1) Project Title: Evaluation of Michigan Native Plants and their Attractiveness to Natural Enemies

Investigators: Anna K. Fiedler and Douglas A. Landis, Dept. Entomology, Michigan State University.

Contact: Anna K. Fiedler, (fiedlera@msu.edu)

Project Description: The use of plants to provide nectar and pollen resources to natural enemies via habitat management is a growing focus of conservation biological control. Many studies employ plant species previously shown to be successful. This has resulted in a small set of annual plants being used worldwide, and often in locations where they are not native. We compared 43 native Michigan, USA perennial and five frequently recommended non-native annual plant species for their attractiveness to natural enemies and herbivores in the 2004 and 2005 growing seasons. In order to make this work applicable in different regions, we examined whether plant characteristics affect the number and type of natural enemies and herbivores collected at flowering plants.

Plant species differed significantly in their attractiveness to natural enemies. In year one, the non-native annual plants outperformed many of the newly established native perennial plants. In year two, however, many native perennial plants attracted higher numbers of natural enemies than non-native plants. In year two, we compared each flowering plant against the background vegetation (grass) for their attractiveness to natural enemies and herbivores. We identified 24 native perennial plants that attracted high numbers of natural enemies, with promise for habitat management. Among the most attractive are *Eupatorium perfoliatum* L., *Monarda punctata* L., *Silphium perfoliatum* L., *Potentilla fruticosa* auct. non L., *Coreopsis lanceolata* L., *Spiraea alba* Duroi, *Agastache nepetoides* (L.) Kuntze, *Anemone canadensis* L., and *Angelica atropurpurea* L.. These species can now be tested in groupings to develop a community of native plant species that attracts diverse natural enemy taxa and provides nectar and pollen throughout the growing season.

We tested whether the number and type of natural enemies and herbivores attracted to a plant were predicted by the following plant characteristics: week of peak bloom, floral area per m^2 plot, maximum flower height, hue, chroma, corolla depth, and corolla width. Natural enemy abundance and plant characteristics were similarly related in both 2004 and 2005. A multiple regression on log transformed natural enemy numbers versus plant characteristics indicated a significant positive linear relationship between week of peak bloom and number of natural enemies that explained the largest proportion of variation in 2005 (R^2=0.30). Natural enemy abundance also increased significantly with floral area in a linear (R^2=0.13) and curvilinear manner (R^2=0.07). A comparison of native and non-native species in 2005 indicated that natural enemies respond more strongly to floral area at non-native than native plants. The first principal component from a PCA of plant characteristics explained 30.1% of plant characteristic variability. A simple regression using PCA factor-1 showed an increase in natural enemy number

with increasing floral area, week of peak bloom, and maximum flower height, and decreasing corolla width (R^2=0.37). Herbivore abundance also increased with PCA factor-1, but the relationship was much weaker (R^2=0.09). Results indicate that consideration of floral area for any given time of the season has potential to streamline plant selection for habitat management and increase the attractiveness of habitat management plantings to natural enemies.

In addition to these research activities, we have disseminated information on the project in several forums. These include discussion of impacts of flowering plants on natural enemies and pollinators at field days held at Michigan State University in 2004 and 2005 (over 100 attended each year), on a website, and at talks for field crops and fruit growers. We are currently developing a 4-6 page bulletin with MSU Extension on the project, due out in December 2006.

For more information: http://www.ipm.msu.edu/plants/plantHome.htm

2) Project Title: Long-term Monitoring of Coccinellid Communities on the KBS LTER Site

Investigators: Douglas A. Landis, Alissa Berro and Chris Sebolt, Department of Entomology, Michigan State University

Contact: Chris Sebolt (sebolt@msu.edu)

Project Description: Since 1990, populations of native and non-native species of Coccinellidae and other selected predators have been monitored at the Kellogg Biological Station LTER site using yellow sticky traps. The study's overall goal is to monitor trends and determine interactions between these populations and other biota, and to serve as a sentinel system to detect and track new or invasive species. Six native coccinellid species, three non-native coccinellid species and several other important predators (lacewings, lampyrids and minor coccinellids) have been consistently monitored on the KBS LTER main site as well as the deciduous, coniferous and succession forest sites. New exotic coccinellids are included in long-term monitoring as they are detected.

Results from the past 15 years reveal shifting trends in coccinelid population dynamics in addition to the first detection of three exotic coccinellids in Michigan. The previously established exotic *Coccinella septempuncta*, has consistently exhibited 4-5 year population peaks throughout the study and is consistently one of the two most abundant coccinellid species. *Harmonia axyridis* was the first new exotic coccinellid detected in this study in 1994. It maintained modest populations for several years until the arrival of soybean aphid (*Aphis glycines*) in the Midwest in 2000. Since that time both the aphid *and H. axyridis* have exhibited strong 2 year cycles with peaks of both species in odd numbered years. The establishment and increase of *H. axyridis* appears to be correlated with the dramatic decline of the native coccinellid *Coleomegilla maculata*. *Hippodamia variegata* was the second exotic coccinellid detected by this study with the first occurrence detected in 2005 (Gardiner and Parsons in review). A native of Eurasia, Africa and India, *H. variegata* was originally introduced to the midwest and western United States in 1986 as a biocontrol agent for *Diuraphis noxia*, the Russian wheat aphid (Ellis et. al. 1999). *Hippodamia variegata* was most often recorded at the LTER in poplar and old-field succession plots during late July and early August. A third novel species, *Propylea quatuordecimpunctata*, also originally released as a biocontrol agent for *Diuraphis noxia*, was first detected in 2006.

The detection of these two new exotic species along with the interaction of *H. axyridis* with soybean aphid, underscore the importance of this monitoring protocol and its service as a sentinel system for new species detection, colonization and long-term trends.

3) Project Title: Landscape Impacts Soybean Aphid Biological Control.

Investigators: Mary Gardiner[1], Nick Schmidt[2], Emily Mueller[3], Jeremy Chacon[4], Doug Landis[1], Matt O'Neal[2], Chris Difonzo[1], George Heimpel[4], Claudio Gratton[3], and Mike Brewer[1].

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Contact: Mary Gardiner (gardin18@msu.edu)

Project Description: The soybean aphid, *Aphis glycines* Matsumura, has become a principal arthropod pest of soybean in the North Central US since its first detection in 2000. This species threatens soybean production through direct feeding damage and virus transmission. Soybean fields are ephemeral habitats where disturbances such as tillage, pesticide application and harvesting force repeated re-colonization by soybean aphid and its predators. The surrounding landscape acts as a source and a sink of these species. Within the introduced range of *A. glycines*, the complexity of a landscape and the spatial arrangement of crop and non-crop habitats can greatly influence predator species diversity and abundance. Our primary objectives were to: 1) evaluate the impact of predator populations on soybean aphid population dynamics across a range of landscape structures in Michigan, Wisconsin, Minnesota, and Iowa. and 2) determine if landscape variables influence the abundance of soybean aphid and the diversity and abundance of predators found within soybean fields in these states.

The impact of the predator community on soybean aphid population dynamics varied across 12 sites sampled in Michigan, Wisconsin, Minnesota and Iowa. In 4 of the 12 sites, predators had no impact on aphid population growth. In the remaining 8 sites, predators either delayed (4 sites) or prevented (4 sites) aphid populations from reaching threshold. We examined the relationship between predator species abundance and the amount of non-crop habitat (woodlots, wetlands, pasturelands, grasslands, and urban areas) and annual cropland in the landscape as well as overall landscape heterogeneity at several spatial scales (0.5 km – 3.5 km at half km increments). Exotic lady beetle species *(Harmonia axyridis*, *Hippodamia vareigata*, and *Coccinella septempunctata)* are positively correlated with non-crop habitat at multiple spatial scales, 1.5 and 2 km were most predictive, explaining 49% of the variability in exotic lady beetle abundance. The abundance of exotic coccinellids also exhibited a strong negative correlation with the proportion of soybean in the landscape; a spatial scale of 3 km was most predictive, explaining 76% of the variability in abundance. Native lady beetle (*Hippodamia convergens*, *Coleomegilla maculata*, *Hippodamia parenthesis*, *Cycloneda munda*, *Adalia bipunctata*, and *Hippodamia tredecimpunctata*) populations were not correlated with non-crop habitat at any of the spatial scales examined. Natives were positively correlated with the abundance of soybean at 1.5 km and the proportion of corn at 1.5 km and 2 km. Exotic and native lady beetles were both correlated with Simpson's D (-

ln(D)) as a measure of land-cover dominance; however their relationship was not consistent. Exotic lady populations were highest in diverse landscapes that lacked a dominant land-cover type while native lady beetle populations were highest in simplified landscapes dominated by corn and soybean.

Overall, these data show that Michigan landscapes with diverse land-cover and high proportions non-crop habitats are preferential habitat for exotic lady beetles. In these landscapes populations of native lady beetles are low. Native lady beetles are most abundant in Iowa and Minnesota landscapes which are primarily dominated by corn and soybean. This relationship may be due to direct competition between native and exotic species or differential habitat requirements. Due to the low abundance of non-crop habitat in Iowa and western Minnesota, these landscapes may limit exotic lady beetles which require these habitats to overwinter while the native beetles to these regions are well adapted the conditions present.

4) Project Title: Evaluating the Potential for Biological Control of Garlic Mustard in Michigan

Personnel: Jeffrey A. Evans[(1)], Adam S. Davis[(2)], Douglas A. Landis[(1)], Douglas W. Schemske[(3)]

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Contact: Jeff Evans (evansj18@msu.edu)

Project Description: Garlic Mustard*, Alliaria petiolata* (Brassicaceae) (M. Bieb) Cavara and Grande, is an obligate biennial forb that is native to Europe, the Mediterranean region, and parts of Western Asia. It is invasive in North America and is now present and spreading in at least 34 U.S. States and 4 Canadian provinces. *Alliaria petiolata* is shade adapted and an aggressive competitor in forest understories, edge habitats, and disturbed areas*.* Established populations of *A. petiolata* set high numbers of seeds, and seeds can remain viable in the seed bank for up to five years. Conventional control methods have proven ineffective on all but the smallest infestations. Four potential biological control organisms are currently under testing in Europe and in quarantine in the United States for host specificity and effectiveness. All are weevils in the genus *Ceutorhynchus.* One of these, *C. scrobicollis*, is the furthest along in testing. A petition to release this agent may be submitted to the Technical Advisory Group in the near future.

We began taking baseline species composition data at eight *A. petiolata* infested sites representing a variety of forest types in the Lower Peninsula of Michigan to document the effects of changes in garlic mustard abundance on the existing community. Two parallel transects of ten 1m x 1m plots spaced 10m apart were established in April 2003 at each site, and percent garlic mustard coverage, species percent composition, percent coverage of plant, rock, and soil were recorded. All measurements have been repeated annually during fall and spring from 2003 to 2006 and will be continued in future years. Transects at seven of eight sites were set up such that *A. petiolata* was not initially present in all 20 sampling quadrats thus allowing us to observe changes in its within-site distribution. *Alliaria petiolata* has expanded or maintaining its distribution at all sites. Although damage from herbivores is seen frequently (84.9% of invaded quadrats), the extent of damage is insignificant (2.9 % of leaf area removed).

A study of variability in *Alliaria petiolata* demography was initiated in June 2004. The objectives of this effort are to characterize spatial variability in *A. petiolata* demography and to model the effects of potential biocontrol agents on *A. petiolata* populations across Michigan and determine whether single or multiple agent biocontrol will be necessary. Demographic parameters are being measured for *A. petiolata* populations at eight locations in southern Michigan and at multiple sites in Illinois representing a

latitudinal and longitudinal gradient as well as both high and low levels of *A. petiolata* infestation. A model of *A. petiolata* demography will allow us to test the effectiveness of single and multiple biological control agents on *A. petiolata* across its Michigan range by applying varied levels of mortality at different stages in *A. petiolata's* life cycle. Results from the first year of this study indicate that *A. petiolata*'s populations are spreading at all eight sites with population growth rates (λ) ranging from 1.2 to 6.2. Values of λ greater than 1 indicate population expansion. Our calculated values of λ generally correspond to the high and low site infestation categories as predicted. Based on our current understanding of the level of mortality imposed on *A. petiolata* by the potential biocontrol agents and these initial data, our modeling predicts that five of the eight study sites may be amenable to intervention by biological control with single or multiple agent releases that impact rosette to flowering survival and fecundity. This fall we will incorporate data from 2006 into the model and will begin working on modeling density dependence in *A. petiolata.*

In May, 2004 we established a factorial study to determine the joint effects of herbivore browsing and *A. petiolata* on native plants in forest understories. Plots with and without deer and turkey access and with our without *A. petiolata* were used to test the hypothesis that herbivores and *A. petiolata* negatively impact native plant communities, both separately and in concert. We marked 96 1 m^2 permanent sampling quadrats in a high quality hardwood forest at the Edward Lowe Foundation's Big Rock Valley in Cassopolis, MI. Sixty-four of the plots were set out in discrete patches of *A. petiolata*, and 32 plots were set out in areas completely free of *A. petiolata* (GM 0). Half of the plots containing *A. petiolata* plants were randomly assigned to have GM clipped at the root crown, bagged, and removed from the site (GM-) and half were left undisturbed (GM+). 16 randomly selected plots from each *A. petiolata* treatment were enclosed by a 1.5 m diameter, 1.5 m high wire mesh fence to exclude deer and turkeys (Deer-). Half of the remaining plots in each treatment were randomly assigned to receive a semicircle of the same material as a sham fence (Deer+) or no fencing (Deer0) as a cage control. Number of *A. petiolata* seedlings and adults and percent coverage of all other vegetation by species were recorded in each plot in June 2004. Changes in vegetation over time are expected to indicate effects of herbivore disturbance and/or *A. petiolata* invasion. Sampling of the site was repeated in May, June and September of 2005 and 2006 and the *A. petiolata* removal treatments were maintained during the June sampling. Analysis of results from this study will begin this winter.

5) Project Title: Integrating New Natural Enemies into Soybean Aphid Biological Control.

Investigators: Michael Brewer, Doug Landis, Alejandro Costamagna, Takuji Noma, Matthew Kaiser and Shaun Langley, Michigan State University, Integrated Pest Management Program, Department of Entomology, B18 Food Safety and Toxicology Building, East Lansing, MI

Contact: Michael Brewer (brewerm@msu.edu)

Project Description: We conducted field studies to 1) assess extant parasitoid and predatory fly species that may be adapting to prey upon the invasive *Aphis glycines*, soybean aphid, and 2) examine the role of predators in limiting parasitoid impacts via intraguild predation.

For objective 1, we detected parasitoids and predatory flies attacking sentinel *A. glycines* on potted soybean plants. In 2004 and 2005, we detected five species of parasitoids and eleven species of predatory flies parasitizing sentinel *A. glycines*. Most common utilizing *A. glycines* were the parasitoids *Aphelinus asychis*, *Lysiphlebus testaceipes*, and a newly described species *Binodoxys kelloggensis*, and the flies *Aphidoletes aphidimyza, Allograpta oblique,* and *Sphaerophoria contigua*. Variation in habitat affinity was detected: *L. testaceipes, A. oblique, and S. contigua* utilized *A. glycines* placed in all crop and noncropped habitats; *B. kelloggensis* was principally found utilizing *A. glycines* placed in noncropped early successional vegetation and poplar stands; *A. asychis* most commonly utilized *A. glycines* placed in soybean; and *A. aphidimyza* was most common in soybean and other cropped plots. Percent field parasitism of *A. glycines* in soybean as measured by field inspection for mummies was disappointing, never exceeding 1%. Predatory flies were commonly found preying on *A. glycines* in soybean.

For objective 2, a field experiment examined the role of predators in limiting parasitoid impacts via intraguild predation (IGP). Using tomato cage frames covered with mesh we differentially excluded all natural enemies (< 1 mm mesh) or only large predators (2 mm mesh), thus allowing natural parasitism to occur protected from IGP by large predators. We also included un-caged plants with and without *A. glycines* manipulation, plants enclosed with a sham cage as a cage control, and plants caged without *A. glycines*. Our results showed strong impact from large predators (mainly Coccinellidae) but very low parasitism and predation achieved by extant parasitoid populations or small predators. Intraguid predation did not play a limiting role in parasitism.

6) Project Title: Seasonal Occurrence of Parasitoids, Predatory Flies, and Pathogens Attacking Soybean Aphid and Impact of Soybean Aphid Chemical Control on Aphid Enemies

Investigators: Takuji Noma and Michael Brewer, Michigan State University, Integrated Pest Management Program, Department of Entomology, B18 Food Safety and Toxicology Building, East Lansing, MI

Contact: Michael Brewer (brewerm@msu.edu)

Project Description:
We conducted field research in lower Michigan to assess seasonal occurrence of aphid parasitoids, predatory flies, and pathogens that prey upon soybean aphid (objective one). The effect of field-applied insecticides for soybean aphid control was also considered (objective two).

For objective 1, we found diverse communities of aphid specialist natural enemies attacking soybean aphid at two soybean sites in lower Michigan. They included 6 species of parasitic wasps, 9 species of predatory flies, and 1 species of pathogen. In addition to lady beetles and other predators previously documented, these aphid specialist enemies are naturally present in Michigan soybean fields. Species diversity and relative abundance of aphid enemies varied seasonally. In general, predatory flies tended to be more common early in the growing season while parasitic wasps tended to be more common late in the growing season. For fungal pathogens, one species was detected early August 2005, in which 90 % of winged aphids were infected. The epidemic was followed by the crash of soybean aphid population.

For objective 2, impact of an insecticide application on aphid-specialist enemies was tested in July, 2005 using replicated 1-acre soybean plots. Four plots were treated with insecticide (Warrior) and other four plots were untreated when soybean plants were at R3 stage. Natural enemies were sampled one week after the insecticide application. Predatory flies were the most abundant natural enemies and parasitoids were relatively rare. The insecticide application significantly reduced predatory fly populations by 91% compared with control populations, and 83% fewer predatory flies were recovered from the potted plants placed in sprayed plots than in untreated plots. The results confirm adverse impact of insecticide on aphid-specialist enemies present in soybean fields.

7) Project Title: Parasitism of Grape Berry Moth (Lepidoptera: Tortricidae) in Commercially Managed Vineyards in Michigan

Investigators: Paul E. Jenkins and Rufus Isaacs, Department of Entomology, Michigan State University.

Contact: Rufus Isaacs (isaacsr@msu.edu)

Project Description: The grape berry moth, *Paralobesia viteana* (Clemens), is one of the most economically important arthropod pests of grape vineyards in eastern North America. From 2003-2005, a survey of the *P. viteana* parasitoid complex in commercially-managed grape farms in Michigan was conducted to determine species occurrence and abundance. Parasitoids attacking *P. viteana* larvae were collected from 18 1.4-4 ha commercial 'Concord' grape vineyards (*Vitis labrusca*) located in Van Buren and Berrien Counties, Michigan, the primary juice grape production region in the state. One-hundred berries (5 sub-samples of 20 berries) showing signs of *P. viteana* infestation were collected from each vineyard border adjacent to woods where pest pressure is highest. Individual berries were placed into separate 37 ml plastic cups with white paper insert lids along with a small piece of plastic for pupation. At the end of five to six weeks, the number of *P. viteana* adults, pupae, larvae, or parasitoids of *P. viteana* was recorded. Parasitoids were identified to genus or species by taxonomic specialists.

A total of 649 parasitoids were reared from berry samples infested with *P. viteana* (N=55 in 2003; N=196 in 2004; and N=398 in 2005). *Sinophorus* sp. was the most common parasitoid reared and accounted for 24-57% of all specimens in each year. Twelve parasitoid species belonging to four families and one superfamily were identified (Table 1). This is the first report of the parasitoid community attacking *P. viteana* in Michigan, and provide opportunity for comparison with previous research. The two common larval parasitoids of *P. viteana* described in New York (*G. mutica* and *A. polychrosidis*) were also found to be dominant in Michigan. *Sinophorus* sp. has not been previously reported from other regions on *P. viteana*.

Table 1. Parasitoids attacking grape berry moth larvae in Michigan vineyards.

Year	Family or Superfamily	Species	Total	Percent of Total
2005	Bethylidae	*Goniozus foveolatus*	3	0.8
	Braconidae	*Apanteles polychrosidis*	96	24.1
	Braconidae	*Bassus annulipes*	7	1.8
	Braconidae	*Bracon variabilis*	10	2.5
	Eulophidae	*Euderus cushmani*	6	1.5
	Ichneumonidae	*Enytus obliteratus*	92	23.1
	Ichneumonidae	*Glypta mutica*	47	11.8
	Ichneumonidae	*Scambus brevicornis*	1	0.3
	Ichneumonidae	*Scambus hispae*	1	0.3
	Ichneumonidae	*Sinophorus sp*	133	33.4
	Unknown		2	0.5
2004	Bethylidae	*Goniozus foveolatus*	2	1.0
	Braconidae	*Apanteles polychrosidis*	9	4.6
	Braconidae	*Bracon variabilis*	1	0.5
	Ichneumonidae	*Enytus obliteratus*	19	9.7
	Ichneumonidae	*Glypta mutica*	39	19.9
	Ichneumonidae	*Sinophorus sp*	112	57.1
	Ichneumonidae	*Xorides calidus*	1	0.5
	Unknown		13	6.6
2003	Braconidae	*Apanteles polychrosidis*	2	3.6
	Braconidae	*Bracon variabilis*	7	12.7
	Ichneumonidae	*Glypta mutica*	4	7.3
	Ichneumonidae	*Sinophorus sp*	13	23.6
	Microgasterinae	*sp.*	1	1.8
	Unknown		28	50.9

8) Project Title: Response of Natural Enemies to Implementation of a Reduced-Risk IPM Program in Michigan Blueberry – Year 4

Investigators: K.S. Mason, C. Garcia-Salazar, J.C. Wise, and R. Isaacs
Department of Entomology, Michigan State University

Contact: Rufus Isaacs (isaacsr@msu.edu)

Project Description: As part of a 4-year USDA-RAMP funded project comparing blueberry pest management programs that employ either conventional, broad spectrum or reduced-risk insecticides, we measured abundance of natural enemies in the Michigan highbush blueberry agroecosystem. Two fields were chosen at each of six blueberry farms in southwest Michigan, one field received each management program. Yellow sticky traps, pitfall traps, tuna-baited test tubes, and periodic scouting were used in each field to test whether reduction in the use of broad-spectrum insecticides leads to increased generalist predator (coccinellid, syrphid, lacewing and spider), terrestrial arthropod predator (carabid and formicid) or parasitoid abundance.

Although not yet fully analyzed, data from this fourth and final year of this study seem consistent with data from previous years. The rate of parasitism of blueberry aphid and ground foraging ant abundance were greater in fields receiving a reduced-risk IPM program. The abundance of some key species of carabids was also higher in field managed with reduced-risk IPM programs, but we expect to see fewer differences in carabid abundance between management programs compared to that in previous years because of single pyrethroid insecticide applications used to achieve our pest management and program cost targets. In past seasons we have documented higher abundance of some generalist predators (coccinellids, spiders and ants) in fields managed with reduced-risk IPM programs, but this may also have been affected by the use of a pyrethroid insecticide.

We also used exclusion cages to measure rates of predation on cranberry fruitworm and Japanese beetle in 2005 and Japanese beetle in 2006. Results from both years suggest carabids are important predators of these two key blueberry pests. This research has helped to demonstrate the potential contribution of natural enemy populations to the control of major insect pests in blueberry and how natural enemy populations are affected by the use of different types of insecticides.

9) Project Title: Biological Control of Japanese Beetle In Michigan Through Parasite and Pathogen Introduction

Investigators: David Smitley, Department of Entomology, Michigan State University

Contact: David Smitley (smitley@msu.edu)

Project Description: In 1999, two insect parasites of Japanese beetle (*Tiphia vernalis* and *Istocheta aldrichi*) and one protozoan pathogen (*Ovavesicula popilliae)*, were collected in Connecticut and introduced into research plots on 5 golf courses in Michigan. For each introduction site, control plots were established at a different golf course located nearby, for a total of 10 golf course sites. In 2005 we returned to the same golf courses to sample for Japanese beetle and the introduced parasites and pathogen. *T. vernalis* was not found, *I. aldrichi* was detected at 4 of 10 locations, and *O. popilliae* was found at all introduction sites and two control sites, sometimes at epizootic levels (> 20% infection). Populations of Japanese beetle on golf courses where *O. popilliae* is epizootic are now much lower than levels in 1999 and 2000. In 2006 we will attempt to demonstrate long-term biological control of Japanese beetle by comparing the population density of Japanese beetle at 5 locations with little or no *O. popilliae*-infection to the same at 5 locations with moderate to high levels of infection.

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