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Vision and action in scientific discourse. *The Disappearance of Butterflies*. Josef H. Reichholf. (2021). Polity Press.

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Scientific study has always combined, in different ways and to varying degrees, research designed to increase understanding and build knowledge, together with making forecasts, warnings or proposals on the basis of that knowledge. Moreover, in recent decades many phenomena related to accelerating global change have tended to increase the need to unite vision and action within scientific discourse. The fact that the world is now facing a sixth mass extinction, involving one million plant and animal species that are at risk, largely attributable to human impacts, is but one example of such a development.

Within this context, in *The Disappearance of Butterflies*, Josef Reichholf offers a series of fascinating insights into the biology, the physics and the chemistry of Lepidoptera, including their remarkable adaptive capacities in the face of eco-systemic transformations. At the same time, he also poses a range of questions that act as provocations for all those who study the multiple, interwoven facets of living organism and human trajectories, within life sciences in general and sustainability science and ecology in particular, and ultimately those, including politicians, who should assume the responsibility for taking action when those trajectories become either threatening or threatened. The majority of the data he uses is related to Germany, the country in which he has carried out a lifetime of research, but the analysis he proposes and the issues he deals with are largely relevant on a global scale.

Reichholf is constantly at pains to emphasize the complexity of ecological processes and warn against distortions due to overgeneralization or simplistic explanations and solutions:

> […] it is crucial to distinguish ordinary fluctuations from the general trend. This is critical not only for understanding the natural cycles but also for identifying the correct measures required to reverse the downward trend. It will not be achieved, for example, by simply reducing the application of poisons, as worthwhile as this might be (p.3).

At times, he is scathing in his criticism of what he sees as unscientific positions and facile policy prescriptions. He also assumes a clear position as regards the widespread diffusion of current antiscientific trends:

> Whatever we commonly associate with 'green' or 'eco' holds its own problems with respect to the conservation of species. […] The ecology movement lost its claim to scientific integrity in my opinion when it was converted into a 'nature religion' through crises that lent themselves to political manipulation. […] Scientific discourse differentiates itself from the exchange of publicly entrenched opinions by accepting better findings. This makes natural science stronger but also increasingly unpopular. It remains qualified and flexible while today people seemed to delight in dogmatically countering one principle with another. Scepticism does not disqualify you from being a natural scientist. Instead, it is the praiseworthy habit of someone who does not submit to dogmas, even if they are currently supposed to be in fashion (p.3).

He also underlines the need to be clear about the relationship between scientific enquiry and the natural world and how this awareness should be employed as regards his own research, in order to not jump to hasty conclusions:

> Nature is dynamic. Changes can and will always occur. My initial claim that we have lost 80% of the butterflies in the last 50 years refers to the overall frequency and requires much more concrete evidence (p.9).

Indeed, 50 years of study, for example of ermine moths, have led him to summarize his conclusions in two "key statements":

> First: many years of investigation are insufficient for understanding the population dynamics of moths or butterflies; often, even a decade is too short. Second: the interactions between insect and plant are much more profound and complex than we like to imagine, particularly in the area of pest control (p.94).

The dynamics of biodiversity: variation, variability and adaptive capacities

New ways of estimating global species richness are constantly being developed and existing ones modified as new data emerge and statistical tools are refined. As a result, we have clearly become increasingly aware of the range of biodiversity, both in terms of the richness and distribution of species in the world and those that are at risk as a result of global change. At the same time, Reichholf stresses the importance of recognizing a particular aspect of these changes in techniques of estimation:

> Modern molecular genetics [have led to classifications] based on an arbitrary determination of genetic distances for a justification of species differentiation. Currently the "splitters" dominate the field and have done so for about 100 years so that many species are becoming subdivided into two or more species. Numbers therefore grow whenever new species are recognized as such. However, they are not newly formed, but have simply been discovered using a new method (pp. 150-151).

His principal aim is, however, to underline that the true significance of biodiversity lies in its relationship to variety and the ecological significance of this. "Species are not so easy to pigeonhole, however desirable this might be. Their fundamental principle and the reason for their success is variation and variability" (p.151).

The Disappearance of Butterflies provides numerous and detailed examples of such variety in Lepidoptera. This involves illustrating the multiple ways in which the complex interactions between biology, physics and chemistry are interwoven in a range of different species and how these interactions determine their particular behavioural characteristics within the ecosystems in which they thrive, together with the extraordinary ways in which they manifest their adaptive capacities in the face of perturbations that lead to eco-systemic transformations.

At times, Reichholf focuses on genetic peculiarities and their relationship to particular features of the evolutionary history of butterflies and moths.

> With butterflies and moths, the female sex is genetically marked XY and the male XX; that is, the exact opposite from us. For this reason, it is much easier for females to develop two different forms than it is for males. This characteristic manifests itself with particular clarity in forms of 'mimicry', that is, through the imitation of poisonous or foul-tasting examples by non-poisonous imitators that are not protected by unpleasant flavours. In short, in moth and butterfly circles it is worthwhile for the females to be

more highly diversified (p.29).

He frequently describes in great detail the adaptive capacities of particular species, such as the brown china-mark aquatic moth, through an examination of their physiological characteristics and how these are shaped by their interactions with their physical environment during each of their developmental stages. For example, since the metamorphosis of a pupa into a butterfly:

> […] requires a great deal of energy, the pupa must breathe. In contrast to the caterpillar, which floats on the water surface in its air-filled vessel and can replenish its air directly, the pupa is dependent on the plant for its air supply. It is even possible that the leaves that remain green in the water carry out photosynthesis for longer, just to provide oxygen to the air bubble of the pupa. The highly complex problem of how an air-based animal can breathe underwater is therefore solved in different ways: an adaptive achievement that one can only wonder at (pp.22-23).

The brown china-mark aquatic moth also provides an example of the challenges posed by the establishment of ecological niches and the struggle to survive in the face of modification or destruction of biotopes.

> The female brown china-mark will leave the pool from which she emerged if the floating leaves of the water plants have been overconsumed. She will examine the edges of the floating leaves quite thoroughly before laying her eggs, and for good reason. If there is extensive feeding damage, she will leave and search for other waters with better conditions. A tendency to disperse would already be expected since such small bodies of water are normally only temporary under natural conditions. They arise through inundation of the floodplains. New ponds will last a couple of years or a few decades, depending on how large or small they are when they form and gradually disappear again through sedimentation and plant succession. Species that colonise an environment that is by its nature unstable must seek alternatives in good time (p.26).

The relationship between the biology of Lepidoptera and the physics of both light and sound offers many examples of behaviours that go well beyond the most frequently studied phenomena of positive and negative phototaxis, as well as often taking us well beyond the current limits of human understanding.

> Certain species of moth have developed the quite extraordinary capacity to detect the ultrasonic pulses emitted by bats without having 'heard' them. Then, if they are struck by them, they let themselves fall into the grass or the bush is as quick as lightning. This is quite hard for us to grasp (p.33).

Navigating the dark requires a seemingly precarious balance between processing chemical and physical stimuli.

> Night-flying moths are above all concerned with finding a flight path through the darkness without crashing into obstacles if somewhere, perhaps several hundred metres away, a newly emerged female is exuding her own kind of sexual lure. The travelling males remain unscathed, which is surprising considering that they are practically flying blind with only their scent-sensors in their antennae to steer with. How they manage this never ceases to amaze me, since it is light that steers them off their course and causes them to bump into obstacles. 'More light, worse sight' is hard for us to comprehend, since we depend so much on vision. […] The moths and night-flying butterflies evidently […] need […] residual light. But based on the current level of knowledge we can barely even begin to speculate how they process this and how they use it to manage their often quite rapid flights, since, in terms of structure and function, their eyes are not significantly different from those of the butterflies and day-flying moths (p.34).

The relationship between Lepidoptera, light and sound is therefore highly complex and recognizing how partial our understanding of this complexity is should help us avoid making overgeneralizations based on inadequate timescales.

> Many nocturnal insects fly towards UV-rich light … What is so beautiful and appealing in individual butterflies lies in the eye of the beholder, that is, in our eyes. They do not see each other like this at all and birds also recognise them in other ways. On their night-

> time hunts, bats estimate where they are using sonar imaging, which is different again. Yet over the thousands and millions of years of their existence butterflies and moths must have learned to deal continually with the visual ability of birds and the echoes produced by the ultrasound of bats. The challenges presented by humans, on the other hand, are still relatively new. A century of nights illuminated by electric light is not enough. Or so one might think.
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> But perhaps we should not take such a pessimistic view. There is actually a rich diversity of species in nocturnal moths living in those big bright cities. Light pollution in general cannot therefore be the main factor in determining their occurrence and abundance (p.37).

Once again, for Reichholf it is of fundamental importance both to consider the relativity of different timescales and to avoid overgeneralization in reaching conclusions. Cities are one of the most salient examples of the Anthropocene and the ever-increasing human impacts on the biosphere. At the same time, as the author stresses, the relationship between cities and biodiversity is much more complex than might appear. This emerges as a development of the author's analysis of what is certainly the most disrupting human impact for Lepidoptera, that caused by industrial agricultural, and a comparison between the very different human impacts in two places: the countryside and the city.

The resourcesphere and industrial agriculture

The *oikos* studied by eco-logy is both life itself and a place in which to live, since without somewhere in which to do so life simply could not "take place". In the same way, the biosphere is both all life and the place (*sphaira* = terrestrial globe), the physical environment, or particular biotope, that hosts all life. The interactions between biotic and abiotic elements that take place within the biosphere give rise to constant reciprocal impacts which derive from the continuous interplay between the characteristics of the elements, the relations between them that are determined by these characteristics, and the transformations these relations give rise to. These in turn determine new characteristics, relations and transformations in an ongoing series of interlinked cycles.

In recent decades, we have come to be increasingly aware of how human actions and interactions within the biosphere have led to all-pervasive transformations and devastating outcomes such as global warming and a massive loss of biodiversity and the disastrous ramifications that follow. The COVID-19 pandemic has perhaps raised the awareness of such effects to a much higher level, particularly as regards how the destruction of ecosystems and the consequent loss of biodiversity is a powerful driver of emerging infectious diseases, although this is but one example of the overall ecological effects of the destruction of the diversity of living organisms. Many of these destructive human interactions are the result of our way of conceiving the entire biosphere as a gigantic *resourcesphere* (Dodman et al., 2020) in which any form of natural capital is considered "ours" to dispose of as we wish, without any regard for how that impacts on the biosphere as a whole. In this way, our attitude to the resourcesphere continues to compromise it for all life, including ourselves, in terms of all the provisioning, regulating, supporting and cultural ecosystem services it furnishes.

Among the numerous examples of such impacts, the development of agriculture – and in particular industrial agriculture and its concomitant international agribusiness – has been among the most devastating. The advent of agriculture transformed the biosphere in terms of impacts related to changes in human food supply and diet, health, population, social structure, mobility and resource use. The interaction between each of these factors has determined the many outcomes of our resource use and Reichholf offers a series of examples of how this use has been characterized by a dramatic acceleration in the ever-increasing scale of blind exploitation and profit seeking and the multiple consequences that ensue, for nature, for biodiversity and for farmers themselves:

> Over the past half century, nature has changed to an extent and at a speed that are simply unprecedented in such a short period. The findings are staggering and the prospects that they imply are exceptionally grim. This is because we cannot expect the main agent of this loss of species diversity – agriculture – to undergo any substantial change. Anyone who delves into the agricultural problem in any depth will find that it has less to do with the farmers themselves than with agricultural politics. The billions of

> subsidies they have received over the past 50 years have resulted in a highly competitive displacement of the small-scale farms by the large ones. Traditional farmers more or less disappeared, until only a tenth of their former numbers now remain, and yet the victor in this situation, international agribusiness – in particular the producers of crop protection products – managed to keep a low public profile while the decline of insects and birds proceeded in shocking parallel to the death of small-scale farm-based agriculture (p.12).

Particularly devastating aspects of industrial agriculture among those examined are competition, monocultures, fertilization and pesticide use. Competition and monocultures are often linked in terms of the effects produced:

> […] as a result of the concentration by agricultural businesses on a few, and increasingly just one, field crop, and the enlargement of production units, costs were lowered, but at the same time competition between farmers was enhanced. More and more farmers had to give up because the areas that they managed were too small to withstand the pressure from competition and to carry the enormous costs of the machinery and the monocultures required. In just 30 years prior to the turn of the century, approximately 90% of farmers in Germany gave up farming. The remaining 10% survived as businesses because they received area-related subsidies from the state or from the EU agricultural budget. This is a state-controlled command economy. In practice the public has already bought off the farmer's land several times over with the subsidies (p.201).

Reichholf repeatedly emphasizes the complexity of analysing ecological processes related to reasons why insect biomass has decreased by over 70% since the 1990s, a calculation based on "numbers recorded either in nature reserves or in other areas not used for agriculture" which clearly demonstrates how the effects of the crop enhancing and protecting products employed by industrial agriculture go far beyond the areas directly treated:

> This decline can only have been caused by the combined effect of fertilizers and pesticides. The application of fertilizer, which in this case came above all from exposure through the air, strengthened plant growth and caused the principal effect of colder and damper living conditions in the zone close to the ground. This expelled those species that need warmth and sunlight. Others that could cope with the increased density of plants and should thus have become more abundant did not compensate for the losses. The study was concerned with the mass of insects more precisely their biomass, or live weight. This, not the mere number of insects, had decreased by almost three-quarters (p.202-203).

Both the paradoxical, often absurd, consequences and the pernicious nature of the massive pesticide use that characterizes industrial agriculture are also clearly illustrated:

> Conventional agriculture is carrying out by far the largest weed and insect annihilation program that has ever taken place. In comparison, the burning of stubble, field margins and drifts that used to be practiced after the harvest, with a virtually harmless interference living things could cope with, that since it is visible and conspicuous stubble burning has been prescribed for decades but it has been replaced by poisoning which is invisible and inconspicuous (p. 178).

Moreover, there are many examples of what is known as the pesticide paradox, in terms both of the range of environmental impacts caused by their manufacture and use and how this can have effects that are opposite to those desired, and also of its relationship to the negative ecological consequences of monoculture:

> […] the fact that the (agro)chemical fight against pests seems to aspire to the total destruction of the pest species that it targets should give us food for thought. The speed at which the opposite is achieved, that is, resistance by pests to pesticides and new mass proliferations of the pest species in question, has led to an abstruse race: between the pests, which are constantly getting faster and better, and the chemical insecticides which are constantly being redesigned. This problem is aggravated by the extreme genetic standardization of crop plants, since it has long been known that mass proliferation and the development of resistance in pests is best controlled by genetic

diversity in the relevant crop (p.91).

The role played by livestock farming and the huge quantity of sewage this produces is also highlighted, particularly as regards the insane consequences of the blind pursuit of profit:

> […] hundreds of billions of litres of slurry end up directly on the fields, with huge consequences for nature, not only for plants and animals but also for the quality of air and groundwater these vast quantities of animals must be looked after if they are to produce corresponding profits sometimes this includes the use of medicines and other additives that inevitably place a burden on nature and our environment all of this has been reported frequently and in vain the agribusiness seems to be immune to its significance (p. 184).

The far-reaching consequences of the move towards obtaining biogas from biomass, based on a massive increase in maize monoculture, is also clearly illustrated in order to demonstrate the link between ecological and socio-economic impacts:

> In 1960 maize production covered only a couple of 1000 hectares in Germany. Now, in 2018, it covers 2.5 million hectares. That is 1000 times more land, thanks to the use of maize as a biofuel. The area of maize cultivation had already risen to 1.5 million hectares by the late 1990s. Maize cultivation was heavily subsidized by the state. With the arrival of biogas from biomass, farmers rapidly changed their crop portfolio. They became energy farmers while still maintaining all the privileges and public subsidies of land farmers (p.183).

All these examples regard ways in which industrial agriculture is based interventions designed to maximise monocultural plant growth and "protect" agro-ecosystems and crops from pests. The impacts have been not only on the land to be cultivated, but also all the surrounding areas which make up what we commonly call the countryside, with multiple paradoxical consequences. In this respect, Reichholf constantly returns to the comparison between "nature-friendly cities" and the "inhospitable countryside" and how this manifests itself in the different levels of loss of biodiversity with:

> […] largely stable populations in the city, smaller populations in smaller towns and villages, high losses outside these, even in protected areas, and only minimal residual populations of insects in the conventionally used agrarian landscape. As bizarre as it may seem, it is not the metropolis that spells the end of nature but the maize field […]. Nobody should be astonished, least of all those involved in industrial agriculture, whose objective was and is to maximize profit. Society has sanctioned these developments with its financial support. Whoever is willing to pay money so that pesticides and slurry can be applied *en masse* will inevitably be confronted with this outcome. (p.204).

Biodiversity in the city is conditioned by a multiplicity of factors and manifest in many different ways, whereby:

> […] woods have a quite different, truly public function […] trees are generally left to grow old and hollow. They do not have to deliver a good yield of timber they can be calculated as a profit to set against costs. Recreational value and beauty take priority over utility and monotony. The contrast is massive. One sees it as soon as one looks a little closer. In the cities whatever arrives and can cope with the inner-city living conditions is allowed to grow and live. Control and defence measures are limited to what is strictly necessary and even this is the subject of public discussion. […] This means that cities are (1) much richer in structure; (2) offer better living conditions; (3) warmer than their surroundings; and (4) subjected to far less fertilizer and pesticide than the countryside; also (5) the urban population is much more prepared to take into account the living requirements of animals and plants. Visible expressions of this are the fact that birds in the city are not shy, mammals show themselves by day and do not need to remain hidden in the dark of the night. Moths and butterflies also benefit from the advantages of the city, as the findings clearly demonstrate. […] It is not the cities that are bad but rather the countryside that is become inhospitable, and to quite a large extent (pp. 179-80).

If we look at the Anthropocene in all its complexity, we can see that urban nature is indeed more diverse than that of cultivated rural areas. Their diversity of micro-ecosystems, due to the diversified structure of cities, has led to those cities becoming islands of biodiversity.

Towards a biotope for each community

In *The Disappearance of Butterflies*, Reichholf pursues two principal aims. The first is to describe and explain the marvels of Lepidoptera in order to help us understand "what makes these creatures so distinct" (p.233). This understanding should lead us to a full appreciation of their beauty if we have the opportunity to observe them in a park or garden:

> Wings as fine as tissue paper with patterns and colours that an artist could barely imagine without the living model; antennae that pick up signals from the environment and convey them to the butterfly; eyes made up of many tiny ommatidia that register movement much more quickly than our own far larger eyes; and legs with a tactile sensitivity far more acute than our fingertips – yet all this only produces a rough superficial impression of the essence of a butterfly (or moth) (p.233).

Even if superficial, this impression must surely be an example of something that induces in us *biophilia*, "the love of nature", and its two fundamental constituents – *fascination* and *affiliation* (Barbiero & Berto, 2018). Each of these must unquestionably be at the heart of the kind of engagement necessary in uniting vision and action in promoting biodiversity.

Reichholf is equally concerned to warn against the pitfalls inherent in interpreting data on the basis of categorical, overgeneralizing thought patterns. This means differentiating "continuing trends from natural fluctuations" and recognizing that "the time periods used for investigations must be long enough" (p.133). Such investigation shows how "not all species have been affected equally" (p.119) by disturbances and consequent impacts. The mass of data he has collected during 50 years of scientific enquiry leads him to stress that "comparative trends must be independent of one another, in the same way that weather and climate trends are independent from butterfly populations" (p.134). In the search for causes, it is extremely important to differentiate between general effects, such as climate change, and special ones which are independent of this (p.156).

> This is not the first time that the climate is changed, and it is not changed only because of human activity. We use the term climate change to refer to long term lasting changes in the weather. Since nature has never been stable, these weather changes form part of the normal events that lead to the development of lifestyles. This is exactly why nature is so species rich (p.116-117).

At times, he expresses his position with biting irony, both in terms of unscientific positions regarding cause and effect and how this deviates attention from what has true responsibility for the loss of biodiversity – industrial agriculture.

> It was a stroke of luck for those who caused these various problems that climate change was discovered and exposed as the alleged cause of all change. Since this discovery there are no longer any guilty parties as everything can be attributed to the climate […]. The evasion of real soluble problems by labelling them as climate change reduces our sense of obligation to demonstrate the true causes and find effective measures here and now (p.205).

In many respects, this is a question of agricultural politics. If "today farmlands dominate 38% of the global land surface, almost 30% of global net primary production is appropriated for human use […] and the demand for agricultural commodities is projected to increase inexorably (Zabel et al., 2019), then much depends on the determination and the willingness of politicians and of the international agribusiness industrialists to bring about radical change. At this level, Reichholf is sceptical, since:

> […] a great many people have been commenting on industrial agriculture for several decades, but they are still too few to achieve the political pressure that would be required to bring about a change for the better (p.4).
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> […] Making industrialized agriculture environmentally compatible in the foreseeable future is an objective that must be pursued, but not an option that is likely to be successful in the short term. It will continue to hold its course like an overloaded super

> tanker […] (p.228).

At the same time, he believes that community awareness and action must be the essential drivers of change:

> I am convinced that the path must be from the bottom upwards from the foundations to the top of the organizations, authorities and political committees. The objective must be for the critical public to become more interested in the species. We should concentrate on the beauty, individuality and unique characteristics of butterflies, moths, beetles, wild bees and other insects as well as our wildflowers (p.230).

In this respect, what is essential is to focus on the role of biodiversity in terms of its importance for cultural, in particular spiritual, ecosystem services that promote wellbeing and the desire to create "a biotope for each community" in which that very diversity can thrive.

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