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Research paper

Predicting potential rice damage by insect pests using land use data: A 3-year study for area-wide pest management

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ABSTRACT

To mitigate crop damage by insect pests, it is important to determine priority areas for the allocation of available pest management resources, which are usually limited. We tested whether the occurrence of pecky rice damage caused by the sorghum plant bug *Stenotus rubrovittatus* (Hemiptera: Miridae), a major rice pest in Japan, could be predicted using a spatial model based on land use data. Using a data from a 3-year field study, we examined the relationships among the land use of the area within a 300-m radius around each focal paddy field, the abundance of *S. rubrovittatus*, and level of pecky rice damage in the Maesawa region of northern Honshu Island, Japan. We also used mapping to visualize potential priority areas using a model and GIS software. From a linear mixed model analysis and model selection by Akaike's information criterion values, areas of source habitats, soybean fields and rice paddies were selected for the best model, but the abundance of *S. rubrovittatus* was not. Based on the model's evaluation, the predicted value of pecky rice damage, when compared with the observed value, was not sensitive enough for a quantitative prediction. However, the model was accurate enough to predict whether the brown rice was first grade, which is of greatest importance to local farmers. Therefore, it is possible that potential pecky rice damage by *S. rubrovittatus* could be predicted when the spatial arrangement of arable fields in a certain year is determined. Our results will be useful to support decision-making that involves insecticide applications to mitigate pecky rice damage.

1. Introduction

Using predictive spatial models to forecast potential environmental hazards, such as crop damages from pests (Thies and Tscharntke 1999; Taki et al., 2014; Masetti et al., 2015), plant diseases (Krupinsky et al., 2002; Meentemeyer et al., 2004; Kondoh et al., 2015) or wildlife (Saito et al., 2012a,b), as well as vector-borne diseases (Brownstein et al., 2005; Eisen and Eisen 2011) and alien species invasions (Giovanelli et al., 2008, Fand et al., 2014), could be effective, such as early warnings and targeted prevention measures. Determining the priority areas where such environmental hazards could occur would be useful in helping local people to deploy resources for countermeasures, which are usually limited. Several studies have discussed priority areas for forest pests (Paritsis et al., 2011; Kärvemo et al., 2014) and sanitary insects (Leicester et al., 2008; Yang et al., 2014); however, visualizations of such priority areas for insect crop pests using spatial predictive models has been scarce (e.g. Panassiti et al., 2015).

Maximizing the effectiveness of pest management resources is essential for mitigating crop damage. Pest management resources are typically limited by time and space, and thus intensive management at high priority areas is required. For every pest, optimal timing of insecticide application, such as when pests first enter crop fields or at their peak abundance that usually coincide with developmental stages of the targeted crop or at suitable periods for pest suppression by natural enemies are known for each pest. The non-crop habitat, such as the amount or arrangement of the source habitats of pests, and surrounding agricultural fields affect the abundance of pests occurring in the field (Thies and Tscharntke, 1999), the level of crop damage (Zaller et al., 2008; Takada et al., 2012), and the crop yield (Zaller et al., 2008; Venugopal et al., 2014; Schneider et al., 2015; Martin et al., 2016). Therefore, it is sometimes possible to predict potential crop damage to certain fields or regions using statistical models based on land use

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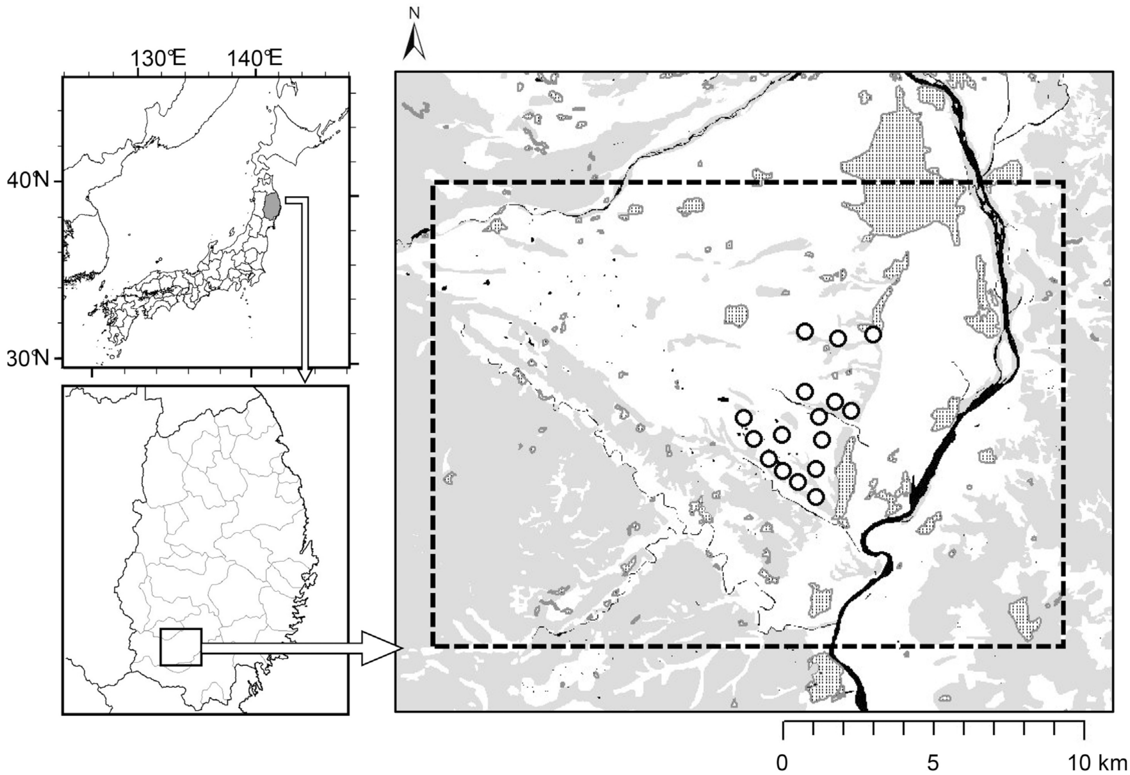

Fig. 1. Map of the study area showing the positions of the 16 rice paddies (white circles). Gray, white, black, and dotted areas represent forest, agricultural land, open water, and other land uses, respectively. A square with a dotted line indicates where the priority area map was created. Maps throughout this paper were created using ArcGIS® software by ESRI (2016).

information, such as the amount of a source habitat that has a critical effect on crop damage caused by insect pests and pest suppression by natural enemies from surrounding habitats (Schellhorn et al., 2015; Schneider et al., 2015).

The relationship between land use and pecky rice damage caused by hemipteran insects, including mirids, pentatomids and alydids, has been investigated in Japan for decades (Yasuda et al., 2011; Takada et al., 2012). These pest species have almost no major natural enemies in the field other than generalist predators (Takada et al., 2012), and thus, the configuration of the source habitat in the agricultural landscape plays a major role in the occurrence of pecky rice damage. The source habitats of these species are crop and non-crop fields dominated by poaceous and cyperaceous grasses (e.g. Ichimori et al., 1990; Tabuchi et al., 2015). Among the pecky rice bugs, the sorghum plant bug *Stenotus rubrovittatus* (Matsumura) (Heteroptera: Miridae) is a major pest species of rice in Japan and South Korea (Lee et al., 2009; Tabuchi et al., 2015). For this species, recent one-year field studies have shown that land use within a 300- to 400-m radius is the most predictive spatial scale in which affects their abundance responding to landscape variables (Yasuda et al., 2011; Takada et al., 2012). Therefore, by including the annual variation of *S. rubrovittatus* occurrences and its damage in a multi-year study, we aimed to predict rice damage using statistical models based mainly on land use information, which is the key aspect of this study.

To predict potential pecky rice damage caused by mirid pests, we performed a 3-year field study to construct an explicit spatial model based on land use data within the functional spatial scale that included inter-year variations of pest abundances in the area of southern Iwate Prefecture, on Northern Honshu Island, Japan. Identifying priority areas for deploying pest management resources is an important goal, because the optimal window for spraying insecticides against pecky rice bugs, including *S. rubrovittatus* is limited. Mirids and stink bugs that cause pecky rice damage usually enter rice paddies ~5–10 days after the heading of rice panicles (reviewed in Tabuchi et al., 2015). Therefore, farmers need to spray insecticides within a limited 5- to 7-day period across the entire field. We propose that by visualizing potential priority areas, insecticide application schedules could be adjusted, and pecky rice damage could be mitigated.

We hypothesized the potential occurrence of pecky rice damage could be predicted using a spatial model based on land use data within the biologically relevant spatial scale. The specific objective of this study was to examine the relationship between the area of the source habitat and the level of pecky rice damage caused by *S. rubrovittatus*. The land use types such as the crop types and weeds within the functional spatial scale were surveyed around each paddy field to evaluate land use characteristics, and the level of pecky rice in each paddy field was determined to evaluate the damage. We also investigated the abundance of *S. rubrovittatus* using a trap containing a synthetic sex pheromone as a bait placed in each paddy field.

We assumed that pastures and fallow lands dominated by graminoid and cyperaceous weeds increased the occurrence of pecky rice damage, although the influence varied among years depending the abundance of *S. rubrovittatus*. We evaluated the effectiveness of the constructed model by comparing predicted and observed values. The most important goal of a farmer is to produce first-grade brown rice with less than 0.1% pecky rice damage classified by the Agricultural Products Inspection Act in Japan (Ministry of Agriculture Forestry and Fisheries, 2001). We also validated the relevance of the model to predict the rice's classification grade. Moreover, we constructed a potential priority area map using our predictive spatial model for visualizing areas susceptible to pecky rice damage.

2. Materials and methods

2.1. Study site

The field study was conducted from 2011 to 2013 in the Maesawa region in southern Iwate Prefecture, northern Honshu Island, Japan