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Scientific Clarification and Countermeasures to Ecological Impacts of Pesticides on Dragonflies

GOKA Koichi
National Institute for Environmental Studies
16-2 Onogawa, Tsukuba, Ibaraki 305-8506, JAPAN
E-mail: goka@nies.go.jp

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The ecological impacts of new types of systemic insecticides such as neonicotinoids have become a worldwide issue. In Japan, it has been argued that wild populations of dragonfly and damselfly species have decreased due to systemic insecticides used in paddy fields. We have few quantitative data, however, concerning the ecological impacts of these pesticides on Odonata species, and no concrete measures have therefore been taken to address this issue. We attempted to approach the impacts of systemic insecticides from various perspectives, ranging from laboratory toxicity testing to field studies. We then used the data we had obtained to clarify whether systemic insecticides are indeed a factor in the reduction of dragonfly populations and to propose a new test method for pesticide risk assessment in Japan (Fig. 1).

To formulate an ecologically realistic toxicity test, we investigated ecological issues in the present test guidelines. We point out the need for a long-term toxicity test using species with life cycles longer than the usual test species. After combining these considerations with the results of previous mesocosm studies, we decided to focus on Odonata species as test organisms. We then set up an automatic breeding system for steady provision of damselfly nymphs for toxicity tests. Using this system, we tested long-term (4-week) toxicity in damselflies. We found that long-term toxicity (i.e., chronic EC_{50}) was likely to be much less than acute toxicity (acute EC_{50}), suggesting that Odonota in the field were sensitive to insecticides (Fig. 1).

Previous studies on the ecological impacts of pesticide application on paddy ecosystems have focused largely on the direct toxicity of pesticides to organisms. Therefore, our knowledge of indirect pesticide effects, which are mediated by interactions among organisms in paddies, is still limited. By conducting a three-year paddy mesocosm experiment, we found some indirect effects of a herbicide (pentoxazone) on Odonata larvae via a decline in macrophytes, as well as strong direct impacts of an insecticide (Fipronil). On the basis of our results, we concluded that the impacts of the use of pesticides should be assessed in more realistic situations, in which both insecticides and herbicides are applied.

Field investigations of the Odonata on Saga Plain, a major rice-growing area in Kyushu, have revealed that some species have rapidly declined in the past few decades. Consistent with the findings of previous studies, the abundance of the dragonfly *Sympetrum eroticum eroticum* was negatively related to concentrations of a systemic insecticide (Fipronil). The spring generation of the damselfly *Ischnura senegalensis* seldom occurred in localities surrounded by paddy fields, and increasing concentrations of Fipronil negatively affected its abundance, strongly suggesting that Fipronil causes population decline in this species.

Our review of previous studies by scoring based on Hill's causality criteria indicates that neonicotinoid pesticides are very likely to be a major causative factor in the sharp decline in dragonfly populations. In addition, application of a statistical causal inference method using pesticide usage and field monitoring data reveal that insecticide use decreased dragonfly populations. The simulations that we performed using population models suggest that the sharp decline in *akiakane* (the endemic autumn darter, *Sympetrum frequens*) in the 1990s was caused by a combination of insecticide application to nursery boxes and field maintenance that increased the dryness of paddy fields.

By using two Odonata species and 15 major pesticides as a model case, we successfully generated fine-scale pesticide risk maps at 100 km^2 grid size. These maps incorporate the predicted distribution of Odonata species, the estimated use of pesticides, acute toxicities and dependency on paddy fields. Visualization of the ecological risks posed by pesticides at the landscape scale will help us better to manage and maintain the biodiversity of Japan's highly productive land.

From these results we conclude the following:

1) To conserve wild odonatan populations, the use of neonicotinoid insecticides on paddy fields should be regulated strictly.

2) To clarify the ecological impacts of pesticides, chronic toxicity testing should be implemented in pesticide risk assessment systems.

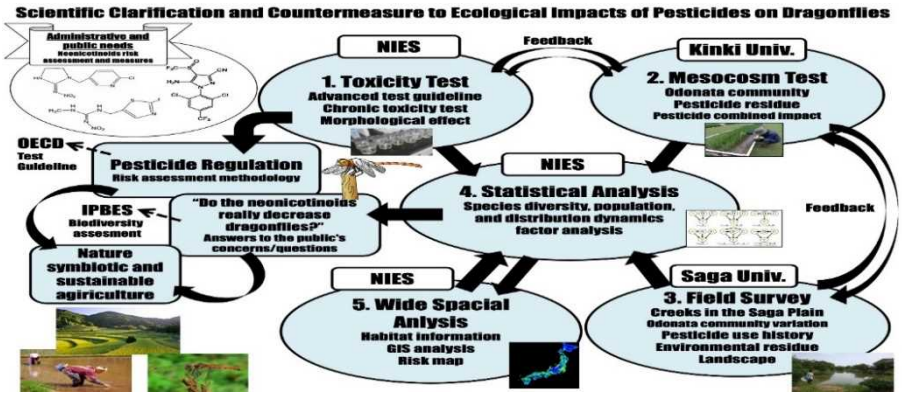

Fig. 1 Conceptual framework of our study project.