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Thoughts of a Travelling Ecologist, 5

When the "worst case" is not bad enough

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The condition of our Earth is changing, and it is changing due to human dominance. We realised that our influence on biota is overwhelming, building up to a mass extinction, the sixth in the history of life on Earth. The later this realisation is turned into action to decrease our fatal influence, the worse are the chances of the survival of the human race. How can we fail? One plausible scenario is that this can happen via the loss of ecological services (also named ecosystem services). These, provided by various organisms are essential, irreplaceable, and we increasingly rely on them. In spite of this, the status of most ecological services is declining (Carpenter *et al.*, 2009). In order to reach this synthetic understanding, even to realise that such large-scale ecological processes existed, we needed several elements of technology, among them satellite technology, computer power, and remote sensing capabilities. Before this, we literally "could not see the forest" —for we were able only to look at the "trees" —and these smaller elements, disjointed, just did not form a synthetic picture. Today all this is changed. We know what is at risk, and this new knowledge is the reason why any new intervention or technological innovation must now undergo a strict environmental impact assessment. The methods of manipulating genes came onto the scene by about this time, and it is largely due to the ecological ignorance of other biologists that they see various manipulative forces behind the demands of a strict environmental impact audit for this innovation.

The outdoor growing of transgenic crops triggered substantial changes in agricultural operations, with large-scale effects. One of the best examples comes from China: the spread of transgenic cotton caused a landscape-wide increase of some natural enemies of aphids (Lu *et al.*, 2012) while increased the density of other pests (Lu *et al.*, 2010). This is not simply due to the introduction of transgenic cotton, but due to the growing of cotton in a specific way in a particular landscape configuration. All of these factors (and not only that the cotton is transgenic) are responsible for this effect. Such large-scale effects are likely to happen in other parts of the world, and they are indeed happening. There was much discussion about the monarch butterfly *Danais plexippus* in the US and the official standpoint was that the fate of the butterfly does not depend on the large-scale production of transgenic herbicide-resistant maize. No one notified the butterflies, it seems; they have become rare in areas with high transgenic maize landscapes, and now are in general decline everywhere (Pleasants & Oberhauser, 2013). There is probably no single culprit but it is unlikely that changes that happened due to the introduction of GM maize did not contribute.

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Given that such effects are probable, how shall we protect ourselves by making sure that beneficial ecological services are not harmed? Of course, by testing the impact on them (Lövei,2001). A host of sophisticated recommendations have been published, the most detailed of them being the three-volume book series developed by a large collaboration (Andow *et al.*, 2008; Hilbeck & Andow, 2004; Hilbeck *et al.*, 2006). This endeavour is still unparalleled in its detail and the number of scientists involved, especially from developing countries. Other recommendations come from a more restricted set of developed-country scientists (e. g. Romeis *et al.*,2008), with a predictable outcome of limited generality and usefulness.

Virtually all suggested pre-release testing systems suggest a start with laboratory experiments. After this, they diverge, revealing serious rifts in the views and approaches. In this essay, I would only like to touch on one important element: the so-called worst case scenario construction.

It is logical to test for unwanted effects by exposing the target organisms or functions to a higher than expected level of stress, or stressor in a confined setting. This way a margin of safety can be obtained: if a negative reaction is not manifested under higher exposure to a toxic material in the laboratory, a smaller dose of same will rarely trigger a more severe reaction. However, current practice of such experiments ignores very basic ecological knowledge (Andow & Zwahlen, 2006). I stress that this ecological knowledge is not in the contested, avantguard area of ecology —these conclusions are well supported by numerous documented cases, and are not at all surprising. In a review published seven years ago, we summarised the until-then-published laboratory experiments on natural enemies (Lövei & Arpaia,2005). When we looked at the so-called "worst case scenarios", we found that while the assumed toxic stress was indeed higher than expected under natural conditions, this was the only element that was "worst". Virtually all the other factors were optimal: the natural enemies had an optimal thermal regime, feeding conditions were ad libitum, had access to high-quality prey, there was no competition, predation, nor parallel stresses imposed on the predators. So, these were unrealistic, single-factor experiments. Under natural conditions, things are very different: temperature and other conditions vary and are often suboptimal (i. e. worse than in the laboratory experiments), predators are often hungry, they are exposed to multiple stresses, and these factors can modulate, and at times, substantially change the reaction of the exposed organisms to a toxic stress. Conclusion: the current practice of these "worst case" laboratory experiments in the transgenic biosafety field constitutes no worst case at all. They almost make sure the natural enemies meet the intended GM-related stress in the best physical condition and most favourable environment a laboratory can provide. Even in toxicology, the necessity to consider combined stress factors has since been realised (Holmstrup *et al.*,2010).

The reaction to this supposed extreme exposure provides grounds for suggestions that if the "non-target organism" does not show negative effect in these experiments, no further testing is necessary, as the harmlessness of the transgenic plant has been proven (Romeis *et al.*, 2008). I believe this claim is unfounded and we have argued this point repeatedly (Andow *et al.*,2006; Andow & Lövei,2012). As it was pointed out, it is doubtful that acute toxicology tests provide a reliable base for making inferences of expected effects in nature. Additionally, at least at our current state of ignorance, one species cannot be considered as true representative of the reactions of all other species in its taxonomic category. The necessary ecological knowledge and experimental technology is available, and thus it is easy and feasible to create ecologically more realistic conditions in laboratory settings. In spite of this, laboratory tests are not able to show several potentially significant effects, due to the genotype/environment interaction. Laboratory experiments are necessary but not sufficient. Even if laboratory tests do not show negative effects, interaction effects should be explored at least in semi-field experiments before field release, and these experiments should include outdoor conditions and several species.

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