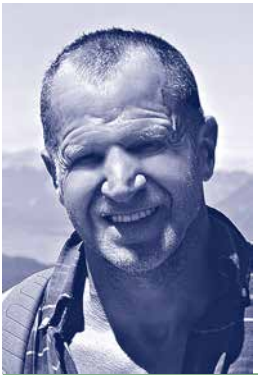

A PARALLEL REALITY
MARCELO A. AIZEN

Marcelo Aizen graduated in Biology at the Universidad de Buenos Aires in 1985 and obtained his Ph.D. at the University of Massachusetts in 1992. At present, he is Investigador Superior of CONICET (the National Research Council of Argentina) and Profesor Titular at the Ecology Department of the Universidad Nacional del Comahue in Bariloche. His research has focused on a diversity of basic and applied topics in plant reproductive ecology and plant-pollinator interactions, from the study of pollen tube-pistil interactions to global assessment of pollinator declines and the so-called pollination crisis. He is the author of more than 150 articles. Some of his research has been published in journals such as *Science*, *Nature*, *PNAS*, *PloS Biology*, and *Current Biology*. In the last few years, he and his group have been studying the consequences of the invasion of the buff-tailed bumblebee (*Bombus terrestris*) on the native biota of Patagonia and of invasive bees, in general, on agriculture. – Address: Grupo de Ecología de la Polinización, Centro Regional Universitario Bariloche, Universidad Nacional del Comahue and INIBIOMA, Quintral 1250, 8400 San Carlos de Bariloche, Río Negro, Argentina. E-mail: maizen@comahue-conicet.gob.ar.

I arrived in Berlin in late September from Bariloche, Argentina, after sorting out several pandemic-related obstacles: a long wait until the German embassy opened up in Buenos Aires to obtain my visa; travelling to Buenos Aires (about 1,700 km. distant from my hometown in NW Patagonia) in the absence of any regular domestic transportation due to severe mobility restrictions; and finally getting to Europe in one the few international flights departing from Ezeiza, Buenos Aires' international airport. But after all, as the saying goes "God is Argentinean" (well, at least the Pope is!), and against all odds and

thanks to continuous support and encouragement from Wiko's staff, I managed to get to Berlin and started a year in which I have lived in the parallel world of Wiko's cozy reality.

During my sabbatical year and being physically alone in Berlin (my partner never managed to make it to Berlin because of travel restrictions), my Co-Fellows, staff, and amazing new friends from outside the institute became my family. This was a small but immense world of affection, smiles, and care, in which I have never felt alone. I will always remember the day of Maradona's death in late November, when the Fellows and staff gave me their condolences as if Maradona were a close relative of mine. Even though I am not a football fan, I was very moved by the gesture and realized for the first time that, perhaps just by being Argentinean, Maradona was a close relative of mine after all. This network of stimulating talks and warm human interactions became the center of my new Berlin world during the last pandemic year.

Containment, comfort, and a long, gray, pandemic winter provided a perfect environment for inspiration and exploration. The focal idea of my proposed sabbatical project was assessing the extent to which the portfolio effect can increase crop diversity on the country and global scales and thus increase agricultural sustainability; this topic was preempted before I started my fellowship (see Renard, D., and D. Tilman (2019), "National food production stabilized by crop diversity," *Nature* 571: 257–260). Therefore, using the freely available dataset of the Food and Agriculture Organization of the United Nations (www.fao.org/faostat/en/), I explored instead the question of what ecological characteristics have led to the decline in the yield of many crops over the last few decades (1961–2018). It has been proposed that a global decline in the abundance and diversity of bees, the most important pollinator group of wild and cultivated plants, is the main driver of decreasing agricultural productivity, particularly affecting those crops that greatly depend on pollinators. For instance, wheat and rice are wind-pollinated crops and thus do not depend on pollinators, whereas apples and cocoa are crops that greatly depend on pollinators to produce the fruits and seeds we consume. However, comparisons of the mean yield of crops from different categories of pollinator-dependence hide the fact that most crops that greatly depend on pollinators are trees. A worldwide trend of increasing tree mortality has been related to global climate change, which could indicate that decreasing crop yield might be more closely related to the growth habit of a crop than to its dependence on pollinators. Disentangling the influence of these two confounding factors is important for understanding the causes of yield decline. The analysis I conducted assessing the incidence of positive and negative temporal trends in yield from > 6500 crop x country time series (1961–2018),

involving a total of 137 crops and 170 countries and territories, showed that about one quarter of all time series exhibited a negative trend. I found that being a tree is a more important predisposing factor of yield decline than having a high pollinator-dependence. I conclude that climate change is probably having a direct effect on crop productivity, affecting differentially crops that are trees, the growth form most vulnerable to the stresses imposed by reductions in water availability and increasing temperatures.

In addition to carrying out this evaluation, during my sabbatical year at Wiko, my students and colleagues from my research group back home and I published four scientific articles, all of which note the Wiko affiliation. In the first article on the list (see ref. 1 below), directly related to the research I have been conducting at Wiko, we investigated the role of ecological factors in determining yield and variability among 107 crops on a global scale. We found that yield decreased with increasing pollinator-dependence in tree crops, but not in herbaceous and shrubby crops. We also found that interannual yield variation tended to increase with increasing pollinator-dependence, and it was greater in crops from temperate regions, in those cultivated for their reproductive organs, and in tree crops. Thus, despite millennia of artificial selection and decades of genetic engineering, the main processes behind plant domestication, the growth of crop plants is still subject to the same intrinsic and extrinsic ecological constraints ("boundaries of nature") that limit the growth of any other, wild plant.

Regarding the boundaries of nature, we further investigated more explicitly whether plant domestication can produce extreme phenotypes that transcend these boundaries (ref. 2). Specifically, we asked whether annual crops, given a limited resource budget, exhibit a trade-off between seed size and seed number that resembles that occurring in wild plants. This analysis involved a compilation of data from the literature that included data on seed size and seed number for 49 grain-crop and 87 wild annual plant species from 15 families. We found that seed number-size characteristics of grain-crop species lie within the bivariate variation exhibited by wild species, and so they do not exceed the boundaries of nature. Therefore, human domestication can create phenotypes that are at the limit of what is found in nature and that can persist in the environment thanks to external subsidies (nutrients, agrochemicals, etc.), but man has not so far created "monster plants."

Although domestication does not create monster plants, it can change a plant phenotype in predictable ways. In particular, we investigated whether crops' greater susceptibility to herbivores than their wild relatives can be explained by either artificial selection for decreasing defense levels, which increases its palatability to humans, or for increasing nutritional

quality (ref. 3). Our results confirmed higher herbivory and lower levels of all types of defenses in crops compared with wild relatives. However, contrary to expectations, nutritional quality was lower in crops than in their wild relatives, which may enhance biomass loss to herbivores if they increase consumption to meet their nutritional requirements. These findings are meaningful in advancing our understanding of how changes in defensive and nutritional traits following domestication could influence crop susceptibility to herbivore attacks.

One of the questions I addressed during my colloquium at Wiko ("Myth and reality of the global pollination crisis") was how much evidence exists for a global pollinator decline. Although we count on evidence that pollinators are decreasing in abundance and diversity on local and even regional scales, the evidence that these declines scale up globally was missing. To fill this knowledge gap (ref. 4), we focused on bees, the most important and one of the most diverse pollinator groups (the common honeybee is just one species among about 20,000 species of bees), and turned to publicly available data on specimen collections and observations gathered at the Global Biodiversity Information Facility (GBIF), mostly coming from museum and academic collections and supplemented by citizen-science efforts. Based on the analysis of a data set that included about 4,000,000 bee records, we found that the number of bee species being collected or observed over time has been steadily declining worldwide since the 1990s. After addressing several potential biases associated with this non-systematically collected dataset, we conclude that a ca. 25 % decrease in bee diversity observed during the last few decades can be attributed to a great extent to the fact that many species are becoming rarer and less likely to be found. Given the relevance of bees and pollinators in general for agriculture production and for the reproduction of hundreds of thousands of wild plants, the publication of this article had immediate global repercussion, and its main findings have been reported in some of the most important news media worldwide (e.g. CNN, Euronews, CBS News, *Die Welt*, etc.). More importantly, as part of the biodiversity crisis we are witnessing caused by man's unsustainable use of earth's natural resources, the results of this study have contributed to increasing pressure on governments to take swift action to avoid further species loss and to preserve our natural heritage.

Even though I did not achieve as much academically as I wanted (a common feeling among the Fellows), my stay at Wiko was a much-needed break in life, particularly a temporary escape from the hardships of Argentina's daily reality. Going back to a country with chronic ~50 % annual inflation after a year is like experiencing the "Good Bye Lenin" syndrome. I know I will be shocked when I step into a supermarket for the first time back at home. However, my fellowship at Wiko reaffirms my conviction that it is worth

continuing to develop a scientific career in a country of the Global South such as my beloved Argentina. Despite dealing with limited resources and many obstacles, our work there can make a difference, not only in terms of our research contribution, but also of keeping the wheel moving by training a new generation of scientists. I firmly believe that developing a well-connected local scientific community is not a sufficient but, yes, a necessary condition for increasing a country's general welfare and for diminishing inequality. In this respect, I am sure that Wiko can play an even more important role by increasing the representation of Fellows from the Global South, which this year was ~10 % of all Fellows (e.g., in the present cohort I was the only representative from Latin America) and by fostering more and stronger links with institutions from our part of the world.

After being so well cared for and pampered at Wiko, I know it is time to go home. However, I am sure that my links to this unique place and to my new friends from Berlin will last forever. Finally, I cannot thank Wiko's exceptional staff and my Fellow friends enough for creating, in the middle of a pandemic world and despite many limitations on social interaction, this soft and cuddly parallel reality far away from home, but so close to the best of human nature.

Reference list of the scientific articles published during my fellowship and with Wiko's affiliation

1. Gleiser, Gabriela, Nicolay Leme da Cunha, Agustin Sáez, and Marcelo A. Aizen (2021). "Ecological Correlates of Crop Yield Growth and Interannual Yield Variation at a Global Scale." *Web Ecology* 21: 15–43. https://doi.org/10.5194/we-21-15-2021.
2. Fernandez, Anahí R., Agustín Sáez, Carolina Quintero, Gabriela Gleiser, and Marcelo A. Aizen (2021). "Intentional and Unintentional Selection During Plant Domestication: Herbivore Damage, Plant Defensive Traits and Nutritional Quality of Fruit and Seed Crops." *New Phytologist*. https://doi.org/10.1111/nph.17452.
3. Garibaldi, Lucas A., Marcelo A. Aizen, Agustin Sáez, Gabriela Gleiser, Marina M. Strelin, and Lawrence D. Harder (2021). "The Influences of Progenitor Filtering, Domestication Selection and the Boundaries of Nature on the Domestication of Grain Crops." *Functional Ecology*. https://doi.org/10.1111/1365-2435.13819.
4. Zattara, Eduardo E., and Marcelo A. Aizen (2021). "Worldwide Occurrence Records Suggest a Global Decline in Bee Species Richness." *One Earth* 4, no. 1: 114–123. https://doi.org/10.1016/j.oneear.2020.12.005.