The Entomological Society of America’s (ESA) Committee on Student Affairs organizes student debates at the national meeting of ESA annually. The primary objective of student debates is to foster critical thinking in the next generation of entomologists. Contemporary issues about entomology that are of interest to scientists and the public are usually the subjects of debates.

Human activities have led to drastic changes in our environment on local and global scales. Consequently, species are being lost at an unprecedented rate. The expansion of modern chemical-intensive agriculture and global climate change present major threats to arthropod biodiversity. At the same time, the effects of modern agriculture (e.g., pesticide use, biological control, and transgenic insecticidal crops) and global climate change on arthropod biodiversity are often controversial. To better understand the positions on both sides of this issue, “Impact of Biological Control, Transgenic Insecticidal Crops, and Global Climate Change on Arthropod Biodiversity” was selected as the topic of the 2010 ESA Student Debates, held at the 58th Annual Meeting of ESA in San Diego.

The three statements that were debated were (1) Increasing natural enemy diversity among arthropods is compatible with the goals of biological control and IPM; (2) Transgenic insecticidal crops will conserve arthropod biodiversity; and (3) Global climate change will have substantial long-term negative effects on arthropod diversity. Three teams (unbiased, pro, and con) were recruited for each of the topics on a first-come, first-served basis. Fred Gould (William Neal Reynolds Professor of Agriculture, Department of Entomology, North Carolina State University) was invited as Distinguished Speaker to introduce the concept of biodiversity.

Biodiversity
Fred Gould
William Neal Reynolds Professor of Agriculture, Department of Entomology, North Carolina State University

Finding an entomologist who will not defend the general need to preserve biodiversity is a difficult if not impossible task. The aesthetic losses and ethical dilemmas associated with reduction in our planet’s biodiversity are reasonably clear to most professional entomologists and a large portion of the public. Less obvious is how a loss of biodiversity would quantitatively impact specific ecosystem and biological community functions. The topics debated in this article demonstrate some of these uncertain relationships.
Before delving into the details of the debate, it is worth stepping back a bit to examine the issue of biodiversity more broadly. Most entomologists think they know what it means when someone says “System X has more biodiversity than system Y.” But do we all mean the same thing when we say this?

I have presented descriptions of hypothetical insect communities to numerous entomological audiences and asked them which is the most diverse. When presented with community A having three species with 100 individuals of each species and community B having six species with 100 individuals of each species, I always get unanimous agreement that community B is most diverse. When community A is paired with community C that has six species but where one species is represented by 100 individuals and the other five by 10 individuals each, most entomologists judge community C as more diverse than community A; but there are some entomologists who disagree or are not sure. When community A is compared with community D that has six species, one of which has 100 individuals, and the other species are represented by a single individual, most entomologists view community A as being more diverse than D even though D has twice as many species. What value system are entomologists using to make their judgments?

In his classical textbook on insect ecology, Price (1997) states that “Diversity may be defined by use of a formula.” Many indices of diversity have been proposed (Pieiou 1969, 1975; Poole 1974; Begon et al. 1996; Stiling 1996), but the most commonly used in the past is the Shannon–Weaver diversity index $H'$, where $H' = -\sum p_i \ln(p_i)$. Here $p_i$ is the proportion of individuals in the community made up of individuals of species $i$.

If we now go back to the hypothetical communities and rank their diversity with the Shannon–Weaver formula, we find $H'$ for A, B, C, and D, as 1.10, 1.79, 1.44, and 0.27, respectively. This is a reasonably good match with the answers of entomologists. We must ask the question of whether the Shannon–Weaver index is most commonly used because of its ecological basis compared with other formulae of diversity, or because it fits with our gut feeling about what constitutes biodiversity?

Lacking from my hypothetical examples and the Shannon–Weaver index are biological attributes of the species. Would it matter to entomologists if some of the species with 100 individuals were aphids, and the ones with lower numbers were adult grasshoppers? Would it matter if one community only had herbivores and another had an even mix from three trophic levels? Ecologists have long wrestled with these issues, questioning how to measure diversity and how to examine its effects on the functioning of communities and ecosystems. When entomologists ask whether a specific change in an agricultural practice will affect biodiversity or if increased biodiversity will assist pest management, we must carefully define what we mean by biodiversity. Biodiversity can be taxonomic and functional. (There’s species richness and evenness, obviously, but both of these fall under the umbrella of taxonomic diversity.) Functional diversity can be difficult to assess because there’s little agreement over what metrics to use to amalgamate taxa into functional groups.

Most of the empirical studies in this area have been conducted by plant ecologists who have found a clear relationship between the number of plant species in a community and the biomass productivity of the ecosystem (Hooper et al. 2005). In some cases, the natural enemy diversity partitions the pest species and attacks multiple life stages or is more effective in different environmental conditions. In other cases, the diversity of natural enemies results in direct competition between constituent species for the same life stage or environmental conditions (Wilby and Thomas 2002). The degree to which the predator is host-specific (Torre-Bueno 1989) will drive the type of interaction that occurs when a diversity of natural enemies is present. Diversity is a metric that takes into account the relative abundance of each species and the number of species that are present at a site (Ives et al. 2005). To
increase diversity, an increase in species richness and homogenizing evenness among taxa at a particular location without decreasing the abundance or removing natural enemies already present at a location might be necessary (Ives et al. 2005).

Biological control is the use of a natural enemy to reduce the host population to a lower level than before (Torre-Bueno 1989). Biological control is implemented in one of three ways: namely classical, augmentation, and conservation (Parrella et al. 1992, Landis et al. 2000, Evans 2004). Classical biological control is the importation of a natural enemy into an area where they previously did not occur (Evans 2004). Classical biological control can displace or outcompete natural enemies that are already functioning in the system (Evans 2004), or it can fill an ecological role where native natural enemies could not compete (Vinson 1988). Augmentation biological control is a supplemental release of natural enemies into an area (Parrella et al. 1992). Conservation biological control encourages natural enemies to remain or increase in abundance in an area where the pest occurs (Landis et al. 2000). IPM is an environmentally sensitive approach to managing pest species below the economic injury level that relies on a combination of common-sense practices to economically produce crops.

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Pro Position

Katherine A. Parys, Jennifer Gordon, Sebe Brown, and Blake Wilson
Louisiana State University

Agricultural intensification involving the removal of noncrop habitats results in simplification of the landscape, reduced biodiversity and the loss of ecosystem processes (Altieri and Nicholls 2004). Agroecosystems are further simplified by intense chemical control of insects and IPM. IPM incorporates a balance of biological, chemical, and cultural control methods to suppress pest populations while minimizing selection pressure and adverse effects from over-reliance on individual tactics (Metcalf and Luckman 1994). Biological control as a component of IPM reduces reliance on pesticides and can provide long-term sustainability to pest control (Van Driesche et al. 2008). Increasing natural enemy diversity among arthropods is compatible with the goals of biological control and IPM.

Biological diversity improves ecosystem function by increasing nutrient cycling, regulating microclimate, encouraging soil health, and controlling agricultural pests, which together have been credited as saving an estimated $4.5 billion in revenue losses annually (Altieri 1993). Persistence of these ecosystem services depends on the maintenance of biodiversity within the system (Bianchi et al. 2006, Straub et al. 2008). Multiple natural enemies enhance overall ecosystem stability and resource utilization. Increasing diversity leads to a greater number of trophic links within a community and a more stable ecosystem (Altieri 1993, Cardinale et al. 2003, Snyder et al. 2008). Management practices which influence herbivore dynamics within agroecosystems decrease reliance on any one tactic, reducing selection pressure and the chance of secondary pest outbreaks (Altieri and Nicholls 2004).

In communities with multiple natural enemies, the most efficient predator or parasitoid usually dominates resource acquisition within an ecosystem (Hackett-Jones et al. 2009). High diversity increases the chance that the most effective natural enemy is present within the system, and competitive exclusion regulates populations of less effective natural enemies (Tylianakis et al. 2006). If superior control is provided from a single biological control species, then this species will become more prevalent; however, it does not necessarily eliminate other natural enemies. Thus, increased diversity of natural enemies may lead to greater resource consumption (pest suppression) via an increased probability that particularly effective predator species will be present and contribute disproportionately to pest suppression through resource partitioning and niche differentiation.

Increased diversity by natural enemies generally enhances pest suppression through interspecific facilitation or complementary resource use (Straub et al. 2008). Species complementarity results from resource partitioning, such as natural enemies that attack different life stages of prey or stratify populations by spatial differentiation within the microhabitat (Wilby and Thomas 2002, Cardinale et al. 2003, Hackett-Jones et al. 2009). All of these can lead to higher levels of resource consumption and thus greater pest suppression.

Increasing the diversity of natural enemies is compatible with IPM and biological control by using ecological principles in the development of successful pest management programs. Utilizing multiple, host-specific biological control agents supports the fundamental goal of IPM by reducing reliance on a single pest control tactic. Similarly, increasing biodiversity is compatible with the goals of biological control by providing natural pest regulation while reducing selection pressure from the use of insecticides. Thus, increasing natural enemy diversity supports IPM and biological control.

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Con Position

Shaku Nair, Whitney Boozer, Rachel Bottjen, Sonja Brannon, and Stephanie Weldon
University of Georgia

Biocontrol is a key component of IPM. It has been argued that increasing natural enemy diversity within agricultural systems will maximize control of insect pests. More recent literature shows minimal support for a correlation between natural enemy diversity and the efficacy of biocontrol.

Denoth et al. (2002) summarized the results of 108 biocontrol projects relating the number of natural enemies released to their successful establishment and control of pest species. Of all the multiple-agent projects assessed, only 47% of released enemies became successfully established, compared with 75% in single-agent projects. Ehler and Hall (1982) found that the rate of establishment of exotic enemies was inversely related to the number of species released simultaneously. Additionally, Denoth et al. (2002) determined that in 56% of the successful multiple agent release projects, a single agent was responsible for establishing control. Finke and Denno (2004) observed that decreasing natural enemy diversity improved plant biomass production in marsh systems, and their previous work suggests that the effect would likely be magnified in agricultural systems (Finke and Denno 2003).

According to Rodriguez and Hawkins (2000), only a single key species is required for strong top-down control in the majority of parasitoid biocontrol programs. This was supported by their own study, which found no relationship between parasitoid species rich-
ness and increased parasitism. Finke and Denno (2004) combined wolf spiders *Hogna modesta* (Thorell) with mirid bugs (*Tytthus vagus* Knight) to suppress a scale insect pest; instead of cooperative consumption of the pest species, they found that wolf spiders preferentially fed on the active mirids, relaxing the herbivore suppression and allowing a surge in the pest population. Yet another example of predator–predator interactions that negatively affect biocontrol is reported by Rosenheim et al. (1999); multiple generalist predators preferentially preyed on each other rather than the target insects.

It is important to state here that classical biocontrol theory for predator–prey interactions has been traditionally based on three discrete trophic levels of plant, herbivore, and predator. The release of multiple agents at the same trophic level creates a new paradigm of interactions that become of paramount importance.

Greater diversity may also lead to interference and displacement of biocontrol agents. Zhou et al. (2010) demonstrated a case where competition among parasitoids consistently drove one or more species away. This becomes especially important when considering exotic enemies, and their ability to drive out native natural enemies. Ehler and Hall (1992) discussed that displacement led to elimination of superior control agents. In cases where displacement did not occur, interspecific competition could still negatively affect biocontrol. Bográn et al. (2002) provide an example in which the most effective parasitoid in pure culture became severely less successful in mixed culture.

Biocontrol has a high (80–90%) failure rate and often carries unanticipated ecological risks (Lockwood 1993, Louda et al. 1997). Simberloff and Stiling (1996) reported numerous biocontrol introductions that adversely affected nontarget native species. In the notorious case of the multicolored Asian lady beetle [*Harmonia axyridis* (Pallas)], this introduced predator attacked fruit crops and affected wine quality (Kovach 2004).

Greater diversity may not be cost-effective. Every introduced insect has costs associated with rearing, research and release. The maintenance of multiple refugia also requires resources, land, and time. Furthermore, there are the risks of refugia harboring pests and pathogens. Araj et al. (2006) discovered that floral resources for a desired parasitoid benefited its hyperparasitoid even more.

In summary, although biodiversity is important in natural systems, increasing diversity in agricultural systems is often unpredictable, and releases are irreversible. Therefore, focusing on one or few biocontrol agents is preferable to acting on the erroneous assumption that increasing enemy diversity will maximize control of pest populations.

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**TOPIC**

**Transgenic insecticidal crops will conserve arthropod biodiversity**

**Unbiased Introduction**

*Serena Gross*

*Purdue University*

Transgenic insecticidal crops are genetically modified organisms used to minimize loss caused by pest insects. Transgenic insecticidal crops potentially could conserve arthropod biodiversity, by reducing the use of broad-spectrum pesticides, which could reduce the mortality of natural enemies and beneficial arthropods (Wraight et al. 2000). Transgenic insecticidal crops might not conserve biodiversity because of effects on nontarget arthropods and problems with secondary pest insects. The most common insecticidal protein currently used in transgenic crops is from the bacterium *Bacillus thuringiensis* Berliner (Li et al. 2007).

*Bacillus thuringiensis* (Bt) toxins kill only a narrow range of species; the insects it targets depends on the particular crystal (Cry) proteins encoded in the specific crop (Li et al. 2007). Much testing has been done to determine the effects of transgenic crops on nontarget arthropods; there is still question as to their effects on biodiversity (Lovei et al. 2009). Species richness is commonly used to describe biodiversity (Aviron et al. 2009). Biodiversity is beneficial in agricultural ecosystems because of the ecosystem services provided, such as nutrient cycling, pollination, and pest regulation (Garcia and Altieri 2005). Transgenic crops may help to decrease contamination of groundwater, soil, and air by broad-spectrum insecticides (Wraight et al. 2000). It is also possible that reducing the use of broad-spectrum insecticides could increase the density of natural enemies (Velkov et al. 2005).

Transgenic plants are tested to determine what affect they might have on beneficial arthropods, but only a small amount of the arthropods that could be affected can be tested (Lovei et al. 2009). It is impossible to test the effects of transgenic insecticidal crops on all arthropod species that may possibly be affected by the introduction of these crops (Aviron et al. 2009). There is often question as to which arthropod species should be tested when determining whether transgenic insecticidal crops are safe for use. Common species are more detectable but are often less sensitive to environmental disturbances, while rare or endangered species are harder to detect in the field, their low abundance may cause problems in achieving statistically significant results (Aviron et al. 2009).

Fewer studies have been done on the effects of transgenic insecticidal crops on other insects (Lovei et al. 2009) because monitoring biodiversity is expensive and time consuming (Schmeller and Henle 2008). There is concern with the chance that transgenic genes flowing to wild relatives could affect the nontarget arthropods associated with those plants (Andow and Zwahlen 2006). Experiments have also found that though the transgenic insecticidal crop lowers the numbers of the primary pest insect, the numbers of a secondary pest insect that is not targeted by the transgenic insecticidal crop can increase (Velkov et al. 2005). Predator levels have been found to be higher in Bt cotton fields than in non-Bt cotton fields that have been treated with insecticides (Velkov et al. 2005). However, it is possible that natural enemies feeding on nontarget herbivores may come into contact with more Bt toxins due to the toxins not binding in the gut of the nontarget herbivores (Garcia and Altieri 2005). Another possible issue is that of pest insect resistance to transgenic insecticidal crops, which has been reported in some organisms (Singh 2005), and could increase the need for insecticides. Biodiversity loss can be measured by the loss of individual species, groups of species, or decreases in the number of organisms (Ammann 2005). Given the impact that transgenic insecticidal crops could have on biodiversity, and the factors involved with determining the effect that these crops have on biodiversity, the debate will likely continue for some time.
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Pro Position
Maggie Paxson, Wendy Helmey-Hartman, Gaurav Goyal, and Harsimran Gill
University of Florida

When considering the prospects for modern agriculture in an increasingly technological society, the topic of transgenic insecticidal crops often appears as a "cure-all" for agricultural issues. Although transgenic insecticidal crops, such as Bt crops, have been shown to be viable, successful, and non-damaging forms of pest management, we find that ecological impacts (including biodiversity) caused by transgenics pale in comparison to the damage done by broad-spectrum insecticides.

The affirmative plan is two-pronged in its support of transgenic insecticidal crops. In field scenarios where Bt and other transgenics have been shown to be viable, successful, and non-damaging forms of pest management such as in corn, cotton, and eggplant (Cattaneo et al. 2006, Arpaia et al. 2007), we advocate the use of these crops. In field conditions where Bt may be damaging or detrimental on the whole, we advocate further research of arthropod-Bt crop interactions to continuously improve this burgeoning technology.

We base our assertions on four reasons. First, numerous studies have shown that in most cases, transgenic insecticidal do less overall damage to beneficial arthropods (Chen et al. 2008, Farinos et al. 2008) and neighboring communities than the broad-spectrum pesticide alternatives (Vellov et al. 2005). In truth, the few laboratory studies that show Bt as a force more damaging than pesticides can be easily countered by proposing a slightly different transgenic cultivar, e.g., one that does not express the Bt toxin in the plant's pollen (Yao et al. 2008). These plants also pose a lowered risk to neighboring environments and ecosystems such as scrub areas or nearby wilderness zones (Icoz and Stotzky 2008).

Second, transgenic insecticidal crops offer many benefits over the current alternative of pesticides that make Bt and other crop cultivars a practical preservation method for biodiversity (Marvier 2001, Ferry et al. 2006). Bt crops require fewer maintenance costs than pesticides and require only an initial planting rather than multiple applications (Wraight et al. 2000). In addition, fears that Bt or other transgenes may jump from one plant species to another are largely speculative with little true risk.

Third, non-transgenic alternative strategies to the status quo are largely infeasible on a large-scale production level and offer little ability for commercial growers to preserve biodiversity and turn a profit (Marvier 2001). The sad reality of agriculture is that control will always be needed, so a low-maintenance, pragmatic control method must be preferentially selected over the wide-scale environmental destruction brought about by broad-spectrum insecticides (Ammann 2005, Vellov et al. 2005).

Our final argument synthesizes the debate, stating that pest management options must be viewed with an on-balance consideration (Wraight et al. 2000). Dangerous transgenics are not released into the wild without scientific investigation (Marvier 2001, Arpaia et al. 2007). With the proper research advocated by the affirmative plan and denied by the negative side, we can work toward a pest management strategy that does more good than harm to the agricultural environment it seeks to mold. Yes, Bt crops damage pestiferous insect diversity; and yes, they may confer slight damage to predators of these insects; but all of this must be viewed through the lens of current pest control methodology, a policy of blanket insecticidal spray with little regard to the affected environment within and outside of our agriculture.

When taking all of these arguments into consideration, we may only affirm that transgenic insecticidal crops will conserve arthropod biodiversity in comparison to the status quo.

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Con Position
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Although transgenic insecticidal (TI) crops are touted for their ability to decrease use of wide-spectrum pesticides, target specific pest insect groups, and boost final yield production (Sharma and Ortiz 2000), we argue that their net impact will harm arthropod genetics, species, and ecosystem diversity in that they:
- increase mortality of nontarget arthropods,
- possibly increase pesticide use and toxins in TI crops with insect resistance,
- disrupt trophic groups and other biological interactions, and
- negatively affect other ecosystems linked to agricultural settings.

Bt toxins, the most commonly used lethal ingredient of TI crops, are proteins designed to target different groups of organisms (Clark et al. 2005). For instance, Cry1, Cry2, and Cry9 are efficient in Lepidoptera and Cry3 in Coleoptera. Several studies, however, have shown increased mortality in insects outside the target group (Andow and Zwahlen 2006); the insecticide is not as specific as previously thought and therefore can harm species diversity. The toxin is expressed in many parts of the plant and has many conduits to nontarget insects, a few of which are important to arthropod conservation. For example, when Bt toxins appear in pollen, they have lethal and sublethal effects in black swallowtail (Papilio polyxenes) and monarch butterfly (Danaus plexippus (L.)) (Hansen Jesse and Obrycki 2000, Zangerl et al. 2001, Groot and Dicke 2002).

Field and laboratory experiments show that the resistance of genetically modified (GM) crops to target pests is short-lived, which will likely result in the application of stronger pesticides and the creation of Bt crops containing an armada of different toxins (Stewart et al. 2001, Schuler et al. 2004). Both of these responses not only negate the expected decrease in pesticide use among Bt crops but will instead lead to increased mortality caused by more potent crops. Overall, genetic biodiversity of nontarget arthropods will decrease.

Interactions between TI crops and target and nontarget arthropods must be preferentially selected over the wide-scale environmental destruction brought about by broad-spectrum insecticides (Ammann 2005, Vellov et al. 2005).
pods can disrupt ecological functional groups, trophic relationships, and controls, subsequently decreasing species and ecosystem biodiversity. Specifically, Bt toxins have been shown to move across trophic levels and disrupt health and behavior with deleterious effects. The green lacewing [Chrysoperla carnea (Stephens)], which is an important predator of pests, showed higher mortality, prolonged developmental time, and decreased weight when fed prey raised on Bt-sprayed corn (Dutton et al. 2002). In one of the few multigenerational studies, adult ladybird beetle [Propylea japonica (Thunberg)] reared from parents that preyed on aphids fed with Bt corn had higher levels of malformations and an altered phenology (Zhang et al. 2009). Parasitoids raised on Bt corn experienced high levels of mortality because their hosts died prior to emergence (Schuler et al. 2004).

Bt toxins do not cease to harm the biodiversity of arthropods when the TI crops are harvested. After the growing season, crop remains decompose in the soil, allowing Bt toxins to interact with soil organisms. Several studies have shown that the toxins persist in the soil for several months and that the TI crops decompose more slowly than other crops (Flores et al. 2005, Janot et al. 2010). As a consequence, nontarget insects in the soil are also exposed to Bt toxins, disrupting the normal process of decomposition and recycling of organic matter into beneficial nutrients that could otherwise improve crop growth. This harms ecosystem functioning crucial to arthropods.

Because of the lethal and sublethal effects of TI crops on arthropods and the poorly understood mechanisms of these effects upon the ecosystem more broadly, we believe Bt crops will not lessen the impact of agriculture on native biodiversity. Insects in our current and future dependencies are exposed to enormous environmental pressures, and the introduction of further lethal components will only increase insect mortality and the specter of species extinction. We call for increased and conclusive studies of risk assessment methods before further implementing these crops in the industrial scale.

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TOPIC

Global climate change will have substantial long-term negative effects on arthropod diversity

Unbiased Introduction

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The Graduate Center–CUNY

Global climate change (GCC) is occurring at an unprecedented rate. That it is already having an effect on species, communities, and phenologies has been documented. Temperatures over the past 100 years have risen by approximately 0.6 °C with a predicted increase of between 1.4 and 5.8 °C by 2100 (Chown et al. 2007, Visser 2008). Atmospheric carbon will rise over the same period. Although increase in precipitation, Ultraviolet B (UVB) penetration, and extreme events (e.g. flooding, storms, and drought) are all predicted, there is less certainty about the extent of these changes (Bale et al. 2002). The question of magnitude of the ecological effects due to GCC centers on whether species will be able to adapt fast enough to keep up with a changing environment (Visser 2008).

During the last warming event, the Paleocene–Eocene Thermal maximum 53 million years ago, arthropod diversity increased in predatory, parasitic, saprophagous and phytophagous guilds. Arthropods enjoy a suite of characteristics that enables them to quickly occupy new niches and to be the most successful organisms on the planet. These characteristics include flexible reproductive strategies and reproductive success in warmer climates. Some predict that the long-term increase in mean global temperature will favor arthropods because of this suite of flexible life traits. These and other characteristics could serve arthropods well in the face of GCC (Wilf and Labandeira 1999).

During the Paleocene–Eocene event, however, the rate of temperature increase was slower than it is today, and there were no anthropogenic factors facing arthropods to thwart their ability to adapt to the new environment. These factors may confound the very characteristics that contribute to arthropod success. Although mean global temperature is critical to arthropods, other factors affect species’ range and changes in their range in complex ways. Some of these are natural oscillations underlying long-term trends and photoperiod (Visser 2008).

Phenology is the timing of seasonal activities of plants and animals alike and is the simplest process used to track changes in the ecology of a species in response to climate change (Walther et al. 2002). However, there is no reason why the phenology of different trophic levels will shift at the same time. If a species’ phenology is shifting at a different rate than the other species within its community, this will lead to mistiming of its seasonal activities, also known as a mismatch in phenology. Range expansion of southern populations into northern areas has occurred (Walther et al. 2002). Some researchers posit that they may have genotypes better adapted to warmer conditions that account for their success. However, this does not take into account that different photoperiod and/or rainfall occur in the more northern areas, and photoperiod plays a crucial role in seasonal timing of arthropods (e.g. diapause) (Bale et al. 2002, Botkin et al. 2007).

Global climate change is a critical factor when looking at, or trying to predict, future diversity. Factors that can affect species range and changes in their range interact in complex ways. This is further complicated by recurring pitfalls in measuring biodiversity and/or the absences of a way to measure species shifts in response to GCC (Gotelli and Colwell 2001, Visser and Both 2005). The challenge of the two teams that follow will be to do just that—predict future biodiversity of arthropods based upon GCC.

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Pro Position

Tom G. Bentley, Margaret R. Douglas, Ian M. Grettenberger, Elina L. Niño, C. Sheena Sidhu, and Jason D. Smith
The Pennsylvania State University

Arthropod diversity stands to endure great losses as a result of the ongoing climate change event. Earth’s temperature has increased 0.6 °C in the past century and is predicted to increase another 1.4–5.8 °C.
by 2100 (IPCC 2002). Although any climatic shift presents challenges to life on Earth, today’s arthropods must respond to these challenges in the context of a landscape dominated by human activity. Given this unprecedented scenario, the current climate change event will cause long-lasting declines in arthropod diversity.

Stressors stemming directly from global climate change and negatively affecting arthropods include increased water and terrestrial surface temperatures, decreased water oxygen content, and increased frequency of extreme events such as droughts, floods, and fires (IPCC 2002). In addition, divergent responses to changing seasonal cues will often result in asynchrony among arthropods and the host species they rely on for survival (Visser and Holleman 2005). As temperatures increase around the planet, arthropod activity will correspondingly increase. These increases will include movement to find new food sources and suitable mates and to escape predation, resulting in increased dispersal and migration (Rhode 1992). Increases in temperature also give physiological benefits to arthropods, such as decreases in developmental time, resulting in greater number of generations per year, which in turn speeds speciation rates (Morrison et al. 2005).

Arthropods are biologically primed for rapid speciation. As current tropical regions migrate poleward, arthropod diversification will certainly follow suit (Wilf and Labandeira 1999, Bradshaw and Holzapfel 2006). This will bring about an increase in plant diversity in temperate regions, which will result in novel food sources. These newly opened niches will be rapidly filled by arthropods as they follow their host plants poleward (Wilf 2008). Selection pressures from these newly acquired niches will cause migrating arthropods to undergo adaptive radiations.

We have a terrific opportunity to learn from a past warming event: the Paleocene–Eocene Thermal Maximum (PETM). This took place 56 million years ago and was a time when the Earth went through a massive short-term increase in mean temperatures (DeLuca et al. 2008). Fossils from this period serve as a great historical reference point to compare against current global climate change (Wilf and Labandeira 1999). During the PETM, substantial poleward expansion and diversification of arthropods occurred, coinciding with adaptive radiations of plants and driving evolution of specialized herbivores (Wilf 2008).

In addition to the past events, contemporary long-term evidence illustrates that arthropods are currently benefiting from global climate change. Decades of research in the Atlantic Ocean have found that phytoplankton and zooplankton populations are increasing their range and diversity in response to sea surface temperature increases (Rombouts et al. 2009, Beaugrand et al. 2010). In addition to this, a 25-yr study in Europe noted significant range increases in nine major groups of arthropods, in altitude and latitude (Hickling et al. 2006).

As a result of arthropods acquiring these available niches, adaptive radiation occurs from new selection pressures. For example, mosquitoes have been found to be expanding their range poleward in response to higher mean temperatures (Bradshaw and Holzapfel 2006). As a result of these newly acquired niches, these mosquitoes experience changes in photoperiods that are fueling unique genetic adaptations (Bradshaw and Holzapfel 2006). Data of plants and arthropods in the Canary and Hawaiian Islands show that there is a
direct positive relationship between species diversity and the rate of speciation (Emerson and Kolm 2005).

Global climate change is a relatively slower process and short-term studies may not be useful to understand its impacts. The literature cited by the opponent team attempts to create extrapolations from mammals, birds, and amphibians, and then somehow relate them to arthropods. For example, Walther et al. (2002) examined a single species of Lepidoptera and then lumped this species with other non-arthropod taxa. It is incorrect to draw inferences on arthropod diversity from this study. Similarly, Thomas et al. (2004) attempted to create background extinction rates based on the International Union for the Conservation of Nature’s Red List, which is highly biased toward vertebrates. The reaction of the spotted owl to global climate change cannot be considered equivalent to that of the spotted cucumber beetle (Diabrotica undecimpunctata howardi Barber).

In summary, historical events show that arthropods will not only benefit but will thrive during global warming events. Contemporary long-term data show that current warming events are not only favoring terrestrial arthropods but marine arthropods as well. Millennia of years of evolutionary adaptations have equipped arthropods with the structures and mechanisms to overcome adversity. With this ability to overcome adversity, arthropods will thrive during favorable periods such as during global warming, thus remaining the most successful and diverse group of organisms on the planet.

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DEBATE PARTICIPANTS

University of Nevada

Joy Newton is a Ph.D. candidate at the University of Nevada, Reno, in the Ecology, Evolution and Conservation Biology Department researching the interaction between the ecology of ants and how it impacts forest management and Lake Tahoe within the Tahoe Basin. Former research as a Masters student at West Texas A&M University included the fire ecology of invertebrates in short-grass prairie and a base-line inventory of invertebrates with Texas Agrilife Research in southeastern Colorado.

Louisiana State University

Katherine A. Parys is a Ph.D. candidate under S. Johnson working on biological control of Salvinia minima Baker and community interactions between biological control agents and native arthropods.

Jennifer R. Gordon finished her M.S. degree at LSU under the direction of J. Otte investigating the role of esterases as a detoxification mechanism for insecticides in populations of Culex quinquefasciatus (Say) and has begun a Ph.D. program at the University of Kentucky.

Sebe Brown is an M.S. student under J. Davis working on soybean looper resistance to methoxyfenozide.

Blake Wilson completed his M.S. degree with T. E. Reagan working on pest management in sugarcane.

University of Georgia

Shakunthala Nair is a Ph.D. candidate working with Kris Braman at UGA, studying the susceptibility and mechanisms of resistance of ericaceous ornamental plants to the Andromeda lace bug Stephanitis tateyi.

Whitney E. Boozer is an M.S. student working with Nancy Hinkle at the University of Georgia, studying insecticide susceptibility of the darkling beetle Alphitobius diaperinus.

Rachel C. Bottjen is an M.S. student working with Michael R. Strand at the University of Georgia, and she studies the roles of bracoviral protein tyrosine phosphatases from the parasitoid, Microplitis demolitor, in host pathology.

Sonja Brannon (Team Leader) is a Ph.D. candidate at the University of Georgia studying IPM in schools and federal buildings in the lab of Brian Forschler.

Stephanie R. Weldon is a Ph.D. student studying a tripartite symbiosis between aphids, a bacterium, and a bacteriophage in the lab of Kerry Oliver.

Purdue University

Serena Gross is a Ph.D. student in the Department of Entomology at Purdue University. Her research focuses on the species composition of necrophagous Coleoptera and Diptera in urban and rural habitats. Previous research for her M.S. thesis tested the effects of amending soil with compost containing lignocellulosic substrates and biocontrol agents known to suppress soil-borne diseases on the Colorado potato beetle and potato-colonizing aphids.

University of Florida

Maggie Paxson is a senior undergraduate student pursuing her B.S. degree in entomology and nematology. She will begin her M.S. degree in fall 2011, under the direction of Marc Branhum at the University of Florida. Her thesis will examine the systematics of Coleoptera: Phenogidae and will seek to establish an evolutionary lineage for bioluminescence and bioluminescent courtship signaling.

Wendy Helmy-Hartman is pursuing a Ph.D. under the guidance of Christine Miller and her research focuses on multimodal communication and sexual selection.

Gaurav Goyal graduated with a Ph.D. in December 2010 from the Department of Entomology and Nematology. The title of his dissertation was “Morphology, biology and distribution of cornlooper resistance to methoxyfenozide. Harsimran Gill completed her Ph.D. in entomology in August 2010 (major adviser; Robert McSorley). Her dissertation title was...
“Integrated impact of organic mulching and soil solarization on soil surface arthropods and weeds.” Currently she is working as Post-Doc Associate with Kirsten Pelz-Stelinski at the University of Florida, Citrus Research and Education Center, Lake Alfred.

Columbia University and American Museum of Natural History
Melanie Smith is an M.A. student in conservation biology at Columbia University’s Department of Ecology, Evolution, and Environmental Biology. Advised by Matthew Palmer, her thesis looks at the arthropod diversity on New York City green roofs and how it differs based on the roof’s plant community.

Isabelle Vea is a Ph.D. student in comparative biology at the Richard Gilder Graduate School at (American Museum of Natural History), advised by David Grimaldi. Her research project focuses on the phylogeny of basal scale insects (Coccoidea) incorporating fossils in amber.

The Graduate Center–CUNY
Kathleen (Kit) Schnaars Uvino is a Ph.D. candidate of the Graduate Center of CUNY, Ecology Evolution, Systematics and Behavior, whose research investigates the relationship of resistance evolution and movement in the Colorado potato beetle. She is also a member of the Hudson Bay Project, conducting research in arctic ecosystems focusing on destructive foraging by lesser snow goose and the recovery potential of tundra vegetation.

The Pennsylvania State University
Tom Bentley is a Ph.D. candidate in ecology working with Mark Mescher. His research explores mediated interactions between herbivores and plants, and between-plant signaling.

Margaret Douglas is an M.S. student in entomology. Advised by John Tooker, she is investigating whether cultural and biological tactics can contribute to sustainable slug management in reduced-tillage field crops.

Ian Grettenberger is a Ph.D. candidate in entomology working with John Tooker. His research is exploring the potential of plant genotypic diversity for sustainable pest suppression and is currently focusing on soybeans and the soybean aphid.

Elina Niño is a Ph.D. candidate in entomology working under the direction of Christina Grozinger. Her research focuses on behavioral, physiological, and molecular characterization of various factors (e.g., insemination volume and seminal proteins) affecting honey bee queen post-mating changes.

Sheena Sidhu is a Ph.D. candidate in entomology working with Shelby Fleischer. Her research interests include promoting and enhancing native pollinators in Pennsylvania agroecosystems through landscape and resource management.

Jason Smith is a Ph.D. candidate in entomology advised by Consuelo De Moraes and Mark Mescher. His research explores chemically mediated aspects of foraging and ant herbivore defense in parasitic vines of the genus Cuscuta.

Auburn University
S. Addison Barden is an M.S. student in David Held’s program, where he is studying management of pests in turfgrass. His thesis is “Red imported fire ant influences on white grub populations and soil foraging characteristics in managed turfgrass.” He graduated in spring 2011.

Charles D. R. Stephen is an M.S. student in Xing Ping Hu’s program, where he is studying diversity and phonological patterns in terminals. His thesis is “Southeastern Nearctic termites: biodiversity, spatiotemporal distribution, ecosystem engineering.”

Prithwiraj D. Das is a Ph.D. student in Henry Fadamiro’s program, where he is using morphological and neurophysiological techniques to study olfaction in parasitoids. His dissertation is “Mechanism of olfaction in parasitic wasps: comparative morphological and neurophysiological studies of olfaction in a specialist (Microplitis croceipes) and generalist (Cotesia marginiventris) parasitoid.”

Esther N. Ngumbi was a Ph.D. student in Henry Fadamiro’s program, where she studied the behavior of parasitoid wasps in reaction to odors from their hosts. Her dissertation is “Mechanisms of olfaction in parasitic wasps: analytical and behavioral studies of response of a specialist (Microplitis croceipes) and a generalist (Cotesia marginiventris) parasitoid to host-related odor.” She graduated in spring 2011.

Debate Organizers
Ashfaq A. Sial is currently a post-doctoral researcher at University of California, Berkeley. His dissertation work at Washington State University focused on developing sustainable IPM programs for lepidopteran pests of tree fruits using reduced risk insecticides. He characterized the complete toxicity profile of new reduced-risk insecticides chlorantraniliprole and spinetoram against obliquebanded leafroller (OBLR) and investigated the evolution of insecticide resistance in OBLR to these chemicals.

Cheri M. Abraham is a Ph.D. candidate at The University of Georgia working with S. Kristine Braman to devise sustainable management strategies to control the primary pest, serpentine leafminer and other secondary pests in greenhouse gerberas. Components of his research include biological control, host plant resistance, and pesticides with low toxicity to natural enemies.

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