COMMENTARY

Conservation biological control: Improving the science base

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Based on the notion that monocultures and highly simplified farmscapes are associated with pest outbreaks (1), there has been an increased focus on "conservation biological control" [also called "ecological engineering" (2)] within the last decades to minimize economic losses to pests (3, 4), and at the same time avoid the use of pesticides. This is expected to be achieved by enhancing natural enemy abundance and functional efficiency through the designing of areas surrounding crops to provide alternative food sources (e.g., pollen, nectar, or prey) or escapes from agricultural disturbances (refugia) (2, 5). Now, in a meta-analysis on the role of surrounding vegetation on crop pests and their natural enemies, Karp et al. (6) come to the conclusion that there is no such general rule when the data are examined globally, across crops, landscapes, and biogeographical areas. Thus, on the surface, the conclusion questions what is assumed to be one of the core beliefs of many people working in the area of agroecology, especially those who regard agroecology rather as a philosophy than as a research field (7).

Karp et al. (6) have compiled a pest-control database of over 130 studies, encompassing more than 6,700 sites worldwide to "model natural enemy and pest abundances, predation rates, and crop damage as a function of landscape composition." While this database, made publicly available, is already a huge achievement in itself, it remains to be seen whether further inputs can significantly contribute to the intended purpose, "to answer critical questions about the ecology of pest control," or whether its value will be mostly found in other ways, such as providing the beginnings of a global "taxonomy" of farmscapes through the lens of pest-control literature.

Many of us who have done research on the effects of landscapes on pest management do not hold, as stated by Karp et al. (6), the "assumption that more noncrop habitat in farming landscapes universally increases biocontrol," nor are we surprised by the large variance in model outcomes across so many crops and geographical areas.

Karp et al. (6) acknowledge that their broad synthesis may have missed several key factors that often help determine pest dynamics in agricultural landscapes. They mention temporal predator–prey dynamics, lost when aggregating data into average abundances; tritrophic interactions among enemies, pests, and crops; crop (and presumably varietal) diversity; presence/absence of insectary plantings; and, perhaps most importantly, levels and timing of insecticide treatments. Indeed, as experienced field researchers, we would point to all of these factors as fundamental elements of the mechanisms determining abundance levels of pests and enemies—more influential in most cases than the likely effects of the surrounding landscapes. What is not clear is whether the addition of this level of detail into their global database would be feasible or provide any greater clarity to the global, singular question of whether increasing surrounding noncrop landscapes improves pest management. More likely the answer will remain, "it depends."

The Case of Tropical Irrigated Rice

Take the example of a widespread tropical crop—irrigated rice from tropical/subtropical regions [extremely underrepresented in Karp et al. (6)]. Rice is a so-called annual crop that actually can be regarded as "perennial" in many parts of the globe due to its continuous cultivation throughout the year. Rice has in many areas a long history, up to hundreds or thousands of years, which has led to well-established and coevolved social–ecological systems, and one of the most important crops on a global scale.

In line with the general outcome from Karp et al. (6), surrounding noncrop landscape effects are not among the major factors we see determining the population patterns of rice pests and their natural enemies. For tropical irrigated rice in Indonesia, Settle et al. (8) demonstrated that the factor of within-season and between-season spatial–temporal patterns of planting and harvesting were critical to pest-beneficial dynamics and yield outcomes. Specifically, extremely large-scale,

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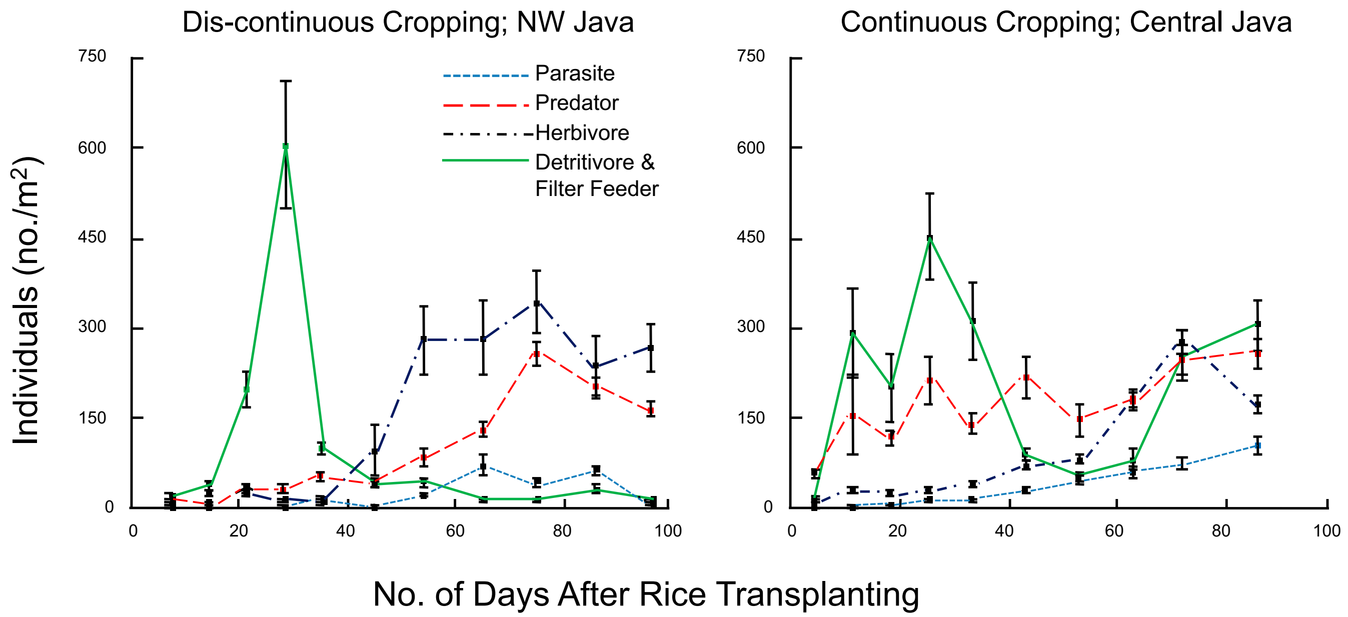

Fig. 1. **Dynamics of insect guilds in discontinuous (northwest Java; left graph) and continuous (Central Java; right graph) systems during the first season. In rice landscapes characterized by synchronous and large-scale planting patterns and preceded by long, dry fallow periods, the arrival of natural enemies is severely delayed and herbivores reach much higher abundances (left graph). Data taken from ref. 8.**

synchronously planted areas resulted in many fewer species overall and large delays in the arrival of beneficial species into the system, compared with regions characterized by small-scale, temporally heterogeneous planting.

The same study showed that this rice field "patch dynamics" interacts with a multitrophic-level model, in which generalist predators play the critical role in regulating pests by being present, in abundance, early in the season and before the arrival of the pests (Fig. 1). Generalist predator populations, when able to remain or rapidly reinvade newly planted fields, are able to build substantial population levels early in the season by feeding on the typically abundant populations of detritus-feeding and filter-feeding arthropods characteristically found in aquatic and semiaquatic systems. Their analysis demonstrated an overall mechanism that leads to much greater species richness and more temporally consistent and robust biological control in the less synchronously planted regions. As a result, the study showed that, at the landscape level, crop temporal and spatial heterogeneity, and not surrounding noncrop plant diversity, was likely the most important habitat factor determining population dynamics between pests and beneficials.

In more recent studies (e.g., ref. 9), asynchronous cropping was shown to create a mosaic of cultivated and temporarily (mostly for short periods) unused fields that provide a continuous supply of resources for predators and parasitoids over space and time, helping natural enemies to avoid spatial and temporal bottlenecks (10).

Landscape Heterogeneity and Habitat Quality

Pests and natural enemies may respond more strongly to aspects of the surrounding landscape that Karp et al. did not measure. For rice Dominik et al. (9) (who studied 28 sites in the Philippines), have shown that the abundance of prey outweighed the importance of landscape heterogeneity for predators, while all other functional groups were significantly affected by the composition and configuration of surrounding agro-landscape features. Particularly, the abundance of parasitoids and species richness of both parasitoids and predators increased with the structural connectivity of rice bunds, which have proven to be an important element in other studies as well (11), but which can hardly be captured with coarser-resolution land-use maps. Bunds (levee of terrestrial area surrounding the fields) build an extensive network that connects rice fields. Typically, they have sparse seminatural vegetation that can potentially offer alternative food resources or refugia to natural enemies (12) and likely facilitate the ability of rice arthropods to move through the rice agroecosystem. For example, specific egg parasitoids that cause high mortality of pest planthoppers occur in wild grasses on rice bunds (13). Some spider species, which commonly inhabit bund vegetation, are known as early colonizers of newly established rice crops (14).

Seeding or planting flower strips on these bunds (Fig. 2) enhances parasitoids but is also important as a food source for honey bees. Because the latter are highly valued in rural communities, it is easier to convince farmers not to spray insecticides, which in turn also leads to less disturbance of the ecological network within and along rice fields. As an additional benefit, landscapes are perceived as more beautiful. The involvement of farmers in these ecological engineering activities enhances the acceptance and effectiveness of landscape-wide management of biocontrol and other ecosystem services (15).

As Karp et al. (6) point out, different pest and enemy species often respond differently to landscape variables. In the case of irrigated rice, for example, specialized parasitoids, which are promoted by bunds, were not supported by surrounding agroforest structures (16).

As many of the species inhabiting rice fields are specialized, open grassland species, the biodiversity present in rice landscapes in tropical Asia is often higher than in many natural ecosystems (17); thus, not surprisingly, these species are more closely linked to surrounding grasslands and nearby rice fields at various stages of development, rather than other types of vegetation.

Conclusions

As already pointed out by Tscharntke et al. (18), major reasons for the noneffectiveness of surrounding vegetation include the following: (*i*) natural habitat is a greater source of pests than natural enemies; (*ii*) crops provide more resources for natural enemies than

Fig. 2. Field margins that have been enriched with flowering plants as food source for parasitoids of rice pests, but also for pollinators, including honey bees. Because the latter are highly valued in rural communities, it is easier to convince farmers not to spray insecticides, which in turn also leads to less disturbance of the ecological network within and along rice fields (see main text) [Image courtesy of Le Huu Hai (Tien Giang University, Tien Giang, Vietnam)].

does natural habitat (as in rice systems); (*iii*) natural habitat is insufficient in amount, proximity, composition, or configuration to provide large enough enemy populations for pest control; and (*iv*) agricultural practices counteract enemy establishment and biocontrol provided by natural habitat [as in irrigated rice ecosystems, with the often-counterproductive application of insecticides (15)].

As soon as we go to more context-specific levels, there are already good examples of general recommendations. With regard to pest management in rice, approaches like ecological engineering manipulate the habitat on rice bunds to enhance biological control (2, 19). By increasing the abundance of flowering plants along the rice bunds, the fecundity and longevity, especially of parasitoids, potentially increase due to the availability of food resources such as pollen and nectar, and alternative hosts (5). The application of ecological engineering at the farm scale led to higher abundances of predators and parasitoids across sites in China, Thailand, and Vietnam (20).

Outlook

While Karp et al. (6) did not find support for their expectation that, as they state, "noncrop habitat in farming landscapes universally increases biocontrol," the authors did list a variety of factors that were not included in the database, which they state could help future analyses by "increasing the predictive power" and thereby "offering remarkable opportunities to answer critical questions about the ecology of pest control." We agree that the factors they list, and maybe others, are critical to answering any such ecological questions. Our experience suggests to us that reliable, singular answers are not likely to emerge when posing questions at the aerial view that span multiple crops globally. In our work with tropical irrigated rice, we have found that adequate ecological descriptions include multiple key factors, resulting in complex direct and indirect effects and substantial geographic variability—just within one crop.

However, we feel it was certainly a worthwhile effort for Karp et al. (6) to compile this large dataset and we support the idea of efforts to include the additional necessary factors required to adequately account for key causal ecological mechanisms for each of the major cropping systems. We further support the idea of Karp et al. (6) to focus on analyses of subsets of their database, as we feel this is the best strategy for arriving at the most cogent, pragmatic, and parsimonious lines of inquiry.

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