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Short communication

Bat pest control contributes to food security in Thailand

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ABSTRACT

Sustainable rice production is critical to food security especially in Asia. Effective biocontrol of major rice pests such as the White-Backed Planthopper (*Sogatella furcifera*, Horváth; WBP) is, hence, of eminent importance. We use newly compiled data from Thailand on the Wrinkle-Lipped Bat (*Tadarida plicata*, Buchanan), WBP distributions and an iterative modelling approach to quantify the importance of biological pest control by a common bat species on WBP. In Thailand, this single species interaction may prevent rice loss of almost 2,900 tons per year, which translates into a national economic value of more than 1.2 million USD or rice meals for almost 26,200 people annually. For the first time, our results show not only the critical importance of bat pest control services in economic terms, but also for sustaining food security. Thus, bat population decline as currently observed in Southeast Asia, will directly affect people by food and money. Functionally important populations, not just rare and endangered species, should be included in conservation management of human-dominated landscapes.

1. Introduction

Sustainable rice production is critical to global food security because it is a staple to almost half of the world's population (Timmer, 2010). In Asia, rice accounts for 85% of all cereal crops produced and almost 50% of the daily caloric intake per person (Timmer, 2010; FAO, 2011). However, rice availability and much of people's access to it is affected by yield losses from major pest outbreaks such as those of the White-Backed Planthopper (*Sogatella furcifera*). Effective control of the WBP[2] is essential to stop it from transmitting rice viruses and physically damaging rice plants with yield losses up to 60% (Ellis, 1996). Biological pest control can be highly effective for planthoppers, even more than heavy pesticide application (Settle et al., 1996).

Bats are known insect pest predators in natural agricultural habitats. In coffee plantations in Mexico and Costa Rica, bats reduced herbivorous insect abundance (Williams-Guillen et al., 2008; Karp and Daily, 2014). In Indonesian cacao plantations, both birds and bats increased yield by decreasing insect herbivore abundance (Maas et al., 2013). Cotton yields worth 741,000 USD annually in the southern US were protected by free-tailed bats (*Tadarida brasiliensis*) feeding on cotton bollworms (Cleveland et al., 2006). Boyles et al. (2011) extrapolate this estimate across the US and found that bat populations may protect cotton harvest of more than 3.7 billion USD annually. Critics argue that these economic evaluations are based on oversimplified assumptions (Fisher and Naidoo, 2011), where for example spatial heterogeneity in commodity, pest, and predator populations have not been taken into account. In the only study from a staple crop, Leelapaibul et al. (2005) shows the predation of the wrinkle lipped bat (*Tadarida plicata*) on WBP in rice in Thailand.

Based on rice coverage maps and newly compiled data of bat roosting caves and foraging ranges, as well as monthly rice pest monitoring reports, we quantify for the first time the value of biocontrol by the Wrinkle-Lipped Bat (*T. plicata*, Buchanan; hereafter *bat*) on a major rice pest (WBP). We do this not only in monetary terms but also for staple food security in Thailand.

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[2] White-Backed Planthopper = WBP.

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2. Methods

2.1. Bat range, rice production, and pest occurrence

We mapped the bat foraging range based on cave locations from Boonkerd et al. (2001) and an online database (http://www.thailandcaves.shepton.org.uk/cave-co-ordinates). We then obtained the bat foraging range of a 25 km radius around the caves from the literature (Utthammachai, 2009), and verified population sizes and cave locations (S. Bumrungsri, personal observations). We generated spatial data of rice yield per hectare based on rice production data (Monfreda et al., 2008) and multiplied the harvested rice area proportion with the local yield per hectare planted with rice. The pest occurrence data was compiled from pest monitoring reports of the Thai Department of Rice (http://www.ricethailand.go.th/). We compensated for a localized and variable occurrence of WBP by averaging the frequency of WBP occurrence across all monitoring stations.

2.2. WBP damage on rice

We expressed the damage of WBP on rice as yield loss per gram of sucked rice sap. Zhu and Cheng (2002) measured the sucking rate of all life stages of WBP and calculated their injury coefficient. We then could compute the rice loss over the entire life time of a WBP weighted by stage-to-stage survival rates (Zhu et al., 2004) and the duration in days per life stage (Tu et al., 2013).

2.3. Bat predation on WBP

We predicted the average number of WBP directly predated by *T. plicata*. Leelapaibul et al. (2005) assessed the diet of this bat in Khao Chong Pran in Thailand over one year. This largest colony of two million individuals was our reference. We estimated the percent mass of WBP in the bat diet from its relative frequency occurrence (for details see the Supplementary information). Then the average number of directly predated WBP was derived from the known mass of adult WBP (Matsumura et al., 2008), the proportion of winged female WBP (Cook and Perfect, 1985), and bat feeding rates (Kunz et al., 1995).

We also estimated the number of WBP indirectly predated by the bat: when consuming a pregnant WBP, the bat also prevents future offspring from hatching. Based on the proportion of pregnant (Weihua, 1990) and winged females, and the survival rate of WBP eggs (Zhu et al., 2004), we could project the prevented damage by indirect suppression of the next WBP generation.

2.4. Extrapolating results to Thailand

We used the prevented rice loss per bat and night as calculated above to extrapolate the pest control service across Thailand. For a measure of directly saved rice, we multiplied the directly saved rice per bat with the number of bats per population, the local rice production relative to the reference site (Khao Chong Pran), and the WBP occurrence. The indirectly saved rice value was calculated similarly but further multiplied by the local tillering rice proportion (i.e., susceptible to WBP infestation). Finally, we used the sum of directly and indirectly saved rice to derive total saved rice; calculations of the monetary value and meals were based on the respective rice price and per capita rice consumption rates in Thailand (FAO, 2011). The entire modelling process was based on 10,000 iterations. For more details on the species, the modelling approach and detailed data sources see the Supplementary information.

3. Results

We found that the reported population size of almost eight million bats may prevent a mean annual loss of 2,892 (±1,749 SD) tonnes of rice in Thailand. The monetary export value of this amount of rice is US$ 1,213,997 (±734,225 SD). Given that on average 71.4% of Thailand's rice production is consumed within the country (FAO, 2011), this single bat species likely protects food for 26,152 (±15,817 SD) people annually (Fig. 1).

4. Discussion

In the current reality of famines and discussions about how ecosystems provide food security, our results of a single-species interaction securing food for almost 26,200 people annually could not be timelier. Bat population declines will affect food security of local people most severely, if the amount of rice protected is consumed within the country rather than exported. As this is the case for Thailand, a bat population reduction would translate into reduced food availability. Moreover, food security is also determined by the ability to purchase available food, and hence, linked to poverty. We found that the bat protects rice worth more than US$ 1.2 million annually. This shows that because poor people in Thailand live mostly in rural areas (Worldbank, 2014) where rice is produced, a reduction in bat populations would also affect people in monetary terms. Indeed, populations of *T. plicata* in Khao Chong Phran have declined by 12.5% from 1999 to 2005 (Hillman, 2006) presumably due to pesticide use in the area (S. Bumrungsri personal observations). Leelapaibul et al. (2005) also report guano mining from roosting caves of *T. plicata*, which in general is known to affect bat populations (Csorba et al., 2008). Across Asia these bats are widely hunted or their roosting caves are converted into quarries (Clements et al., 2006; Csorba et al., 2008). Hunting pressure and habitat loss in the Philippines has led to almost complete eradication of the once abundant Wrinkle-Lipped Bat (Csorba et al., 2008).

Overall, our estimates are conservative, because the bat likely also feeds on other major rice pests in Asia such as the brown planthopper (*Nilaparvata lugens*, Ståhl), for which no consumption data is available yet. While we used robust calculations and incorporated all known variation to illustrate the utter importance of a single species interaction for food security, validating our results with field research in the near future is crucial. Exclusion experiments to confirm our results in the field should be coupled with diet analyses focusing on a broad range of rice pests. It should further be determined, if bats of the genus *Tadarida* are able to track migratory insects like planthoppers when feeding at high altitudes. As a consequence the bat would then reduce yield loss far beyond its foraging range (S. Bumrungsri personal observation). Therefore, these studies should be conducted across the entire bat distribution range in Asia and extended to other bat species as well. Moreover, we restricted our initial extrapolation across Asia to Thailand, because it is the only country where we could acquire reliable data on all aspects of our model. Given that our extrapolation across Asia revealed three times higher estimates under the most conservative scenario and the broad distribution range of the bat and various pests, we expect that the role of bats as pest control agents is much more important than currently anticipated.

Food security and sovereignty is mostly needed in tropical and biodiverse countries, where poor people are restricted from access to sufficient food. For hunger mitigation, sustainable and local food production – especially in the developing world – is critical (Tscharntke et al., 2012). Conservation management efforts should, therefore, target functionally important and often common species to let smallholders benefit from service provision for sustainable crop production. As a practical management recommendation we

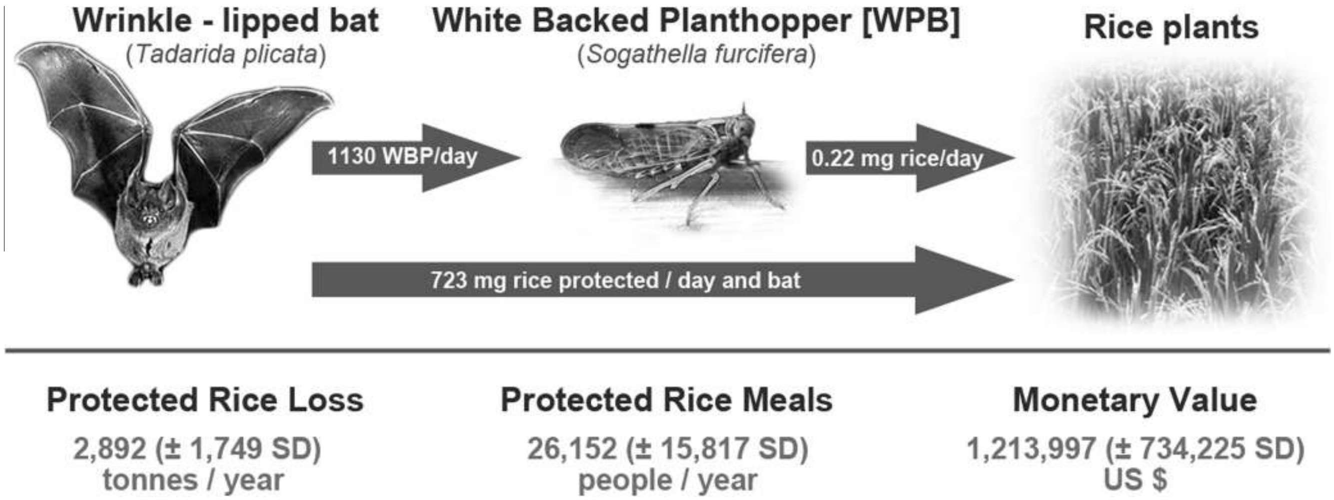

Fig. 1. Contribution of bat pest control to food security in Thailand. The Wrinkle-Lipped Bat (*Tadarida plicata*) feeds on White-Backed Planthoppers, a major rice pest in Asia, and thereby protects rice, which is critical for food and income of local people. The value of rice loss prevented per day and individual bat is the directly prevented rice loss (see text). SD = Standard deviation; Picture credits: Bat – modified from AnimalPicturesArchive.com; White-Backed Planthopper – modified from IRRI (S. Villareal).

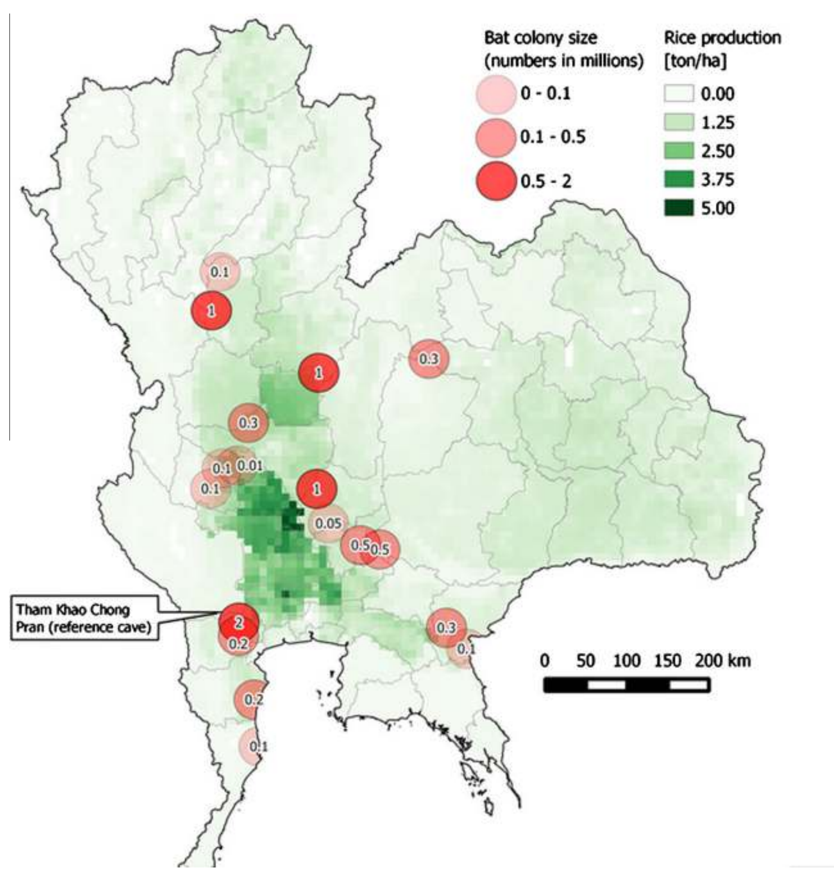

Fig. 2. Map illustrating the bat foraging range, colony locations and rice production. Note that despite bat foraging ranges (25 km radius around caves, indicated by the size of the circles) are not in areas where rice production is highest, they are protecting on average more than 2892 tonnes of rice annually.

suggest that Thai rice farmers consider establishing bat roosting boxes. In California, USA, farmers install roosting boxes for a closely related bat species (*Tadarida brasiliensis*, Geoffroy) to help controlling agricultural pests (Tuttle and Hensley, 1993). *T. plicata*'s foraging range in Thailand does not cover the most productive rice areas (see Fig. 2), but even small bat colonies of 300 individuals – living in one large roosting box – could enhance farmers' rice productivity locally by protecting an average of 657 kg rice per year according to our model. This represents rice savings of US$ 276 per roosting box and year. Sustainable pest control approaches such as Integrated Pest Management programs (http://www.fao.org/agriculture/crops/core-themes/theme/pests/ipm/en/) should consider such a broader landscape perspective. This would allow securing important resources for common species that fulfil a locally important function. As poverty is linked to insufficient access to food (Barrett, 2010), sustaining functionally important populations may locally also contribute to poverty mitigation.

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Appendix A. Supplementary materials

Supplementary data associated with this article can be found, in the online version, at http://dx.doi.org/10.1016/j.biocon.2014.01.030.

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