A few months ago, I started a new research project on invasive insects in Europe. These animals seem to be the perfect connecting thread to speak about ecology, capitalism and mass tourism within our entangled, globalised world. The issues raised by their rapid invasion involve all the contradictions of our modernity, resonating at so many levels with our deepest phobias, our fear of invasion and our fear of the unknown. The project took me to Paris' Natural History Museum, to the South of France and the suburbs of Paris, where several entomologists and laboratories are studying the invasion's impact on what looks like a lost war. So far, I have met the specialists of the Asian hornet, the boxwood moth, the Asian ladybird, the palm tree weevil, the Argentine ant and the parasitoid wasp. Trade, travel and population movements constantly displace endemic fauna and flora all over the planet. We are all familiar with the story of the dodo and the accelerated disappearance of several local species after the arrival of the European colonisers during the 16th century. What seems different nowadays is that with the combined effects of global warming, new trades routes with Asia and the mass market defined by globalisation, we've come to the point that we might have to abandon our familiar attachments to castles surrounded by boxwood gardens or towns on the Riviera lined with palm trees...

DUST met with Franck Courchamp, researcher at CNRS, the Laboratoire d'Ecologie Systématique & Evolution, Université Paris-Sud and with Didier Rochat researcher at INRA, Versailles to talk about insects and the world we live in.

AGNÈS VILLETTE *in conversation with* FRANCK COURCHAMP *and* DIDIER ROCHAT

AGNÈS VILLETTE: **I was particularly interested in the methods you use to design predictive scenarios for future invasion. Are forensic science and speculative thinking the right tools to apprehend the complex worlds of insects?**
FRANCK COURCHAMP: I worked for 6 years on a project which aimed at identifying and defining which species of ants could potentially become invasive and cause chaos. To do so, we used a profiler system, borrowed from American TV series. When the police wants to find out who the serial killer is, they conflate data such as personality, skin colour, sex, education... We did the same with invasive ants, feeding data based on biology, behaviour, ecological traits and eating patterns of more than 2000 species, among which 19 were invasive. Using the dominant traits of the most invasive ones, we came up with a statistical profiling system which identified the perfect criminal. Applying the profile to the rest of the species, we found 15 new species that could become invasive in the future. We also found an innocent species among our 19. Its profile differed radically; it had been included on the list by mistake. Among the 19 was the Argentine ant which we knew was problematic. It was the first time that such a model had ever been used, and it allowed us to define some characteristics, but more importantly, to predict which were the future invasive ants. From the statistics, we created probability curves pointing to the accused. It was a little bit like knocking at someone's door to arrest them on the presumption that their profile fitted a killer in waiting. Currently, these specific species are under surveillance. We check that they are not entering new countries. Secondly, we worked on distributed species' models to inform us where in the world they could arrive, where they could thrive. We used climate data, feeding patterns, presence of local species to understand where they could spread and proliferate. Future invasive ant species mainly come from Asia and South America, all originating from the Tropics and from new emerging world economic powers such as Brazil, India, China. We need to keep in mind the 10% rule. Among introduced species, 10% will survive and acclimatise to a new country. Among those 10%, again 10% will be invasive. The others will pacifically live and acclimatise, or barely manage to get by. It takes 50 years between a species' introduction and its known impact. What we are going through at the moment is the result of WWII's invasions. However, the current climate warming is a tricky factor that complicates globalisation, as insects are cold-blooded animals, particularly sensitive to climate change. Warmer climate impacts their ability to reach extended territories, to survive longer periods during the year, to feed more and to increase their reproduction.

Some critics, and they are numerous, underline that the story of invasive fauna and flora has been going on since the beginning of human settlements on the planet. Yet global warming, accelerism and globalisation seem to be creating a more challenging situation. True, there are peaks: the discovery of the New World, the great discoveries of the 16th century... Back then, boats would arrive on an island and unload their food: chickens, rabbits, cows, goats... they would also let rats and cats escape from the ship. During colonisation, what we called acclimatisation societies underlined how European colonisers liked to reproduce their native environment by bringing plants and birds to recreate the natural flora and fauna of their native countries. And vice versa, with the introduction of species from the New World. Then there are lows: World Wars I and II, for example. We are currently in a peak but, as shown by a polemical scientific study entitled 'Non saturation of biological species' that was published last year, we have attained a historical level which is far from saturating and shows signs of an exponential peak curve.

THIS IS WHAT SOME CALL THE MCDONALDISATION OF THE WORLD, THE GLOBALISATION, WHICH IMPLIES THAT THE STRONGEST SPECIES SURVIVE, AND THEY ARE THE ONES CAUSING CHAOS.

The Holy Grail of invasion biology is to predict and act beforehand, to have the capacity to point out the invasive species of the future. Normally, we have to prove that a specific species causes damage. We do not have any legal or logistical frame to act on it before they commit damages. Among us, there are a lot of scientists who insist that, until damages can be proven, there is no ground for action. It is similar to the principle of the taxed polluter. It used to be up to environmentalists to prove that a factory was polluting. Now it is up to the factory to prove it is not polluting. Within the circle of invasive insects biology, this is not yet the case; scientists still have to demonstrate that a specific species can become invasive.

It seems that France is at the heart of the invasive insects propagation in Europe. There are several pragmatic reasons for that. France is at the heart of Europe, both geographically and economically, it is surrounded by 3 different seas. It is a top tourist destination, with 89 million tourists visiting France per year for a population of 67 million. It is one of the first commercial destinations for Europe. It is an ideal point of entry for the rest of Europe. Once in Europe, an invasive insect can go anywhere, at the administrative level as well.

When we studied invasive ants, we identified Biarritz's airport and harbour as the ideal point of entry. We merged information regarding climate, flights' origins, and the regional ecosystem. Of course, more goods arrive in containers at Le Havre harbour, but insects will struggle to settle there due to the colder climate. What is lacking in the chain of information to stop invasive arrivals and propagation is a human link – a post to be created – which could implement the knowledge gathered by the scientific community. But no one at the moment is taking this place. If we had more bio security in place, we could regulate the insects' entrance to a country and then to the Euro zone. Everything is doable. It's mainly a question of cost and the legal system in place. Consider the global problem of ballast tank sea water used in supertankers to stabilise boats while they are not loaded – last year a law was passed that stopped tankers from releasing in situ water they had pumped in Asia. There used to be around 3000 living organisms released in European waters every day. Most of those organisms die, but some survive. The water now has to be filtered, stopping around 90% of organisms from entering our ecosystem.

From the interviews I conducted with entomologists, it seems that funding is the main issue. Is that true?
I worked on a 6 year study analysing the cost of the invasive Asian hornet in France, which will be released soon – currently it is being reviewed. But the Asian hornet is not the only factor decimating local bees, there is also the varroa parasite, which is still responsible for 41% of the decline of bees among the French livestock, impacting 100 million Euros on honey production, without even taking into account pollination. If we counterbalance these numbers with the cost of the destruction and intervention of hornets' nests, it is clear that it is always cheaper to finance early prevention and protection. It is a question of will and determination. We still need to assess the true cost of the Asian hornet's propagation. We know that there are hundred of nests. Nature hates emptiness, so those heminopters must take other species' territories, eat others' food. And this is not even taking into account their long term impact on nature. If we really want to eradicate Asian hornets, we can do it. Let's not forget that 80% of European insects have disappeared in the last 10 years. Though, the single female Asian hornet that arrived in Bordeaux, from Central China, hidden in a clay pot in 2004, might come again...

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The palm tree weevil and the Mediterranean landscape

AGNÈS VILLETTE: **All invasive insects have a specific biography, a sort of founding tale. What is the story of the palm tree weevil?**
DIDIER ROCHAT: The palm tree weevil arrived in France in 2006. It was simultaneously found in Corsica and in the Var region. I will remain vague about its point of entry as it is still quite polemical. Let's say that the most acceptable hypothesis today would be that it arrived from

Italy or Spain. We understand that it arrived with an imported lot of palm trees, which had a stamped certificate of European trade emanating either from Spain or Italy, and should have guaranteed it was clear of insects. Within Europe, there is no security constraint, and back then, there was no qualification of quarantined organisms or mandatory eradication. We therefore consider that our neighbours already hosted the invasive insect. In Europe, the first encounters with the palm tree weevil happened in the south of Spain in '94 or '95. The most plausible hypothesis is that it was introduced from the Middle East ahead of the Universal Exhibition in Seville, in 1992, with extensive palm trees imports. In Spain, a few years before the financial crisis of 2008, there were a lot of property development projects, mainly along the coasts – it was necessary to create new urban landscapes. A palm tree is actually not a tree, it is an herborescent plant with extraordinary environmental properties. It can be easily planted and transplanted to create an exotic landscape. We all like to have the tropics at home! The import trade of Canaries` palm trees from the Middle East was booming then. It also meant there was a lot of fraud going on.

Where does the palm tree weevil come from? It is originally from Asia, from the continental monsoon area. It is known to have been problematic for a century, specifically for Indian coconut trees and in several monsoon countries. In 1985, the palm tree weevil was noticed in the Arabian peninsula. Since then, it has moved towards the West, following mass population movements and the general trade flow. There is no consensus on this but some texts state that it was in Iraq at the turn of the 20th century. With the current Iraqi situation, no one cares to prove the point. The insect is widely present all over the Mediterranean countries. Algeria is the only country to adamantly declare that it does not host it. You see what I mean: it is present all over the Black Sea. It was introduced in Sochi during the Winter Olympic Games of 2014. World forecasts are rather pessimistic. In Southeast Asia, it has contaminated all the zones where it was unknown until the 80s It is now in the tropical parts of Japan and China. Just before 2010, it arrived in some Caribbean islands, though over there, it seems stabilised. The palm tree weevil has several subspecies, like the one invading California, but the genetic research is only very recent, and there are still many unknowns about this insect.

From what you describe, the weevil insect appears to be a real monster. It is much bigger than most European insects. It is red coloured, suggesting an idea of danger, and its size fascinates. What we know is that it has an extraordinary sense of smell allowing it to find its host tree efficiently. Males emit a pheromone which is detected by both females and males. Its sense of smell is better than dogs'. Weevils are able to pick up the smell released by a tiny wound on a palm tree. If we give it anthropomorphic characteristics, we could say that it is a rather lazy lad, as it tends to disperse around its birth place. Some recent research focused on its ability to fly long distances. Out of 100 weevils, 1 to 10 are able to fly up to 50 km in one go. Its genetic potential allows the species to move far away to find more host trees. Until 2010, we did not know much about the insect. We had a general understanding of it, but we didn't know if it flew at night or during the day or even how far...

For a while, we were convinced that because it originated from monsoon territories with 100% humidity, it would be unable to survive cold winters or adapt in dry weather, or that its reproduction capacities would decrease. But it did adapt.

We gradually understood that there is a buffering effect that allows insects to survive in different environments. It is similar to the sea. During winter, the sea slowly cools down and warms up gradually in summer. A palm tree is made of water which remains warm when winter sets in. Eventually it will cool down, but there is a time lag during which the weevil waits for better days while digging its way inside the stipe.

The detection and prevention seem to rely uniquely on visual information, which seems a simplistic way to assess a situation as complex as the invasion of weevils. Until a tree looks really ill, no one wants to act. It seems that the same old story repeats itself... It is understandable! And it is classic regarding invasive species, particularly for species which do not impact agriculture. In 2005, we alerted the authorities, warning them that what was happening abroad was coming to France. The weevil arrived the following year. For 4 years, there were a lot of meetings but nothing was implemented. Damages were invisible, but no one anticipated the death of the trees. In 2007, the weevil entered a list of classified insects requiring an obligation to destroy it, to draw security perimeters, to apply treatments... but at the time, treatments were not operative. There is no consensus on an efficient treatment regarding insecticide use. It is also complicated to carry out in urban areas, where most of our palm trees are.

Are there countries where they successfully eradicated the invader? There is only one happy story, a single example where the weevil has been eradicated: in the Canary Islands. Discovered there in 2005, it was officially declared eradicated for good this year. For the past 3 years, not a single palm tree weevil has been seen on the Islands, and there is no record of a diseased tree. What the Canary Islands did is exactly what we have been recommending for the past 10 years. The authorities reacted immediately. The Canary's palm tree is endemic to the islands; it is their emblem. The population did not want to see their native forest disappear. The mobilisation touched all layers of society. They used a lot of European funds and declared an embargo on all palm tree imports, then relied on human and technical interventions. It worked. There is a second example, but it did not end successfully. Israel contained the problem for 10 years. The insect was discovered in date palm groves in 1999, as well as in Jordan and the West Bank. Collectively, Israeli, Jordanians and Palestinians took action and for 3 to 4 years, the weevils seemed gone. But then, one alert happened in Eilat. Then a dead palm tree was found in Tel Aviv. Since then they are fighting continuously without any success. Their configuration is similar to ours in urban seascapes. The only countries able to contain it long-term are Oman or Saudi Arabia. But they have colossal funds and the palm trees are situated in agricultural areas.

Is it difficult to imagine that there is no solution? We are not used to being told nothing can be done. The Weevil does not have predators in Europe. In their zone of origin they are eaten by lizards. There might be some diseases we could use to kill them, but they are unknown at the moment. Trained dogs can be used to find them; it is the same principle as searching for drugs, the insects have a distinctive olfactive signature. But it is costly. We now understand that we won't be able to save all palm trees. We could imagine taking care of some limited areas with extensive use of insecticides, like in Nice, along the Promenade des Anglais. We noticed that some palm trees resist better, such as the Washingtonians, and we are studying their genetic background, but it will take 10 years before we come to some conclusions. Cityscapes will be transformed. Until 1850, there were no palm trees in European cities. When they arrived in the 19th century, following trade routes, it brought a tropical and exotic touch to the Mediterranean coast. The city of Hyères changed its name to call itself Hyères-les-Palmiers. We will have to adapt to changing landscapes.