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Thoughts of a travelling ecologist 11.

The marriage of invasion biology and social science is preordained

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The human race now declared that it rules the world. We "officially" declared the start of a new era in the history of the Earth, the Anthropocene. The Executive Committee of the International Union of Geological Sciences accepted the proposal that humanity's impact is so large that it merits to call an era after itself, although there is remaining disagreement of its precise start (Head *et al.*, 2015). Some argue that this is a mark of accepting responsibility – I remain of the opinion that this is hubris, both ridiculous and dangerous. Ridiculous, because it is similar to many fields, where declaration of new and new eras, paradigms, etc. appear at increasing frequency as we approach the present. Earth-shaking discoveries and truths are daily announced. Do they really happen so frequently? Hardly. And the gods are laughing.

It is also dangerous, because it risks supporting the arrogance of those who mix up, willingly or not, their own, short-term interests with larger things. If we are planetary engineers, full throttle ahead! We can do anything. Anyone standing in front of any development may easily be branded an arch-enemy of progress, an irresponsible ignorant, denying our planetary importance and surely must step aside. And the gods are smiling, knowingly.

There remains little doubt, though, irrespective of declaring the Anthropocene or not, that human-induced global change is underway. This is distinctly more than climate change, even though that seems to dominate the discourse. One important element of global change is invasions (Vitousek *et al.*, 1997). The frequency of invasions seems to increase, accompanied by our awareness of the effects and impacts. The old view, that invasions are a largely one-way process originating from Europe, has collapsed. We no longer believe that mostly Old World, mostly European species colonise other, climatically similar, vulnerable geographical areas, such as the New World, New Zealand, Australia, etc. Invasions are no longer a side effect of "ecological imperialism" (Crosby, 1993). The massive cataloguing effort by the European Alien Species Information Network (http://easin.jrc.ec.europa.eu) compiled a list of more than 14000 non-native species that have established in Europe. Similar to many other things, invasions have also become globalised. All regions are affected, including the species-rich ones (Lövei *et al.*, 2012). Not even the most remote corners of the world, such as the Antarctic, are now free of invasive species (Hughes *et al.*, 2015).

When it comes to invasions, humans are undeniably among the most important vectors. We have moved (Mann, 2011), and continue to move, consciously or unknowingly, vast numbers of individuals of various species, and given the imperfect state of our

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knowledge of the Earth′s biodiversity (Juffe-Bignoli *et al.*, 2016), very likely even species that are undescribed, and thus we are unaware that they exist.

The first step of the invasion process is the arrival of non-native individuals to a new location. This is followed, in the case of a successful invasion, by establishment, spread, and then the impact of the invader unfolds. In the analysis of these steps, "routes of entry" or "pathways" gets a disproportionate interest from people dealing with quarantine organisms, biosecurity, and invasions (Hulme *et al.*, 2008). Nonetheless, this is where most surprises occur. In part, this stems from a naive optimism: the belief that if the quarantine system works well, then invasions can be prevented. As recently as 2014, advice concerning invasion to the Antarctic is: "Encouraging self-assessment of visitors may prevent introduction" (Huiskes *et al.*, 2014). Well, the world is full of surprises, and this optimism is regularly found to be misplaced – invaders arrive in unsuspected routes and in unsuspected numbers. This recommendation will not work.

The number of invasives is related to commerce, although a delay in the expression of impacts creates an "invasion debt" (Essl *et al.*, 2011). With the increasing volume of goods transported, the propagule pressure is becoming less and less of a bottleneck. Thus the Danish authorities made a bold step: they asked me to rate, from the Danish perspective, the risk posed to Denmark by all the species on the European quarantine list, but to ignore the consideration of probability of entry. Propagule pressure is important in invasions, but with the increasing commerce, it is often much higher than we think, and invasives continuously "innovate" – i.e. find new and unthought-of pathways of entry. The importance of human agency is recognised, and this is the first step in embracing other disciplines than ecology in the study of invasions.

Once arrived, these arrivées may immediately start to spread – this depends on the interaction of their life history, and the conditions of their new environment. More frequently, though, the new organisms have to establish a self-sustaining population, and produce new propagules, which then start spreading. Spread is another phase of the invasion that is profoundly influenced by humans. This is not always realised, in spite of he existence of several examples.

Not only did the American corn rootworm, *Diabrotica longicornis*, arrive in contaminated shipments during the times of the civil war to former Yugoslavia, but it very quickly spread in Europe – along roads. My late Hungarian colleague, Ferenc Kozár told me that in Ukraine, the first records were always near highways, hinting that humans were major agents of spread.

Just weeks before I moved to Denmark in 1998, a new bridge, the Storebæltsbro, opened, the first time in history linking the Danish islands of Zealand and Fyn. Up to that time, Zealand, this most densely populated part of Denmark, also the location of its capital, Copenhagen, was not reachable by road from the Jutland Peninsula that connects the country to continental Europe. Everyone had to use a ferry to traverse the Storebælt, a 15 km wide stretch of water. When I arrived, first we rented a house on the seashore, and every day I biked or drove to our institute, some 18 km away. The landscape had many shelterbelts, with magnificent old elm (*Ulmus* spp.) trees. I noticed this because elsewhere in Europe, the Dutch elm disease has eliminated these trees from the land. When the bridge opened, traffic intensity immediately increased – now the continent could be reached from anywhere in Denmark without having to board a ferry. Within a year, I noticed large elms displaying wilting leaves during the summer. In a few years, the elms started to die off all over the island, and by today, hardly any large, living elm is left. I learned later, that elms on Jutland fell to the disease some 15 years earlier. I have no direct proof but I believe that the high-speed, intensive car and truck traffic greatly increased the propagule pressure of the pathogen as well as the density of its vectors, bark beetles, and contributed to the rapid die-off.

I think the two important phases of invasions, entry and spread cannot be fully understood by using the toolkit of ecology only. Human activity is very important in these steps, and we have to remove our "ecological blinders". We have to study not only the flow of goods, but also peoples′ behaviour. To borrow

an ecological analogue, non-ecological fields have been occasionally used to study invasions using community-level parameters, such as the value or volume of goods exported. Behaviour such as travel, its frequency, modes and distances, peasant behaviour in exchanging seeds, the postal and electronic commerce, in short, various social activities can contribute to the understanding of invasions. A new publication (Brenton-Rule *et al.*,2016) claims that invasion threat is also related to governance, so even political science can say something relevant about invasion success.

The "marriage" of ecology and social sciences is inevitable. This will not not necessarily make this a "marriage made in heaven". The two fields have very different traditions. Ecology has a strong tradition of quantitative methods, and ecologists may claim that sociology is more "qualitative" and follows different traditions. To this, social scientists will surely hold up the statistical program SPSS (Statistical Program for the Social Sciences) that has, at one period, been among the most frequently used programs by ecologists. Nonetheless, in the classes I teach about scientific communication, the participants coming from the social sciences are the ones who sometimes say the many examples of statistics, description and sampling is too rigorous and formal for them to be useful. They use interviews, stories and various non-quantitative methods while pursuing their research. It would be a mistake to force them to abandon all those tools and methods, but these certainly indicate the existence of different traditions. In spite of this, a working-together is unavoidable and mandatory, if we aim at slowing down invasions – because to stop them we cannot. I am convinced that both can help in understanding how, and why do invasions happen and succeed.

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