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"Wetlands: home and destination"

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Agriculture-wetland interactions: background information concerning rice paddy and pesticide usage (COP11 DR15)

Information paper prepared by the Scientific & Technical Review Panel

A. Introduction

1. This paper provides a summary of the current state of knowledge on the interactions between and impacts of pesticide usage on wetland biodiversity in rice-growing areas and on pest outbreaks, with a focus on information for Asia, which has the largest areas of rice production worldwide. It is provided as background information in support of issues being considered by Contracting Parties at the 11th meeting of the Conference of the Contracting Parties (COP11) in COP11 Draft Resolution DR15.

2. Rice production has a long history, and more than two billion humans now depend upon this production system for their staple food. It is the most important staple food worldwide and involves the world's largest populations of farmers and of consumers (Zeigler and Barclay 2008). Around 96% of world rice production takes place in Asia, accounting for approximately 640 million tons of grain per annum (IRRI, 2011 – http://irri.org).

3. Rice consumers and growers form the bulk of the world's poor, so the stakes are high: any faltering of production can lead to civil unrest and potentially widespread starvation (Gurr *et al* 2012). Similarly, any progress in ensuring sustained rice production (Wilken 1991, Greenland 1997) thus has major global policy and political implications, especially for the poor (Hossain and Fisher 1995, Von Braun 2009).

4. The production of rice (*Oryza sativa* L.) in tropical Asia has evolved from predominantly a low-yielding traditional system using few artificial inputs to a high-yielding scheme founded on genetically improved cultivars, synthetic fertilizers, and synthetic pesticides (Bottrell and Schoenly 2012). New rice cultivars grown as a monoculture now reach harvest maturity relatively quickly (105-110 days for later improved varieties from the Philippines, Bangladesh, and India) compared to the traditional cultivars (160-200 days) (De Datta 1981), allowing farmers with irrigation systems to harvest two and sometimes three crops annually from the same rice paddy.

5. Pest management is regarded as critical to achieving rice production in a sustainable manner (Savary *et al* 2006), because yield losses in global rice output to pests (diseases, animal pests, and weeds) range from up to 20% to at least 30% of the attainable (uninjured) yield (Savary *et al* 2012). Conversely, yield gains of at least 10-20% of the current actual (harvested) yields may be achieved from improved pest management (Savary *et al* 2012). However, various other externalities and additional costs are also associated with human health (Rola and Pingali 1993), the environment (Conway and Pretty 1991), and the maintenance of ecosystem services (Heong *et al* 2010), which, when disrupted, may lead to pest resurgence (Heong and Schoenly 1998). If such progress could be achieved in a sustainable manner, this, in itself, would address a very large proportion of the potential world food needs in the decades to come (Zeigler and Savary 2010).

B. Changing patterns of pesticide production and supply in Asia

6. The supply dynamics of pesticide have dramatically changed, especially over the past decade. For example, Figure 1 illustrates the rapid increase in pesticide production over the last decade in China but with largely unchanged levels of domestic application. Figure 2 illustrates that this increase in production, as compared with other major Asian producers Japan and Korea, is predominantly destined for export.

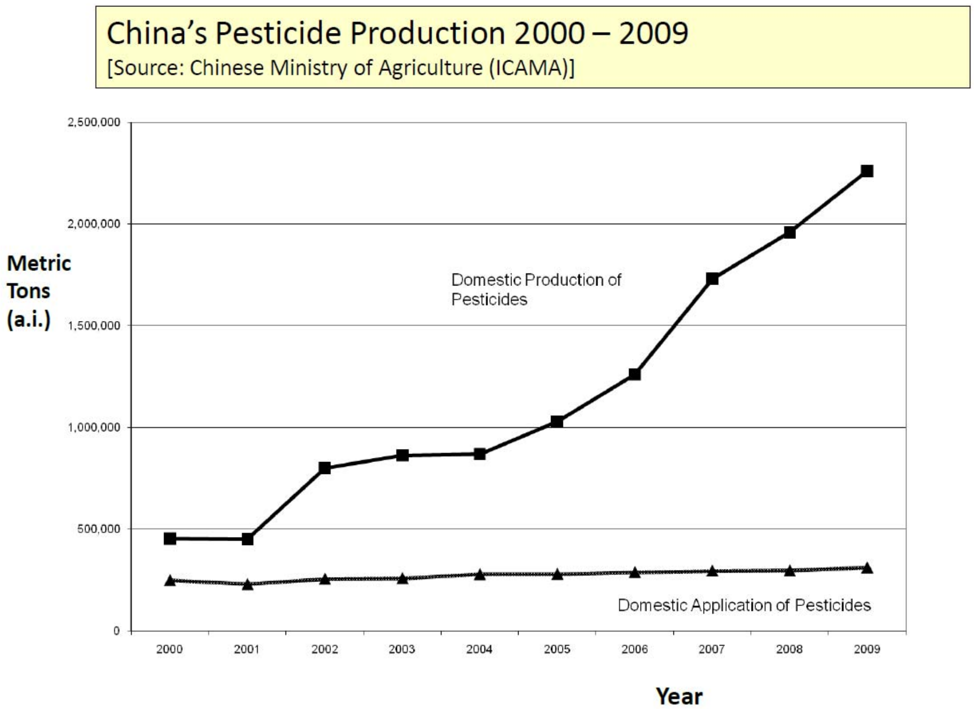

Figure 1. China's pesticide production and usage 2000-2009

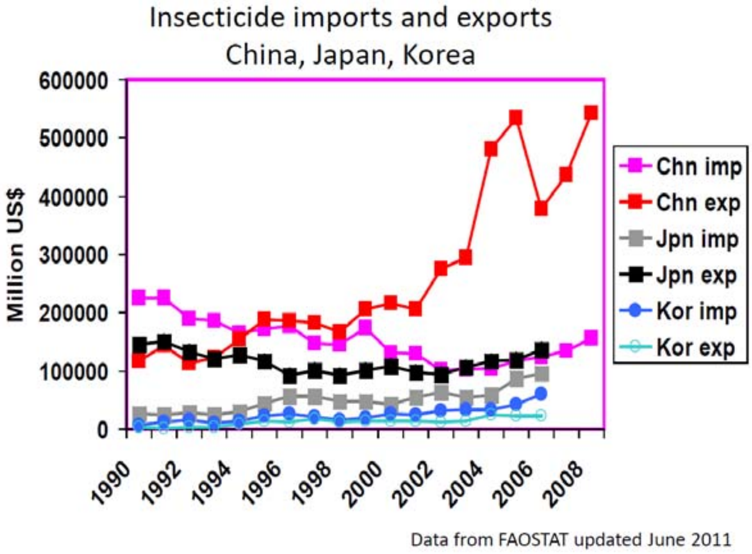

Figure 2. The export and import of insecticides by China, Japan and Republic of Korea, 1990-2009

7. China has thus become the largest pesticide producer and exporter in the world, and whilst rice pesticide sales in China account for 15% of total pesticide sales and reached USD 538 million in 2006 (Zhang *et al* 2011), the volume of exports destined for Asian rice paddies elsewhere is much more significant.

8. However, such dramatic increases in the last decade should be considered in light of the fact that pesticide consumption is already significant in several long established regions. For example, Japan is one of the world's largest pesticide consumers and is the largest pesticide market in Asia, with consumption of rice pesticides accounting for 41% of the total market (Zhang *et al* 2011).

C. Changing patterns of rice pesticide usage

9. Farmers now generally perceive chemical insecticides as insurance to protect investments in fertilizers and other inputs, with insecticide use significantly increasing in recent years (Bottrell and Schoenly 2012). For example, in the Philippine province of Nueva Ecija, a major irrigated rice area of Southeast Asia, Litsinger (2008) found that farmers treated high-yielding rice 1-10 times (average of 1.4-3.2) per crop using 40 different insecticides (comprising 64 distinct brands). Concomitantly, insect epidemics, triggered by insecticides overuse or misuse, have reinforced the farmers' fear of insect pests and the perceived need for more chemical applications (Heong *et al* 1994, Bandong *et al* 2002, Litsinger 2008).

10. Further abetting this situation, some governments have provided insecticides at low costs to ensure that farmers will regularly treat their rice crops (Kenmore 1991, Gallagher *et al* 2009). Few farmers are trained to use insecticides properly, however: rice farmers in the Philippines surveyed by Heong *et al* (1995) applied some 80% of the insecticide sprays at the wrong pest or when pests were not a problem. It has also been shown that, because of poor application equipment, ~75% of an insecticide's active ingredient can end up in the rice fields' water instead of the intended target area (Heong *et al* 1995).

11. Recent work also demonstrates that rice pesticides are found in streams, river mouths, and drinking water (Elfman et al 2011), thus creating further concern for downstream users of aquatic environments.

12. Despite the farmers' belief that insecticides are essential to protect rice yield, numerous evaluations have showed that the insecticides were rarely necessary for profitable rice farming (Waibel 1986, Pingali and Roger 1995, Matteson 2000 as cited by Bottrell and Schoenly 2012).

D. Impacts of pesticide usage on biodiversity

13. There is research evidence suggesting that current and recent patterns of rice pesticide usage can impact on the status of waterbirds, of fish (for example, in rice-fish systems) and of lower organisms such as plankton, with consequent disruptions to food chains.

Waterbirds

14. Waterbirds' use of agricultural wetlands has generally increased as natural wetlands have further declined (Parsons *et al* 2010), a usage pattern recently confirmed for rice paddy using spatial analysis techniques (Toral *et al* 2011). This increasing use of rice habitats by some waterbird species is now considered essential to sustaining their biogeographic populations in some regions.

15. Parsons *et al* (2010) recently analysed 65 peer-reviewed publications specifically to assess the relationship between pesticide use in rice cultivation and its impacts on waterbirds. The authors concluded that innovations in rice production within the past few decades have increased pesticide use and resulted in biodiversity losses in production areas and pollution of water resources. Key conclusions from this review included the following points.

- The prevalence of pesticide use in some rice cultivation countries is significant, and a broad suite of compounds has been applied to rice within recent decades around the world.
- Several insecticides used extensively in rice cultivation in numerous countries are extremely toxic to birds and are expected to cause frequent and largely unavoidable mortality, which may be a serious problem in light of the importance of rice fields as habitat for many aquatic bird species.
- Much research has been conducted to evaluate the transport of rice pesticides to groundwater and to adjacent surface water bodies, and significant contamination of associated water resources is widespread.
- Exposure of rice fauna to pesticides has been documented in a relatively small number of studies.
- Researchers have documented sublethal effects and field mortality of many avian species as a result of rice pesticide applications.
- Many studies have documented indirect effects on birds as a result of pesticide applications; with effects including reduced prey populations and habitat changes.
- Substantial information is available to rice farmers to mitigate pesticide impacts to rice fauna through compound reduction or substitution, water and soil management, modified cultivation strategies, monitoring and farmer training.

- The literature documenting exposure and effects of rice pesticides on birds is relatively undeveloped, and a comprehensive evaluation of research needs is lacking.

16. Wood *et al* (2010) also specifically addressed this issue in relation to wild birds in rice fields in China and concluded that these rice fields, which represent about 6% of the world's wetland area, are potentially a wetland habitat of considerable importance to wild birds. Preliminary data suggest, however, that whilst traditional practices with long periods of fallow flooding (including rice-fish and duck-rice) provide a great benefit to biodiversity, modern techniques reliant on shorter water regimes and greater chemical use are likely responsible for a decline in waterbird biodiversity. Likewise, Amano *et al* (2010) linked declines in Japan of spring and autumn migrant inland wetland-feeding shorebirds to agricultural intensification in Japanese rice fields.

Rice-Fish systems

17. Wild fish and aquatic animals found in rice paddies are a traditional source of dietary protein and an ecologically sustainable form of pest control (Klemick and Lichtenberg 2008). Field experiments have shown, however, that fish species commonly found in Southeast Asian rice fields exhibit high mortality from insecticide exposure and moderate-to-low mortality from herbicide and fungicide exposure (Cagauan 1995, Abdullah *et al* 1997), and these chemicals also indirectly harm fish populations by upsetting aquatic food webs (Klemick and Lichtenberg 2008, Xie et al 2011). Klemick and Lichtenberg (2008) have recently demonstrated, through field experiments, that in Vietnam high toxicity pesticides can be harmful to fish, but their budget studies also suggest that joint production of rice and fish under Integrated Pest Management can be as profitable as rice monoculture using conventional (pesticide) pest management methods.

18. Demonstration of the economic and ecological sustainability of rice-fish co-culture has also recently been replicated in China (Xie *et al* 2011). Such a production system has been designated a "globally important agricultural heritage system" by the FAO, UNDP and GEF (see http://www.fao.org/nr/giahs/giahs-home/en/) and maintained for over 1,200 years in south China. Field surveys demonstrated that, though rice yield and rice-yield stability were similar, rice-fish systems required 68% less pesticide and 24% less chemical fertilizer than rice monoculture (Xie *et al* 2011).

Plankton

19. Negative effects on algae growth and zooplankton feeding rates have been detected mainly after application of herbicides and fungicides in conventional rice fields. In real field situations, low to moderate levels of herbicides and fungicides have negative impacts to planktonic organisms (Suarez-Serrano *et al* 2010).

E. Increased pesticide usage is linked to pest and disease outbreaks

20. The brown planthopper, *Nilaparvata lugens* (Stal), is probably the most devastating insect pest for rice in most parts of Asia. Outbreaks of this planthopper can lead to severe hopperbum and total loss of the rice crop if no effective control is achieved. The resurgence of this major pest of rice after applications of certain insecticides has been repeatedly reported at the International Rice Research Institute (IRRI) (IRRI 1969, 1971,

1973, 1974, 1975 and 1977, cited by Chelliah *et al* 1980). Ge *et al* (2009) have attributed planthopper population increases to the reduction of natural enemy populations (Fabellar and Heinrichs 1984, Gao *et al* 1988) and the stimulation of fecundity (Gu *et al* 1984, Wang *et al* 1994, Zhuang *et al* 1999, Cheng *et al* 2003).

21. Whilst this relationship is well known, it has not prevented severe pest and disease outbreaks over the past five years:

"Since 2004, several Asian countries have experienced severe outbreaks of planthoppers in rice. In China, planthoppers persistently cause losses of about 1 million tons annually. In 2005, damage was about 2.8 million tons. In 2005 and 2006, numerous outbreaks also occurred in Japan and Korea. In 2007, Vietnam suspended exports of rice because of losses caused by planthoppers, and their persistent outbreaks in Indonesia have caused severe losses over tens of thousands of hectares since 2008. In 2009, outbreaks of planthoppers and associated virus diseases intensified in Central Thailand, the southern provinces of China, northern Vietnam, and Indonesia. Between 2009 and 2011, more than 3 million hectares in Thailand were infested, causing losses in excess of 1.1 million tons of paddy rice, with an export potential of US$275 million. The southern rice black-streaked dwarf virus, transmitted by the whitebacked planthopper, has spread into most provinces in the Red River Delta and further south into Central Vietnam. In 2009, an estimated 300,000 hectares were heavily infested in China and Vietnam, and more than 6,500 hectares suffered complete crop failure. The virus has now also spread to Japan" (http://ricehoppers.net/2011/09/action-plan-to-prevent-planthopper-outbreaks-in-rice/).

22. The locations of these major outbreaks in planthopppers in 2009 is shown in Figure 3. As to the impact of such outbreaks, it is currently estimated that the world's largest rice producer, China, loses about a million tons of rice grain from planthopper outbreaks annually and in some years as much as 2.8 million tons (Heong and Hardy 2009). Over recent years, pest damage has been amongst the most important factors leading to crop losses and price rises. Countries such as Vietnam, Brazil, India and Cambodia suspended exports in 2008 to prevent possible domestic shortages (Phoonphongphiphat 2008).

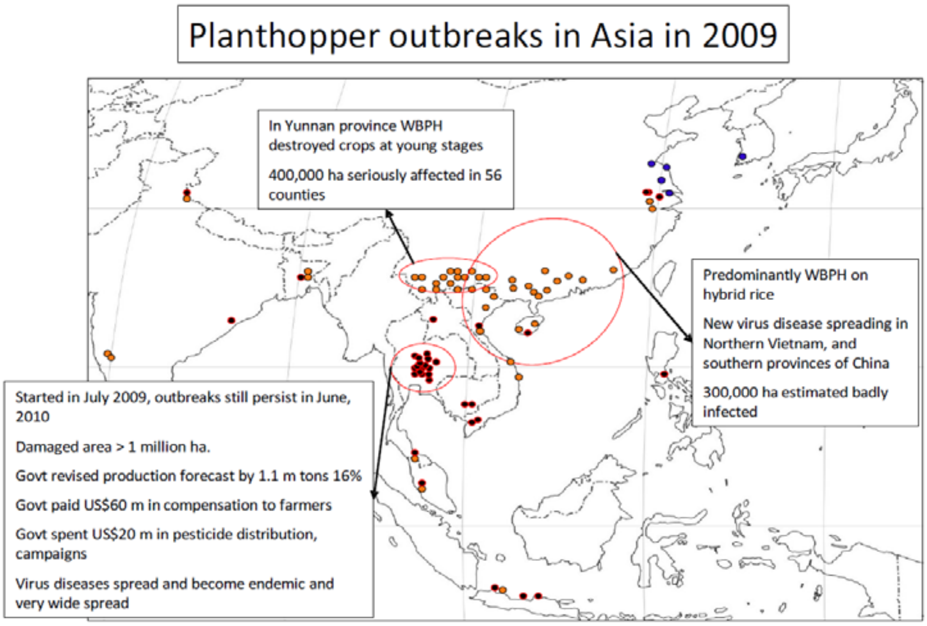

Figure 3. Map showing outbreaks that were reported in 2009.
The most significant outbreaks caused by the planthoppers were in Central Thailand, southern provinces of China and Northern Vietnam, and Yunnan province in China (Heong 2010).

23. Bottrell and Schoenly (2012) have made a compelling argument that pest outbreaks are primarily and regularly induced by insecticides on high-yielding rice cultivars in the tropics. It is acknowledged that insecticides do not always trigger pest outbreaks in the treated fields, but frequent applications do increase the likelihood because of their harmful effects on natural enemies. Pest resistance to insecticides also intensifies the probability of outbreaks, and once significant levels of resistance arise, farmers tend to apply more and more insecticide to combat the resistant population.

24. Azzam *et al* (2009) also conclude that these recent outbreaks of planthopper populations were mainly associated with pesticide overuse and resistance to imidacloprid, one of the major pesticides in use (Gao *et al* 2006, Liu and Liao 2006). The use of synthetic pyrethroids and organophosphates (triazophos) is also likely to have induced the population resurgence (Reissig *et al* 1982, Wang *et al* 1994, Gu *et al* 1996, Yin *et al* 2008). Further, Azzam *et al* (2011) state that the widespread use of imidacloprid against insect pests also increases the rate of the development of target pest resistance. Outbreaks of rice planthoppers in East Asian countries such as Vietnam, China and Japan have been related to the development of insecticide resistance in those regions (Wang *et al* 2008).

25. Furthermore, the results of Yin *et al* (2008) suggest that sublethal applications of the insecticide could increase planthoppers' capacity for migration (survivors secure more energy and become heavier when feeding on the imidacloprid-treated plants); theoretically these can migrate above-average distances and therefore serve as an especially important conduit in spreading imidacloprid resistance alleles into new areas. Zhao *et al* (2011) have recently demonstrated that these insecticides significantly enhanced the flight speed and flight distance of both males and females.

26. Within rice agro-ecosystems, the non-crop habitat is critically important in the control of various natural enemies of rice pests (Gurr *et al* 2011), as are the predators and parasitoids

living within the rice paddy itself (Matteson 2000). Early-season species establish and multiply in paddies before pest herbivores immigrate, a process witnessed in all rice field types, including temperate systems (Wilson *et al* 2008). If left undisturbed, these natural enemies normally prevent significant insect pest problems. For Asian rice systems, the crop and its biological environment have co-evolved for such a long time that these necessary trophic networks, albeit simple, have become inherently stable (Jeger 2000). However, early-season insecticide applications destroy this ecological balance as the insecticide destroys predators along with their food supply, leaving the field vulnerable to pest build-up.

27. Thus there appear to be potentially major co-benefits from reducing pesticide usage to both the maintenance of biodiversity in rice fields, including their role in natural pest management, and the management of pest outbreaks. In response to the reviews of the factors responsible for such pest/pathogen outbreaks which concluded that the increasing use and misuse of various rice pesticides is primarily responsible for more frequent planthopper outbreaks (see recent major reviews by Savary *et al* 2012; Bottrell and Schoenly 2012), action plans have been put in place by the International Rice Research Institute, the United Nation's Food and Agriculture Organisation (FAO) (http://www.fao.org/ag/save-and-grow/), and the United Nations Environment Program (UNEP) through its leadership of the Sustainable Rice Platform (http://www.unep.org/newscentre/default.aspx?DocumentID=2661&ArticleID=8967).

F. Management of increased pesticide overuse and misuse

28. Whilst some information is available to rice farmers about mitigating pesticide impacts on rice fauna through compound reduction or substitution, water and soil management, modified cultivation strategies, monitoring and farmer training (Parsons *et al* 2010), low adoption and in some cases discontinuation of Integrated Pest Management is generally not due to the inadequacy of IPM techniques, knowledge, or principles. Savary *et al* (2011, citing Bentley and Andrews 1996) outline six IPM roadblocks in relation to this issue which require immediate attention: 1) missing technical information, leading to IPM recommendations that are inappropriate to on-farm constraints, 2) a weak public sector, 3) inappropriate credit and subsidies, 4) influential agrochemical companies, 5) agro-ecosystem complexities, and 6) language barriers.

29. FAO (2011) has concluded that most tropical rice crops require no insecticide use under intensification. This is supported by evidence that yields have increased from 3 tonnes per ha to 6 tonnes through the use of improved varieties, fertilizer and irrigation. FAO (2011) cite Indonesia's drastically reducing spending on pesticide in rice production between 1988 and 2005. However, FAO also raises concerns that in the past five years the availability of low-cost pesticides and shrinking support for farmers' education and field-based ecological research have led to renewed high levels of pesticide use and large-scale pest outbreaks, particularly in Southeast Asia.

30. In synthesising an approach to this critical issue, IRRI (2012) have developed an Action Plan to reduce planthopper damage to rice crops in Asia. The Plan comprises two main components:

1. Enhance biodiversity and ecosystem resilience

- Introduce landscape elements such as flowers to promote the buildup and sustenance of a healthy population of parasitoids and predators of planthoppers.
- Promote synchronized planting and fallow periods of one month in between successive crops of rice.
- Implement crop diversification schemes across time and space. As far as possible, avoid insecticide spraying in the early crop stages (the first 40 days after sowing) to enhance the buildup of biodiversity, ecosystem services, and resilience.
- Deploy resistant and/or tolerant varieties judiciously by using a combination of varieties that differ in their resistance or tolerance mechanisms, and avoid using the same varieties for more than two years as this promotes the development of resistance in planthoppers.

2. Regulate the marketing and use of insecticides

- Regulate insecticides: Support national and local governments in market regulation of insecticides that shift their classification from consumer goods to regulated materials.
- Stop certain insecticides: Support governments in exploring options to stop the use of broadspectrum insecticides that induce the resurgence of planthoppers, especially those containing the active ingredients cypermethrin, deltamethrin, abamectin, or chlorpyrifos.
- Certify pesticide retailers: Urge governments to certify pesticide retailers to prevent sales of fake, banned, or unapproved products, and to foster the promotion of Integrated Pest Management and proper pesticide use.
- Train pesticide retailers and extension agents on the correct use of insecticides, such as conditions under which they should be avoided, the correct chemicals to use in case of application, alternating between chemicals with different modes of action to prevent pest resistance, the proper use of spray equipment, and the discouragement of broad-spectrum insecticides and preventive spray schedules.

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