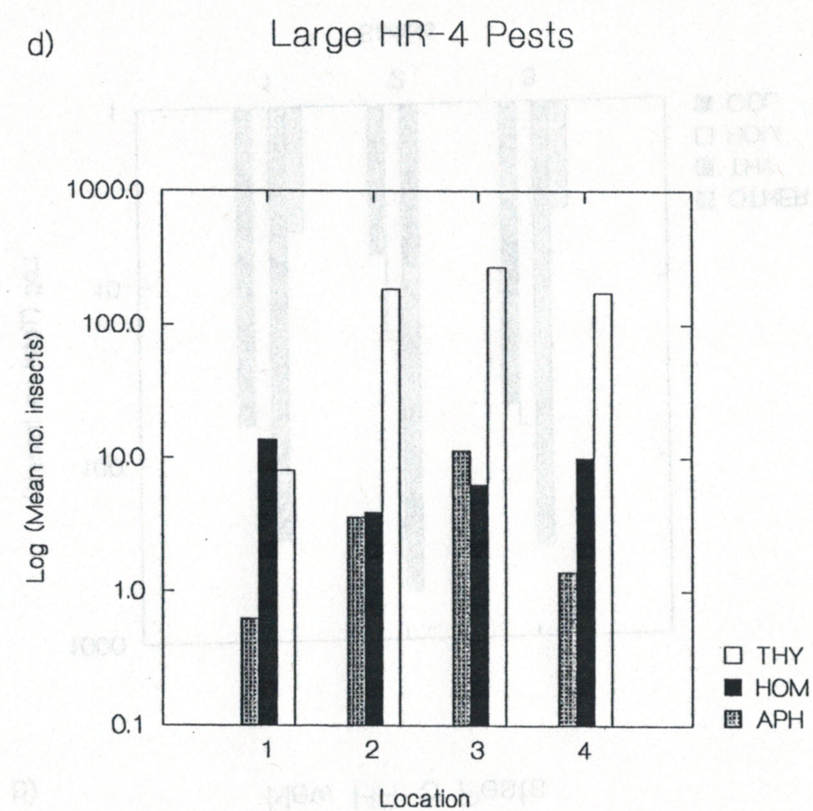
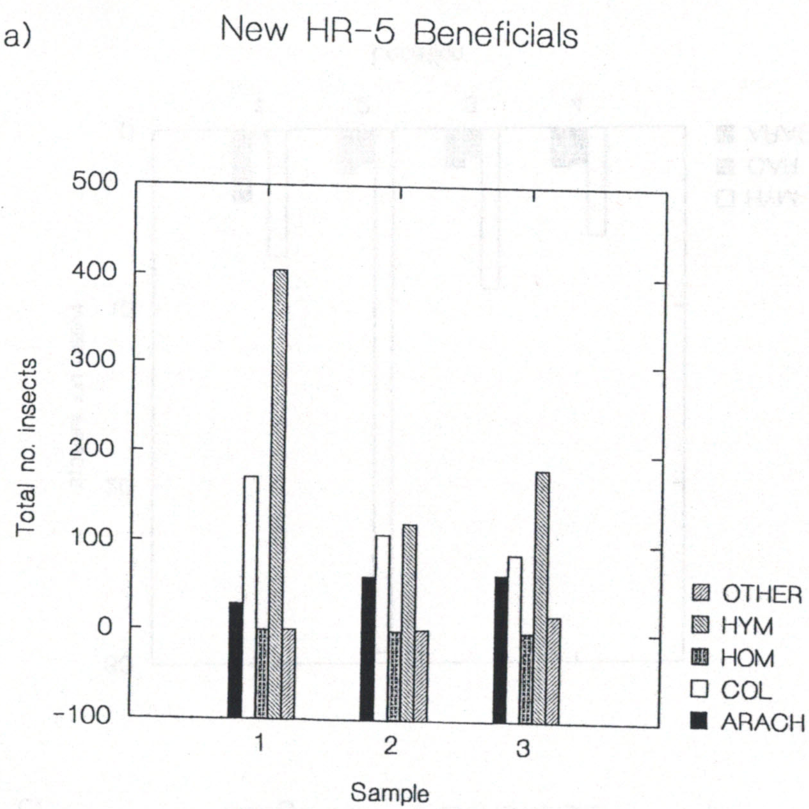


Fig 9 cont. Mean catch sizes of most abundant economically important insects in large established hedgerow site, HR-3, where Location 1 = hedgerow , 2 = grass margin, 3 = 2m into adjacent potato crop and 4 = 10m into adjacent potato crop. Beneficials are c) Arach(nida) = spiders, Car(abidae) = ground beetles and Hym(enoptera) = parasitic and predatory wasps. Pests are d) Aph(idae) = aphids, Hom(optera) = leafhoppers, plantbugs and froghoppers, Thy(sanoptera) = thrips.

a)



b)

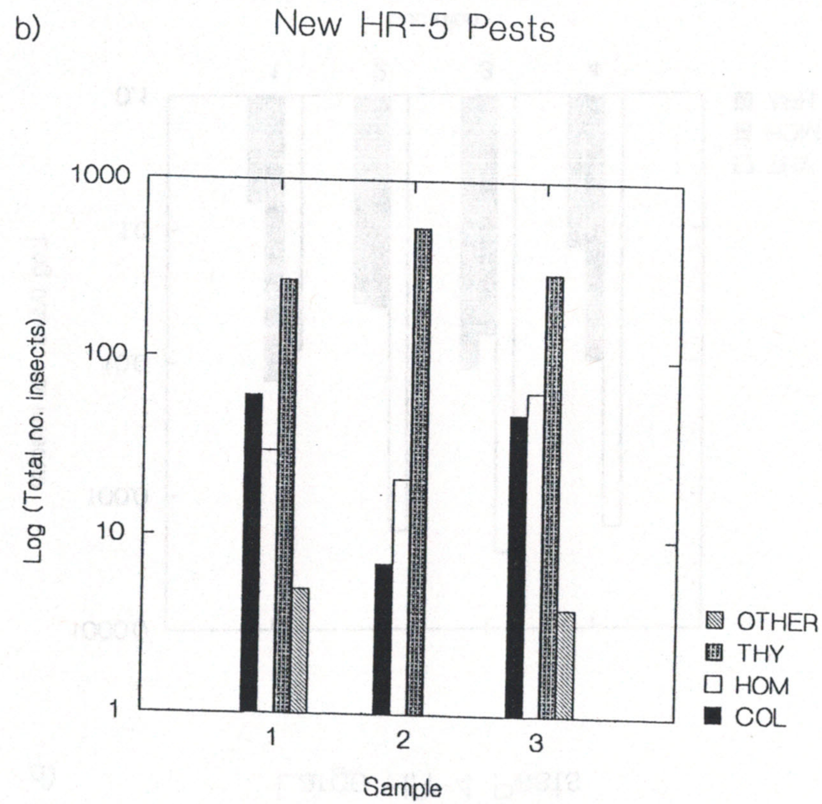


Fig 10. Total catch sizes of most abundant economically important insects in newly-planted hedgerow site, HR-5, where Sample = 1 (early August), 2 (late August) and 3 (mid-September, 1996). Beneficials are a) Arach(nida) = spiders, Col(eoptera) = ladybird beetles, ground beetles and rove beetles, Hom(optera) = damsel bugs, minute pirate bugs and seed bugs, Hym(enoptera) = parasitic and predatory wasps, and Other = lacewings, syrphid flies and damsel flies. Pests are b) Col(eoptera) = flea beetles and weevils, Hom(optera) = leafhoppers, plantbugs and froghoppers, Thy(sanoptera) = thrips and Other = grasshoppers and moths.

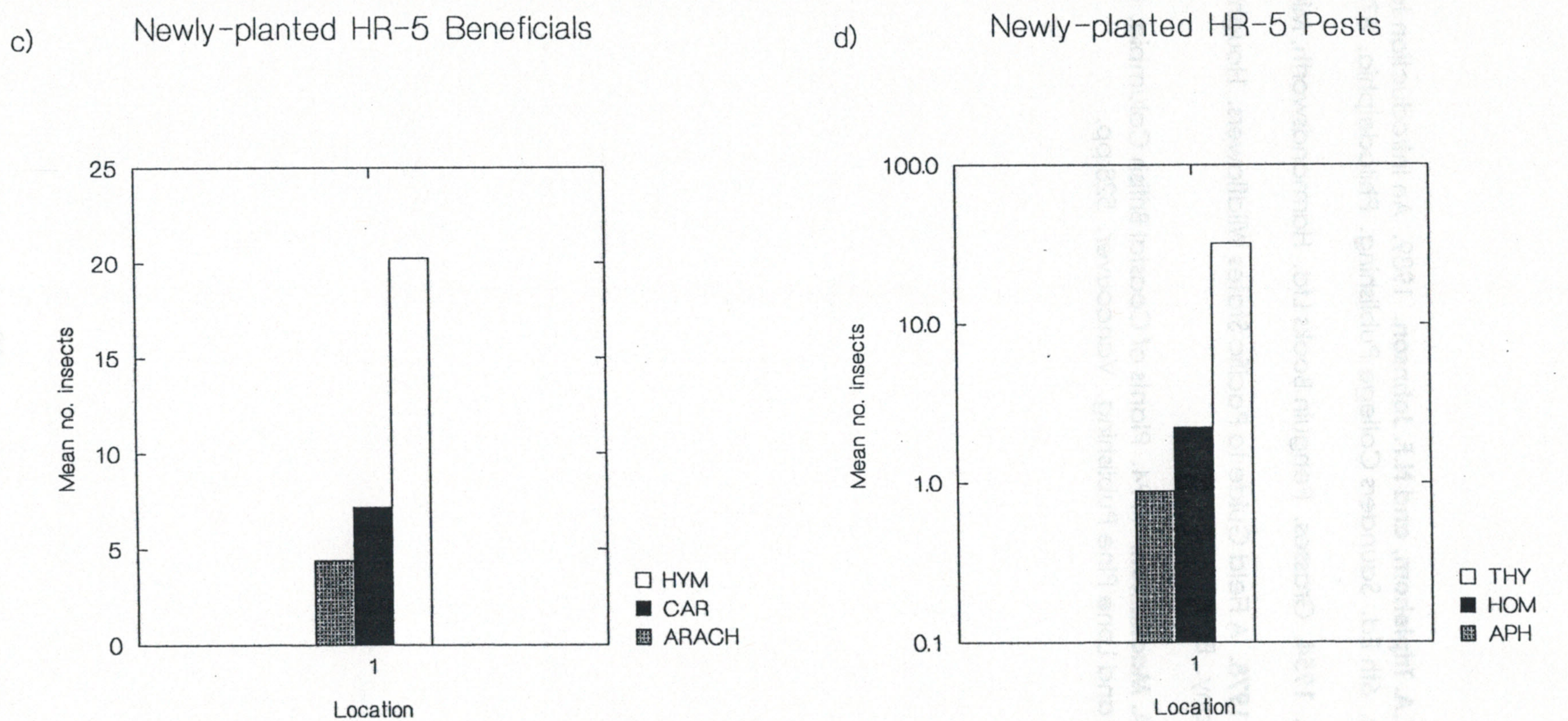


Fig 10 cont. Mean catch sizes of most abundant economically important insects in newly-planted hedgerow site, HR-5, where Location 1 = hedgerow , 2 = grass margin, 3 = 2m into adjacent potato crop and 4 = 10m into adjacent potato crop. Beneficials are c) Arach(nida) = spiders, Car(abidae) = ground beetles and Hym(enoptera) = parasitic and predatory wasps. Pests are d) Aph(idae) = aphids, Hom(optera) = leafhoppers, plantbugs and froghoppers, Thy(sanoptera) = thrips.

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Appendix A

Site Maps

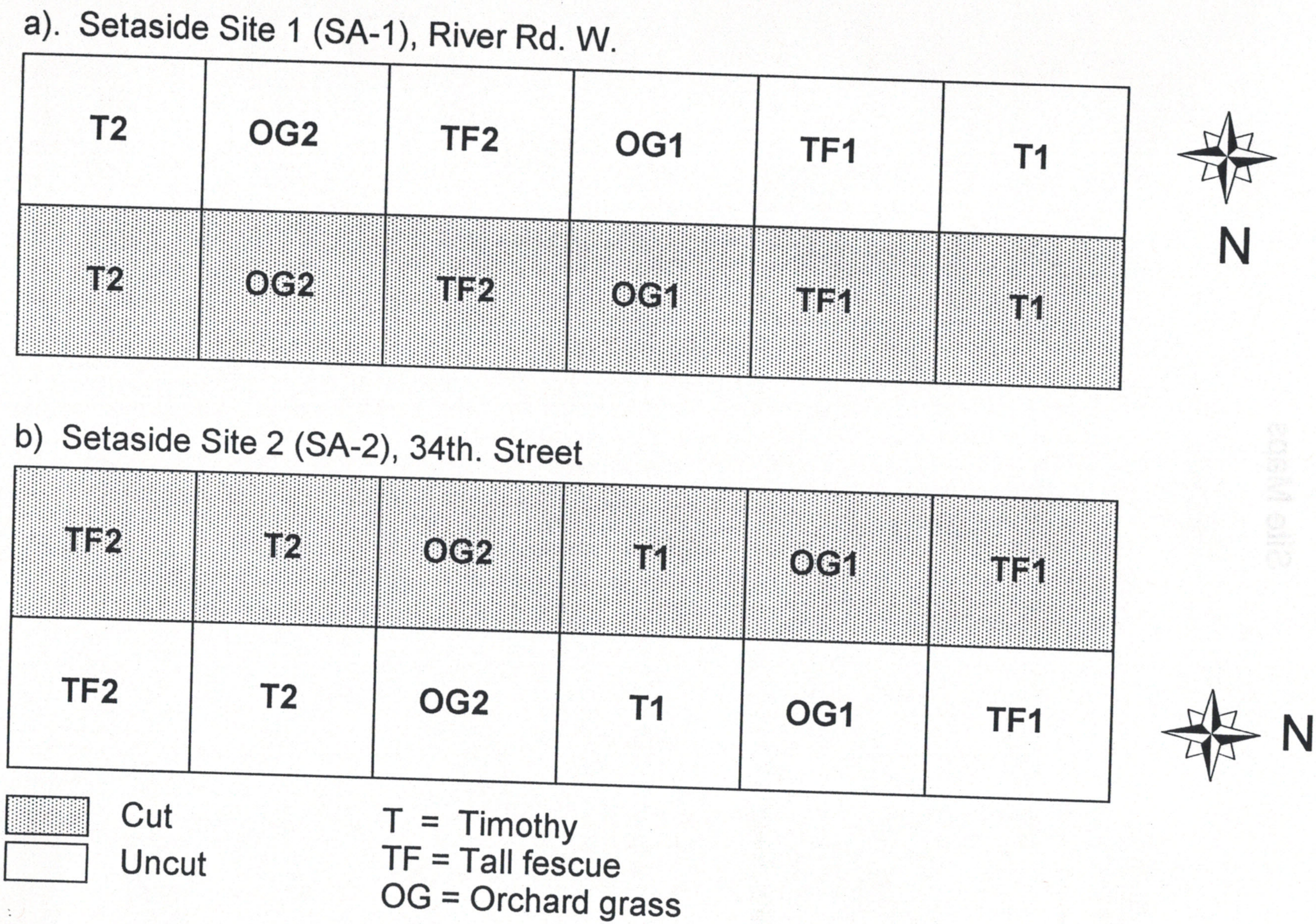

Fig. 1 Established setaside sites. One pitfall trap and one sticky card per sample in each block of timothy, tall fescue and orchard grass in a) SA-1 and b) SA-2.

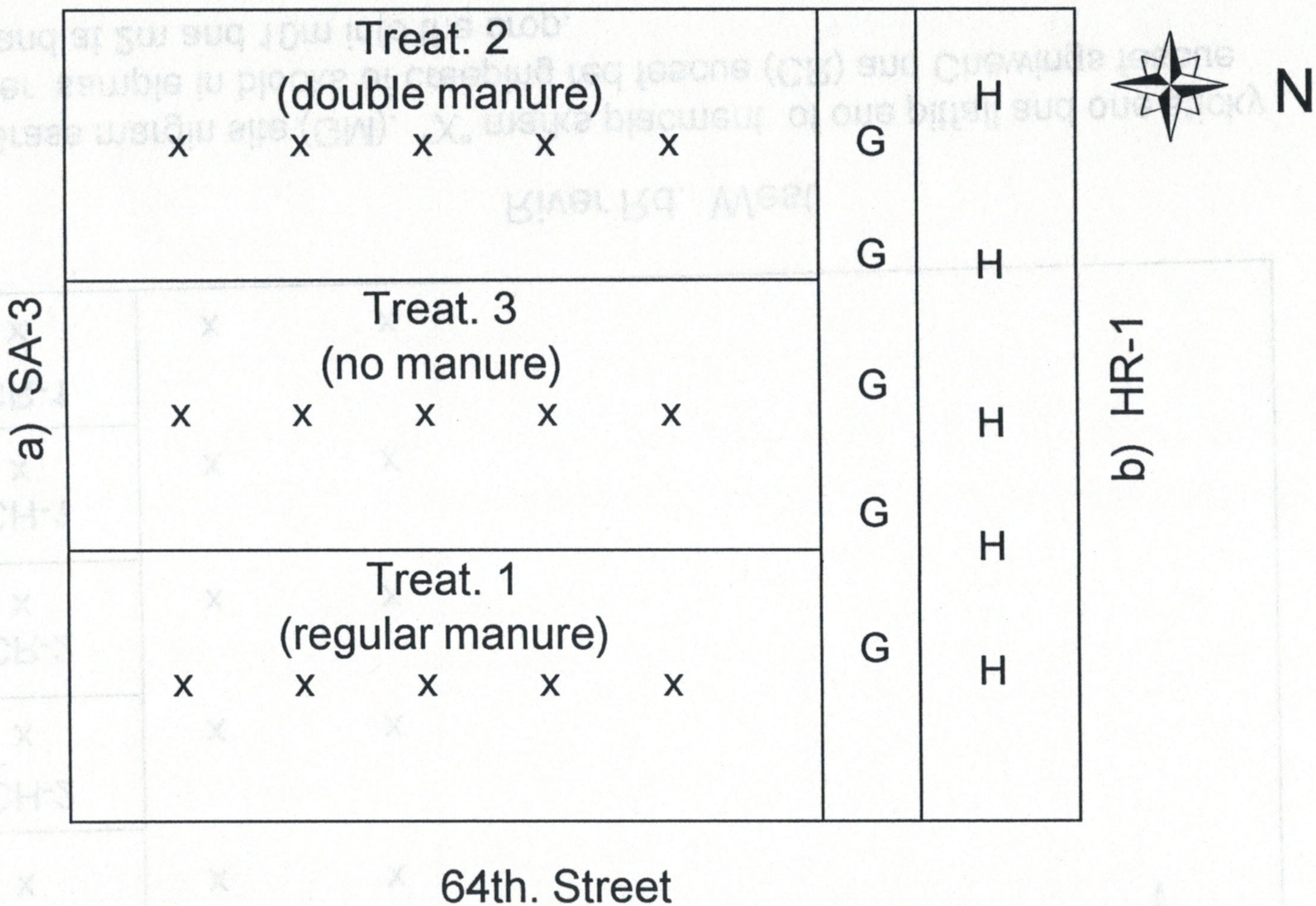

Fig. Newly-planted setaside, SA-3, with 3 turkey manure treatments and medium hedgerow, HR-1, with grass margin. "x" marks location of one pitfall and one sticky card persample in setaside; G and H mark trap locations in grass margin and hedgerow, respectively.

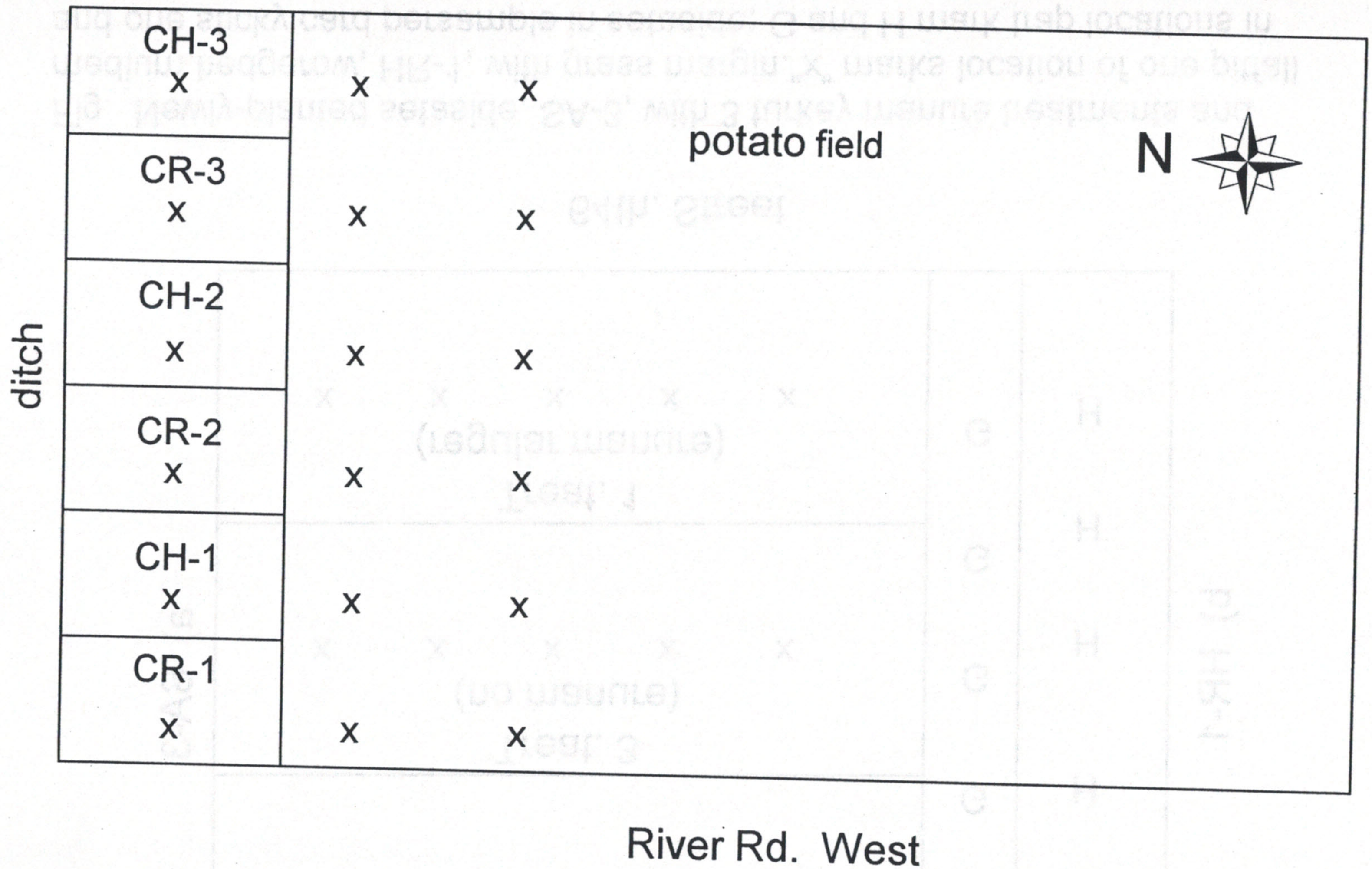

Fig. Grass margin site (GM). "X" marks placment of one pitfall and one sticky card per sample in blocks of creeping red fescue (CR) and Chewings fescue (CH), and at 2m and 10m into the crop.

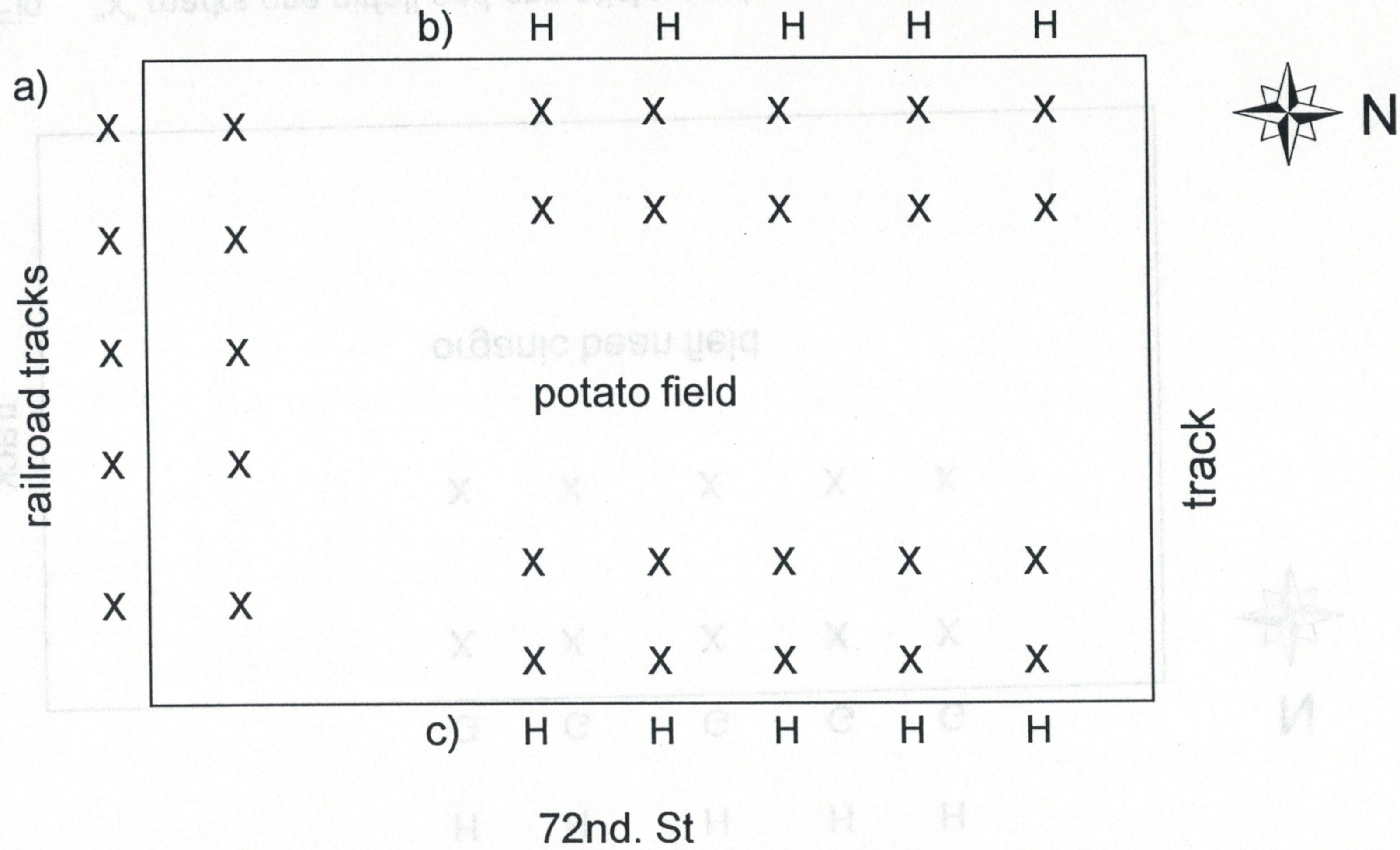

Fig. "x" marks one pitfall trap and one sticky card per sample set in a) crop margin site (CM) at margin and at 10m, b) medium HR-2 in the hedge and at 2m and 10m and c) large HR-3 in the hedge and at 2m and 10m.

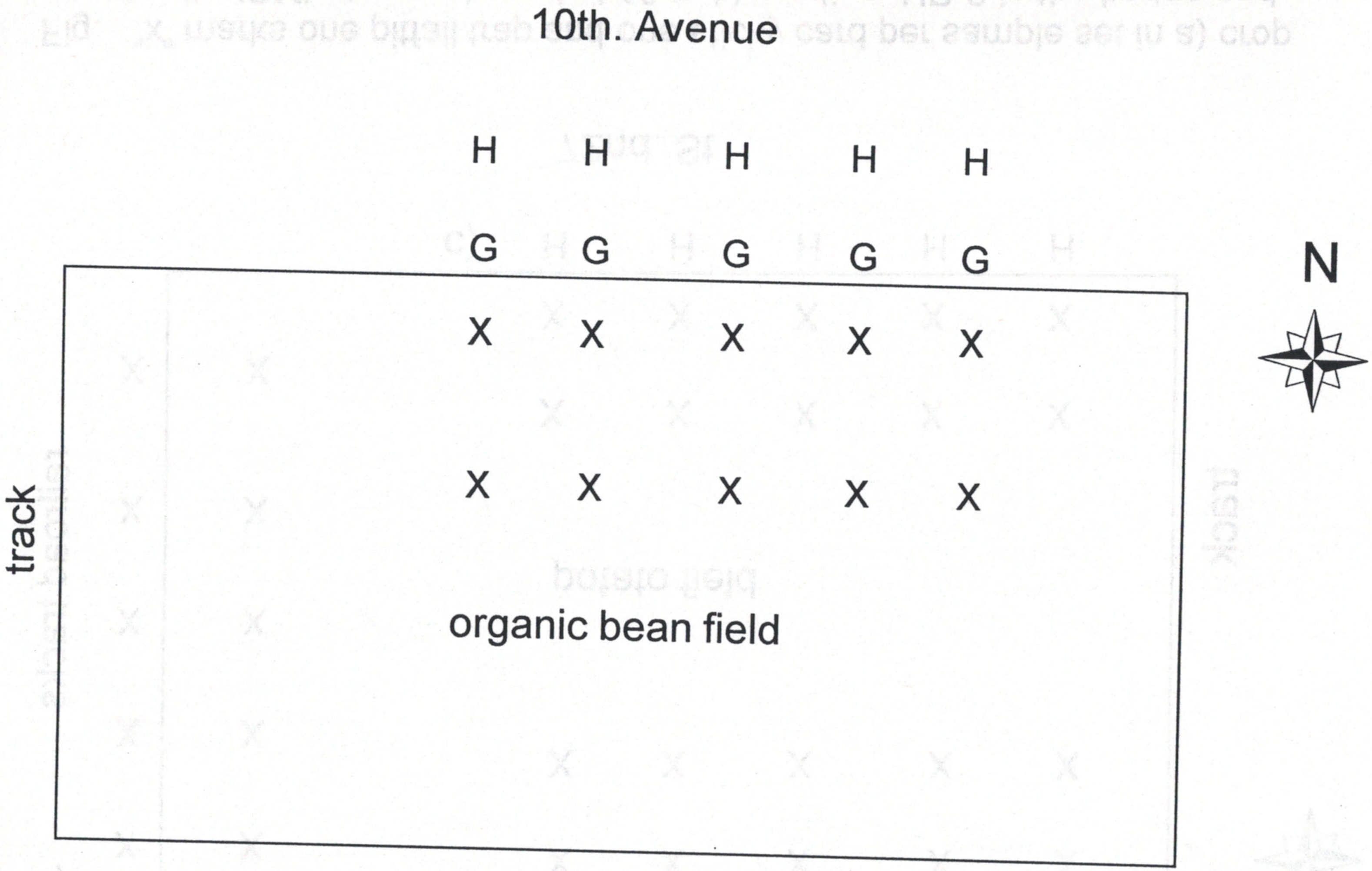

Fig. "x" marks one pitfall and one sticky card per sample in large HR-4 in the hedge (H), in the grass margin (G), at 2m and at 10m.

Appendix B

Delta Farmland and Wildlife Trust Setaside Mix:

Percentage by weight:

- Perrenial rye (*Lolium perenne* L.) 22%
- Orchard grass (*Dactylis glomerata*) 25%
- Tall fescue (*Festuca arundinacea* Schreb.) 20%
- Chewings fescue (*Festuca rubra* L. subsp. *commutata* Gaud.) 30%
- Crimson clover (*Trifolium incarnatum*) 3%

The DF&WT setaside mix is applied at 30 lb/acre with a nurse crop of annual rye at 15 lb/acre.

Appendix C

Simpson's Diversity Index

The Simpson's Divesity Index considers the number of species (s), the total number of individual (N) and the proportion of the total that occurs in each species.

The probabliltiy that two individuals taken at random from a community are the same species

$$I = \frac{\sum n_i(n_i - 1)}{N(N-1)}$$

where I is a measure of dominance. A collection of species with high diversity will have low dominance:

$$D_s = 1 - I$$

and

$$D_s = 1 - \frac{\sum n_i(n_i - 1)}{N(N-1)}$$

Appendix D

Insect species trapped in setasides, grass margin, hedgerows and crops from Aug. 7 - Sept. 14, 1996

Site	Acar*	Anth	Aph	Arach	Car	Cer	Cic	Coc	Col	Cur	Dip	Hom	Hym
SA-1	2602	3	299	602	410	10	65	6	137	293	3051	66	221
SA-2	251	1	116	353	95	22	6	7	108	13	610	87	342
SA-3	502	0	114	270	230	2	6	21	134	2	2028	251	371
GM	493	5	136	241	247	2	10	2	55	40	2127	188	163
CM	177	18	49	61	89	7	6	5	32	0	757	139	173
HR-1	123	1	59	111	69	50	8	86	60	2	777	320	766
HR-2	38	4	144	150	109	6	6	30	25	2	1728	703	765
HR-3	35	20	301	101	15	7	6	8	31	0	1228	327	331
HR-4	144	1	357	246	130	11	5	25	79	3	1651	750	1178
HR-5	99	0	31	155	252	3	0	7	98	19	2079	78	709

Site	Lep	Lyg	Mir	Myr	Nab	Neur	Orth	Psy	Sil	Sta	Syr	Thy	Zyg
SA-1	10	0	51	0	38	10	9	4	70	39	20	217	1
SA-2	4	0	2	0	0	0	6	1	29	10	34	2837	0
SA-3	6	0	2	0	14	4	3	0	6	52	30	12562	0
GM	5	1	55	0	2	26	19	9	6	15	11	884	6
CM	15	0	26	73	5	1	32	4	9	27	15	11197	0
HR-1	15	2	3	1340	4	2	0	10	6	37	83	7227	1
HR-2	11	0	7	0	1	3	4	8	1	20	11	22700	0
HR-3	1	0	5	0	0	5	3	34	0	20	7	13626	1
HR-4	16	0	2	2	0	8	5	379	3	54	29	13520	0
HR-5	10	0	0	0	0	4	0	0	0	108	18	1132	0

Key to Site Abbrevations:

SA-1 established setaside	HR-1 medium hedgerow with grass margin
SA-2 established setaside	HR-2 medium hedgerow with no grass margin
SA-3 newly-planted setaside	HR-3 large hedgerow with no grass margin
GM grass margin	HR-4 large hedgerow with grass margin
CM crop margin	HR-5 newly-planted hedgerow

*Key to Insect Abbreviations

Abbrev	Common name	Scientific name
Acar	mites	O. Acari
Anth	minute pirate bugs	F. Anthocoridae
Aph	aphids	F. Aphididae
Arach	spiders	O. Araneae
Car	ground beetles	F. Carabidae
Cer	froghoppers	F. Cercopidae
Cic	leafhoppers	F. Cicadellidae
Coc	ladybird beetles	F. Coccinellidae
Col	beetles	O. Coleoptera
Cur	weevils	F. Curculionidae
Dip	flies	O. Diptera
Hom	true bugs	O. Homoptera
Hym	wasps, bees	O. Hymenoptera

Abbrev.	Common name	Scientific name
Lep	moths, butterflies	O. Lepidoptera
Lyg	seed bugs	F. Lygaeidae
Mir	plant bugs	F. Miridae
Myr	myrmicine ants	G. *Myrmica*
Nab	damsel bugs	F. Nabidae
Neur	lacewings	O. Neuroptera
Orth	grasshoppers	O. Orthoptera
Psy	book lice	F. Psyllidae
Sil	carrion beetles	F. Silphidae
Sta	rove beetles	F. Staphylinidae
Syr	hover flies	F. Syrphidae
Thy	thrips	O. Thysanoptera
Zyg	damsel flies	Sub.O. Zygoptera

Appendix E

Weeds collected in setasides, grass margins, crop margin, hedgerows and within crops in August and September, 1996.

Common name	Scientific name	Most common habitat
barley	*Hordeum spp.*	crop, new setaside
barnyard grass	*Echinochloa crusgalli*	crop, new setaside
bentgrass	*Agrostis spp.*	grass margin, hedge edge
blackberry, cutleaf	*Rubus laciniatus*	hedgerows
blackberry, Himalayan	*Rubus discolor*	hedgerows
blackberry, native	*Rubus spp.*	hedgerows
bull thistle	*Cirsium vulgare*	grass margin, uncut setasides
buttercup	*Ranunculus repens*	grass margins
Canada bluegrass	*Poa compressa* L.	setasides in orchard grass blocks, grass margins
Canada thistle	*Cirsium arvense*	grass margins
clover, alsike		cut setasides
clover, crimson	*Trifolium incarnaturm*	cut setasides
clover, red	*Trifolium pratense*	cut setasides
clover, white	*Trifolium repens*	cut setasides
curled dock	*Rumex crispus*	grass margin, new hedgerow
deadly nightshade	*Solanum dulcamara*	grass margin
fleabane, Canadian	*Erigeron canadensis*	grass margin
goldenrod, meadow	*Solidago canadensis*	grass margin
groundsel, common	*Senecio vulgaris*	grass margin
hemp nettle	*Galeopsis tetrahit*	grass margin
horsetail, common	*Equisetum arvense*	grass margin near ditch
knotweed, prostrate	*Polygonum aviculare*	grass margin
lady's thumb	*Polygonum persicaria*	in crop, bare crop margin
lamb's quarter	*Chenopodium album*	in crop, bare crop margin
orchard grass	*Dactylis glomerata*	grass margin
perrenial rye-grass	*Lolium perenne*	grass margin, hedge edge
plantain	*Plantago major*	new setaside, grass margin
prickly lettuce	*Lactuca scariola*	grass margin
purple-leafed willow herb	*Epilobium ciliatum*	grass margin
quack grass	*Agropyron repens*	grass margin
red-root pigweed		in crop, bare crop margin
rush, common	*Juncus effusus*	grass margin near ditch
shepherd's purse	*Capsella bursa-pastoris*	in crop, new setaside
smartweed, green	*Polygonum spp.*	in crop, bare crop margin
smartweed, willow	*Polygonum lapathifolium*	in crop, bare crop margin
sowthistle, perrenial	*Sonchus arvensis*	grass margin
stinking chamomile	*Matricaria matricarioides*	grass margin, field margins
stork's bill	*Erodium cicutarium*	field margins, new setaside
timothy	*Phlaeum pratense* L	grass margins, new hedgerow
velvet grass	*Holcus lanatus* L.	grass margin
western lettuce	*Lactuca ludoviciana*	grass margin