



Sensing Lichens

From Ecological Microcosms to Environmental Subjects

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An unusual garden is the entry point for this article. This is not a garden that is a space of familiar vegetal cultivation, but rather of unfamiliar vegetal operations. The ‘Ozone Bioindicator Garden Project’ is a NASA (US National Aeronautics and Space Administration) initiative that serves to demonstrate the ways in which cultivated plants can be studied for signs of injury as a result of air pollution. Milkweed, coneflower and snap beans are species for which NASA provides planting instructions in order to establish an ‘ozone garden’. From specifying fertiliser to outlining techniques for staking, insulating, watering, and labelling plants, the NASA ozone garden guide develops a methodical and standardised approach to cultivation in order to ensure the comparability of observations when examining plants for ‘ozone-induced foliar injury’. This is a garden that requires particular practices as a means to generate insights into botanical processes, including the labelling of leaves as they emerge with small tags, studying plants with magnifying glasses for initial signs of ozone damage in the form of ‘stippling or purpling of leaves’, and photographically documenting plants as they undergo possible ozone-related air pollution. Levels of ozone exposure in the plants are indicated by studying the varying levels of spotting and turning yellow, thriving and wilting.¹ Here, gardening becomes a means by which to engage with the specific vegetal operations of *bioindication*.

Bioindication is a process occurring across multiple organisms as they are affected by, sense and even transform their environments. Many vascular plants can be studied for ozone injury. Still other organisms such as bryophytes (or mosses) can be examined for evidence of air and soil pollution, while fungi can be assessed for indications of forest health, and

1 The National Aeronautics and Space Administration (NASA), ‘Ozone BioIndicator Garden Project’, <http://science-edu.larc.nasa.gov/ozonegarden>, accessed 20 September 2017



Lichens at the Kilipsjärvi Biological Field Station, 2011, documented during an art-science residency hosted by the Finnish Society of Bioart, photo: Jennifer Gabrys

2 There are numerous references to bioindicators and bioindication within environmental science, but comparatively few of these studies engage with other disciplines, including creative practice and science and technology studies. Expanded engagements with bioindication can be found in Jennifer Gabrys, 'Becoming Urban: Sitework from a Moss-Eye View', *Environment and Planning A*, vol 44, no 12, 2012, pp 2922–2939; Anna Lowenhaupt Tsing, *The Mushroom at the End of the World: On the Possibility of Life in Capitalist Ruins*, Princeton University Press, Princeton, New Jersey, 2015; and Christelle Gramaglia and Delaine Sampaio da Silva, 'Researching Water Quality with Non-Humans: An ANT Account', in Jan-Hendrik Passoth, Birgit Peuker and Michael Schillmeier, eds, *Agency without Actors? New Approaches to Collective Action*, Routledge, Abingdon, UK, 2012, pp 178–195.

3 There are many scientific studies on lichen bioindication and air pollution monitoring, both contemporary and historic. References used here include: B W Ferry, M S Baddeley and D L Hawksworth, *Air Pollution and Lichens*, Athlone Press, London, 1972; Thomas H Nash III, ed, *Lichen Biology*, Cambridge University Press, second edition, 2008; Pier Luigi Nimis, Christoph Scheidegger and Patricia A Wolseley, eds, *Monitoring with Lichens: Monitoring Lichens*, NATO Science Series IV: Earth and Environmental Sciences, Proceedings of the NATO Advanced Research Workshop on Lichen Monitoring, Wales, United Kingdom, 16–23 August 2000, Springer Science +Business Media, Dordrecht, 2002; D H S Richardson, *Pollution Monitoring with Lichens*, Naturalists' Handbooks no 19, Richmond Publishing, Slough, 1992.

molluscs can be probed as indicators of water quality.² Certain organisms such as lichens are particularly notable for their bioindicator characteristics, and are frequently studied for their ability to signal air and soil pollution.³ Lichens are sensitive to common air pollutants and heavy metals; their presence or absence in environments, as well as health and morphology, can indicate the quality of air, soil and water. Bioindication through lichens is a specific way in which to understand the ongoing material effects and accumulations of environmental pollutants, especially as they influence the distribution and prevalence of organisms. My focus on lichens here is to investigate the ways in which bioindication as a process is expressive not just of other means of doing environmental sensing, but additionally of other engagements with environmental subjects that attend to the lived effects of pollution as experienced by non-human organisms.

In the context of this special issue, which undertakes a broader examination of 'botanical conflicts', lichens present an immediate conflict since although often grouped within discussions of plants and their bioindication processes, they are not actually plants. To some extent lichens operate in a vegetal way by creating chlorophyll, transforming nutrients, colonising soil and rock, and stabilising ground layers, as with other vegetal organisms. Yet, while they resemble plants in numerous ways, lichens are actually composed of fungi, alga and/or cyanobacteria, and are amalgams of multiple organisms that are located across kingdoms.⁴ As symbiotic organisms, lichens trouble the classification of organisms.⁵ Rather than fixate on a plant species or clearly situated example of plant-ness, this article instead considers how entities come to be identified as individuals and are clearly located within taxonomic orders. By focusing on lichen-based processes of bioindication, I engage with the ways in which lichens are more appropriately characterised as ecological microcosms, rather than as discrete and easily classifiable entities. Bioindicating lichens tune our attention to the relational qualities of organisms, which open toward more *ecological* configurations of entities.

As expressive organisms bioindicating environmental conflicts such as air pollution, lichens take part in collective communities engaged in multi-species world-making projects.⁶ Such world-making projects have been discussed in the work of multiple writers working in feminist technoscience. Isabelle Stengers has developed an approach to constructivism, influenced by the work of A N Whitehead, to describe the ways in which worlds are made through distributed entities, and how those worlds allow for certain subjects and relations to gain a foothold. Also writing about world-making in her discussion of the Matsutake Worlds Research Group, Anna Tsing notes: 'Each living thing remakes the world through seasonal pulses of growth, lifetime reproductive patterns, and geographies of expansion. Within a given species, too, there are multiple time-making projects, as organisms enlist each other and coordinate in making landscapes.'⁷ Yet as she elaborates, these worlds are not in the making through the activities of more-than-humans alone, but are formed also through humans and their livelihoods, and the conditions that all of these entities contribute to making.⁸

Tuning in to these processes of world-making, here I analyse bioindication as expressed through lichens both to understand how other organisms experience pollution, and to articulate how environmental subjects and



Lichens at the Kilipsjärvi Biological Field Station, 2011, documented during an art-science residency hosted by the Finnish Society of Bioart, photo: Jennifer Gabrys

- 4 Lynn Margulis and Dorion Sagan, *Acquiring Genomes: A Theory of the Origins of Species*, Basic Books, New York, New York, 2002, pp 13–14
- 5 Ibid, p 14. As these authors write, ‘though traditionally studied within botany, lichens have always been central to concepts of symbiosis and symbiogenesis in evolutionary thought. And yet their symbiotic nature has led them to be thought of as a marginal evolutionary phenomenon’. See also, Lynn Margulis, *Symbiotic Planet: A New Look at Evolution*, The Science Masters Series [Brockman], Science writers, Amherst, Massachusetts and Basic Books, New York, 1998.
- 6 World-making as a concept and related set of terms now traverses multiple intersecting literatures. I am specifically drawing on a rich vein of feminist technoscience work that engages with this area, including Donna Haraway, *When Species Meet*, University of Minnesota Press, Minneapolis, 2008; Karen Barad, *Meeting the Universe Halfway: Quantum Physics and the Entanglement of Matter and Meaning*, Duke University Press, Durham, North Carolina, 2007; Isabelle Stengers, *Thinking with Whitehead: A Free and Wild Creation of Concepts* [2002], Michael Chase, trans, Harvard University Press, Cambridge, 2011; and Tsing, *The Mushroom at the End of the World*, op cit. See also Jennifer Gabrys, *Program Earth: Environmental Sensing Technology and the Making of a Computational Planet*, University of Minnesota Press, Minneapolis, 2016.
- 7 Tsing, *The Mushroom at the End of the World*, op cit, p 21
- 8 Ibid, p 22
- 9 Rob Nixon, *Slow Violence and the Environmentalism of the Poor*, Harvard University Press, Cambridge, 2011

particular worlds are formed through indications of environmental pollution. Bioindication as a process in part then reorientates environmental sensing towards engagements that are less focussed on singular entities as they are influenced by pollutants, and more towards the sprawling affiliations that are worked and reworked through environmental pollutants. Environmental pollution as a ‘conflict’ in this way is expressed not merely through exceeding acceptable pollution levels or challenges made to polluters, but also through the transformations of environmental health, ecologies, diversity and more that occur when pollution transforms organisms and their environments over time (and as a register of ‘slow violence’).⁹

Bioindication signals the ways in which there are multiple modalities for ‘taking measure’ of environments, which could in turn generate alternative and speculative engagements with pollution. In this register of reworking environmental conflict and environmental sensing, I ask: what does it mean to sense environments together with other organisms? What environmental inhabitations – and conflicts – are expressed with and through lichens? And how could these fungal-vegetal modes of sensing environments go beyond representational modes of politics, to more ecological and generative encounters with environmental politics and worlds in the making? This ‘going beyond’ representation points toward postcolonial debates about representation that unfold in this special issue, while also engaging with the literature on world-making. It is also part of the gardening and gardens that inform this article: how are worlds worked and reworked, not exclusively as human endeavours, but as the making and remaking of environmental subjects and relations?

In order to examine these questions, I first look at the bioindicator qualities of lichens in relation to environmental pollution, and consider how the somewhat unruly characteristics of this organism, with respect to taxonomic classifications, bring ecological communities into sharper focus. Processes of sensing pollution through organisms not only rework the boundaries of these organisms, they also amplify engagements with pollution to include questions of measurable values at any given time, addressing the ongoing and accumulative effects of pollution in lived environments. Such a shift in focus might also challenge the ways in which pollution as an environmental conflict is experienced and addressed.

Following on from this inquiry into how lichen-based bioindication generates particular registers for sensing environments, I consider how the spread and distribution of lichens demonstrates situated changes in environments both as pollution becomes evident in its accumulation and in its anticipated future effects. Much attention to environmental pollution evades issues of accumulation and change over time, focusing instead on abstracted indicators or technological fixes that are seemingly removed from the pollution-based conflicts that inform lived experiences. Lichens’ bioindicative modes of sensing expand the registers of environmental sensing to include these extended and relational effects of environmental change by demonstrating how organisms and ecologies transform through pollution. By extending the bioindicator garden with which I opened this article I consider how a *speculative* bioindicator garden – unfolding from a lichen point of view – could generate different approaches to environmental sensing by engaging with ecological



Lichens at the Kilipsjärvi Biological Field Station, 2011, documented during an art-science residency hosted by the Finnish Society of Bioart, photo: Jennifer Gabrys

relationality and organismal contributions to environmental-political problems. This speculative bioindicator garden is developed in relation to prior fieldwork and practice in the European Arctic, as well as fieldwork and forthcoming practice, on the topic of environmental sensing.¹⁰

In addressing questions about bioindication as a means to engage with the conflict of environmental pollution, I develop a speculative approach to creative practice, both as a propositional way of addressing how to work with and through bioindicative modes of sensing, and as a method by which to engage with the modalities of creative practice that could be designated as ‘an experimental art’, following Stengers, which involves ‘reclaiming as the transformation of experience’. Such practices of experimentation can be applied across arts and sciences, as they search for responses to the ‘intrusion of Gaia’ in this time of planetary distress.¹¹

This speculative approach further attempts to sketch out new types of ‘collective potential’, following Simondon, which could be generated through these different affiliations and ways of parsing environments.¹² These speculative sensing processes and relations could also give rise to speculative citizens and modes of citizenship that take more ecological views of citizenship in order to remake the designations of, and engagements with, environmental conflicts and politics. An environmental citizen, in this view, would be less a responsible consumer-subject amenable to behaviour change, and more an environmental entity or bundle of entities. In this way, Kim TallBear points to the need to indigenise fields such as science studies and animal studies, since not only are human subjects often poor in environment within these fields, but also the organisms that they would recognise are often all too familiar. Drawing on American Indian metaphysics, TallBear seeks to ‘extend the range of nonhuman beings with which we can be in relation’ to engage with multiple entities and forces that inform the ecologies we inhabit, and the environmental subjects that we become.¹³ If, as Jennifer Wenzel writes on Frantz Fanon’s *Wretched of the Earth*, ‘decolonization demands not only a new humanity and humanism but also a new materialism and political ecology: a shift in the valuation and disposition of nature’,¹⁴ then here TallBear points to the ways in which indigenising environmental subjects can be a practice for attending to earthly relations as a way to realise new political and social engagements. Environmental conflict, in this sense, can register as much and even more so in and through the more-than-human entities with which humans are in relation. Speculative environmental citizenship is an attempt to rethink the subject through these relations. Lichens are one group of organisms that can draw attention to these environmental attachments and formations of subjects through the signalling of pollution.

Bioindicators and Bioindicating

Bioindication is a process by which environmental pollution registers in the bodies, inhabitations and relations of organisms. These organisms in one way or another express physiological or other observable changes that can indicate the accumulation or duration of pollution events – or even possible recovery from pollution events. The monitoring

10 See Jennifer Gabrys, ‘Ecological Observatories: Fluctuating Sites and Sensing Subjects’, in Laura Beloff, Erich Berger and Terike Haapoja, eds, *Field_Notes: Field and Laboratory as Sites for Art & Science Practices*, Finnish Society of Bioart, Helsinki, 2013, pp 178–187; and Citizen Sense, <http://www.citizensense.net>

11 Isabelle Stengers, ‘Autonomy and the Intrusion of Gaia’, *South Atlantic Quarterly*, vol 116, no 2, 2017, pp 381–400

12 Gilbert Simondon, *L’individuation à la lumière des notions de forme et d’information*, Collection Krisis, Éditions Jérôme Millon, Grenoble, 2005; Muriel Combes, *Gilbert Simondon and the Philosophy of the Transindividual*, Thomas LaMarre, trans, MIT Press, Cambridge, Mass, 2013, 1999

13 Kim TallBear, ‘Why Interspecies Thinking Needs Indigenous Standpoints’, *Theorizing the Contemporary*, *Cultural Anthropology* website, 24 April 2011, <https://culanth.org/fieldsights/260-why-interspecies-thinking-needs-indigenous-standpoints>

14 Jennifer Wenzel, ‘Reading Fanon Reading Nature’, in Anna Bernard, Ziad Elmarsafy, Stuart Murray, eds, *What Postcolonial Theory Doesn’t Say*, Series: Routledge Research in Postcolonial Literatures, Routledge, Abingdon, Oxfordshire, 2015, p 189



Lichens at the Kilipsjärvi Biological Field Station, 2011, documented during an art-science residency hosted by the Finnish Society of Bioart, photo: Jennifer Gabrys

and measuring of environmental pollution does not rely on instruments, in the usual sense, to capture quantitative values of gases in the atmosphere. Instead, organisms are gauges in a very different sense of indicating through their form and growth patterns the spread and accumulation of pollution in particular sites, as well as the approximate levels of pollutants, without directly measuring pollution as a quantitative value.¹⁵ Indeed, one particular North Atlantic Treaty Organisation (NATO) document indicates that lichens as bioindicators can provide a 'cheap method' for estimating elevated levels of air pollutants such as sulphur dioxide in countries including 'China, India, Ukraine, Czech Republic, parts of Indonesia, Russia', where there is likely to be an absence of instrumented and quantitative modes of monitoring.¹⁶ In this way lichens can be broadly indicative of industrial and military processes that could be taking place – explaining the NATO interest in this method of monitoring.

Often referred to as a 'qualitative' mode of monitoring environments, bioindication captures the ways in which environmental processes such as pollution transform particular organisms, in a nonlinear and yet accumulative way, and demonstrates how those organisms are expressive of these shifts. Bioindicators are 'indicator species' that express certain 'qualities' of ecosystems, especially in relation to pollution. Biomonitoring can be undertaken by studying organisms in their environments, or through transplant studies, where organisms are brought into environments in order to understand how they react to pollution.¹⁷ Indicators are often read in relation to an 'index', which establishes a set of protocols for reading and describing the environmental condition that the indicator is expressing. The qualitative aspects of bioindication are, on the one hand, recognised as a unique aspect of this mode of monitoring, and yet, on the other, are seen to align with quantitative modes of monitoring if undertaken with sufficient systematicity through indices.¹⁸

Environments and environmental pollutions activate the characteristics of bioindicative organisms in specific ways. Lichens are particularly sensitive bioindicators of air pollution because they lack roots, and often colonise relatively rocky and inhospitable substrates, from stone to asbestos roof tiles; they absorb the majority of their nutrients from air and water across their surface, which lacks a protective cuticle layer for filtering out gases and liquids. Surviving on air, water, dust and sunlight, and often living on other organisms (such as trees) as epiphytes, some lichens are even able to float relatively free from substrates. While they are distinct from plants, as bioindicators they often signal pollution effects that could similarly harm plants.

Initial documented observations of lichens shifting in growth patterns due to industry can be found in Erasmus Darwin's text, *The Botanic Garden* (circa 1790), where he noticed altered lichen patterns next to copper mines and smelting plants.¹⁹ In many ways, lichens are an indicator not just of pollution, but also of events such as the Industrial Revolution. Subsequent studies have noted that lichens are absent – or only distinct species are present – in the vicinity of lead mines, copper smelters fertiliser plants, strip mines and factories, where a close relationship is often observed between particular types of (polluting) industry and lichens. Lichens are bioindicators of the effects of these industries, responding to heavy metals in both air and soil, as well as to toxic atmospheric gases.²⁰

15 Chantal van Haluwyn and C M van Herk, 'Bioindication: The Community Approach', in Nimis et al, *Monitoring with Lichens*, op cit, p 44

16 Ibid, p 57

17 Marco Ferretti and Walter Erhardt, 'Key Issues in Designing Biomonitoring Programmes: Monitoring Scenarios, Sampling Strategies and Quality Assurance', in Nimis et al, eds, *Monitoring with Lichens*, op cit, p 112

18 van Haluwyn and van Herk, 'Bioindication', op cit, pp 56–58

19 Erasmus Darwin, *The Botanic Garden: A Poem, In Two Parts. Part I: Containing the Economy of Vegetation; Part II: The Loves of the Plants; With Philosophical Notes*, J Johnson, London, 1789–1791

20 van Haluwyn and van Herk, 'Bioindication', op cit, p 48



Lichens as Ecological Microcosms, at the Kilipsjärvi Biological Field Station, 2011, hosted by the Finnish Society of Bioart, documented during an art-science residency, photo: Jennifer Gabrys

Lichens were first systematically observed as bioindicators of air pollution in the Jardin du Luxembourg in Paris in studies conducted by William Nylander in 1866. Nylander proposed that lichens could be used as ‘hygrometers’ to signal levels of air pollution.²¹ Multiple indices now exist for assessing the bioindicative characteristics of lichens and what they indicate.²² The indices include the designation of ‘zones’ where lichens might be normal, struggling or absent (a lichen desert); as well as a ten-point scale of lichen sensitivity that identifies a gradient for the presence of sensitive leafy lichens to the presence only of hardy crusty lichens, or the absence of lichens, which also maps onto approximate levels of sulphur dioxide.²³ In addition to these indices, there are seven ‘clean air lichens’ that the Natural History Museum of London has identified as also providing a relatively good indication of the quality of air in London environments. Citizen scientists can identify and map these clean air lichens in order to contribute to ongoing documentation not just of air quality in London, but also of the effects of air quality on urban ecologies.²⁴

Lichens can serve as bioindicators for multiple other pollutants, from heavy metals in the form of lead, chromium, zinc and copper, to toxic gases including fluorides, and carcinogens such as PCBs, as well as radioactive contamination.²⁵ Different lichens grow at distinct rates and have specific responses to pollutants, and thus can also be used as indices to evaluate the likely severity of different types of pollutants as they have accumulated over time. Since lichens grow at relatively slow rates and yet can live for centuries, their bioindicative qualities include the ability to temporally mark events, such as when the UK Clean Air Act was introduced in 1956. The subsequent beneficial effects of this Act on air quality and environments can be registered in part through the return and flourishing of certain (but not all) lichens.²⁶

What bioindication highlights is how pollution – as an environmental conflict – becomes entangled with the specific material transformations and incorporations of organisms in their habitats.²⁷ Potentially providing a more dynamic, ecological and complex understanding of pollution, bioindication can map onto numerical indices of pollution, but it also becomes a way to understand the possible ‘health’, ‘vitality’ and even ‘luxuriance’ of organisms.²⁸ Here, pollution is less about a numerical value, and more about an ongoing set of transformative effects that even rematerialise and remake environments. Different ways of ‘taking measure’ and of attending to the expressions of pollution through organisms can also reorientate attention from isolated variables to experiences and relations, thereby remaking what counts as an environmental problem or environmental conflict through an attention to the relations that pollution also affects.²⁹ Bioindication requires homing in on the effects of exposure over time, not necessarily as a measure of pollutants in the air at any given time, but rather as durational materialisations of pollution that affect wider ecologies.

Ecological Microcosms and ‘Phytosociological Associations’

While to some degree bioindication might signal the adherence to an index as a systematic way of reading environmental change, in other respects it

21 William Nylander, ‘Les lichens du Jardin de Luxembourg’, *Bulletin de la Société Botanique de France*, vol 13, 1866, pp 364–372

22 Ferretti and Erhardt, ‘Key Issues in Designing Biomonitoring Programmes’, op cit, p 118

23 Ferry et al, *Air Pollution and Lichens*, op cit

24 The ‘clean air lichens’ used for London air quality monitoring include: *Evernia prunastri*, *Flavoparmelia caperata*, *Physcia tenella*, *Hypogymnia physodes*, *Melanelixia subaurifera*, *Xanthoria polycarpa*, and *Xanthoria parietina*. See OPAL Air Survey, <https://www.opalexplornature.org/airsurvey>

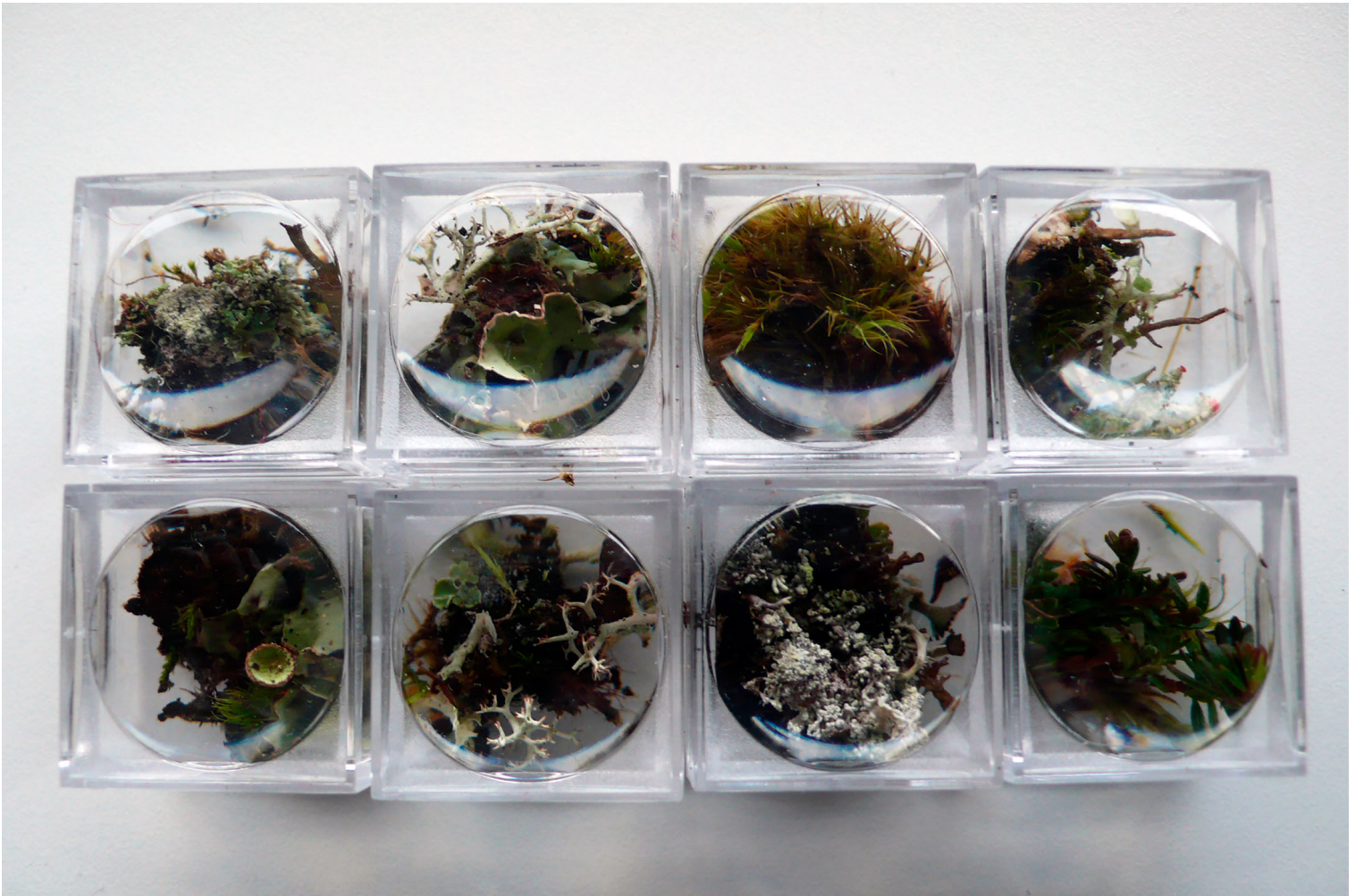
25 Richardson, *Pollution Monitoring with Lichens*, op cit

26 Ibid

27 For a more extensive discussion of ‘incorporation’ undertaken by organisms, see Gabrys, ‘Becoming Urban’, op cit.

28 van Haluwyn and van Herk, ‘Bioindication’, op cit, p 40

29 Gabrys, *Program Earth*, op cit



Lichen and Moss Magnified Collection, at the Kilipsjärvi Biological Field Station, 2011, hosted by the Finnish Society of Bioart, documented during an art-science residency, photo: Jennifer Gabrys

- 30 A N Whitehead, *Process and Reality: An Essay in Cosmology* [1929], David Ray Griffin and Donald W Sherburne, eds, Gifford Lectures Delivered in the University of Edinburgh during the Session 1927–28, Free Press, New York, 1985; Stengers, *Thinking with Whitehead*, op cit
- 31 For an extended discussion, see Jennifer Gabrys, ‘Citizen Sensing, Air Pollution and Fracking: From “Caring about Your Air” to Speculative Practices of Evidencing Harm’, *The Sociological Review*, vol 65, issue 2, supplement, 2017, pp 172–192, <https://doi.org/10.1177/0081176917710421>.
- 32 Combes, Gilbert *Simondon*, op cit, p 4
- 33 Simondon, *L’individuation à la lumière*, op cit; Combes, Gilbert *Simondon*, op cit
- 34 Scott F Gilbert, Jan Sapp and Alfred I Tauber, ‘A Symbiotic View of Life: We Have Never Been Individuals’, *The Quarterly Review of Biology*, vol 87, no 4, December 2012, p 336
- 35 Donna Haraway begins her chapter, ‘Tentacular Thinking: Anthropocene, Capitalocene, Chthulucene’ with the epigraph, ‘We Are All Lichens Now’. See Haraway, *Staying with the Trouble: Making Kin in the Chthulucene*, Series: Experimental Futures, Duke University Press, Durham, NC, 2016, pp 30–57.
- 36 Lynn Margulis and Karlene V Schwartz, *Five Kingdoms: An Illustrated Guide to the Phyla of Life on Earth*, W H Freeman and Company, New York, 1997, p 364; Margulis and Sagan, *Acquiring Genomes*, op cit, p 13
- 37 Toby Spribille et al, ‘Basidiomycete Yeasts in the Cortex of Ascomycete Macrolichens’, *Science* 21 July 2016, see doi 10.1126/science.aaf8287, accessed 2016

gives rise to more speculative engagements. By speculative, I am referring to the distributed capacity of organisms and environments to generate new modes of encounter together with new propositions for ways of being. In this sense of the speculative, I am drawing on Whitehead, as well as Stengers’s reading of his work, who together point to the ways in which subjects are always tied to superjects – or environments of sense and relevance.³⁰ As I have discussed in related work on this topic, environmental monitoring – and the practices and entities involved in monitoring – can make environmental problems and conflicts matter, and in particular ways. The measuring of air quality by monitors for regulation, for instance, generates a particular way of taking account of environments; while an ongoing record of environmental health effects points to the lived effects of pollution over time as it accumulates in bodies.³¹ While speculative modes of environmental monitoring might on the one hand pertain to the new types of evidence and relevance that different types of environmental sensing create, on the other hand they address the different entities and collectives that are individuated through particular ways of taking account of environmental conflicts.³² Individuation, as Gilbert Simondon has developed the concept, refers to the ways in which entities are *in-formed* in relation to each other and to their milieu.³³ Subjects, relations and milieus all have the potential to shift and transform, and are not pre-given, although they can be in-formed by sedimentations and inheritances. This is also to say that what constitutes ‘human’ is not a fixed entity, and can shift in relation to different articulations, relations and milieus.

Here and in relation to lichens and bioindication, speculation also extends to the shifting contours of what counts as an organism, how ecological communities are transformed and affected by pollution over time, and how as a form of environmental conflict pollution is registered through distributed entities and environments. Research focusing on the symbiotic characteristics of lichens suggests that even the notion of an organism as an individual is fraught with problems, and that a more ecological notion of subjects better characterises how entities are bound up with multiple other organisms and environments. In this way, one group of researchers working on symbiosis has suggested not only that ‘we have never been individuals’, but also that ‘we are all lichens’.³⁴ Drawing on this approach to the distributed subject-ness of lichens and by extension all entities, Donna Haraway suggests that lichens can provide a way to rethink designated events such as the Anthropocene to be a less human-centric rendering of a transforming planet.³⁵ A move towards remaking subjects as environmental subjects then has consequences for how we account for and act on our political entanglements and earthly inhabitations.

Although there are approximately 13,500 ‘formally described’ lichen species (and an anticipated 25,000 actual lichens),³⁶ the contours of lichens as distinct ‘species’ are also shifting, since they are organisms made up of a fungus, alga or cyanobacteria, and even a third entity in the form of a yeast.³⁷ The fungal partner provides the structure and protection for the lichen, while the alga produces food in the form of chlorophyll that the fungus taps for sustenance. As composite organisms and relationships situated across multiple kingdoms, lichens are further entangled with vegetation since they both live on vegetation and make



Reindeer Grazing for Lichens at the Kilipsjärvi Biological Field Station, 2011, documented during an art-science residency hosted by the Finnish Society of Bioart, photo: Jennifer Gabrys

substrates available to vegetation by breaking down and weathering rocks and soils. In as much as lichens are distinct organisms, they are also ecological microcosms, reworking the boundaries of species as distinct entities and transforming them into ecological communities and relations that are in flux in response to environmental events. In such a way, environmental subjects are then neither removed from their earthly conditions nor from those processes that continue to shape them through their relations. Such a rendering of a subject is far from the universal and static figure that humanism has propagated.

The shifting contours of organisms and environments indicate the ways in which processes of individuation occur in and through eco-political registers, where what comes to count as an entity is that which is also sustained by other entities and environments. In other words, when other organisms are bioindicating, we could ask: is this process merely about understanding the organismal effects of particular environmental events,

or does it shift the ways in which environmental engagements unfold across multiple entities? By working with and through environmental pollutants, lichens are on multiple levels indicating the shifting inhabitations and conjugations of ecological life.

Lichens, for instance, provide sustenance for reindeer and by extension indigenous people in the Arctic, an environment where considerable changes are underway due to resource extraction in the form of mining and logging. The disruption of lichens captures the emergence of environmental justice issues, as well as the framing of environmental problems. In Kilpisjärvi, a location in the Finnish Arctic, a debate has unfolded over time about the land use conflicts which encompass biologists, reindeer herders, lichens, conservation areas, and rare flowers. Because biologists are keen to study rare flowers in conservation areas, they have come into conflict with reindeer herders who disagree with the restrictions of conservation areas that prevent reindeer grazing. Yet this problem, in part, is formed by increasing pressures on all land use, which mean that fewer and fewer grazing areas are available that have an abundance of lichens. Extractive industries, recreational housing, as well as conservation areas and biological field stations, contribute to the shifting landscape of lichens and its relations to other entities.³⁸

In this way, Tsing has discussed the ways in which organisms can be productive of forms of 'more-than-human sociality'.³⁹ A forest, for instance, encompasses not just the bioindicating characteristics of individual organisms, but also materialises and sustains the more-than-human social worlds that are made through these organisms. Such an encounter with more-than-human sociality suggests that bioindication could then involve a 'community approach' to monitoring. This is a project that has been variously proposed and undertaken within scientific practices as well, 'where indicator values are not assigned to single species or communities, but to groups of species with similar ecological requirements'.⁴⁰ The shared 'phytosociological associations' and 'multidimensional relationships' of indicator organisms are an area of speculative possibility, which has hitherto been largely overlooked.⁴¹ While scientific texts might put this omission down to the lack of a systematic methodology, fledgling methods have been developed that address, for instance, indication of air pollution through phytosociological relationships such as epiphytic lichens that grow on trees, and are affected by the acidity and toxicity, as well as availability of light and water, and abundance of nitrogen, as an indication of the composition of environments. In other words, monitoring bioindicating lichens within ecological communities can serve as an indication of forest health, for instance, since 'the replacement of a community by another one can be considered a clear indicator of environmental change'.⁴²

Engaging with bioindication in a speculative register might then involve speculating about relationships across organisms, the composition of ecological communities, and the expressive effects of their inhabitations. Modes of sensing are also ways of characterising environmental problems. If, as Isabelle Stengers suggests, 'practice imposes upon its participants certain risks and challenges that create the value of their activity',⁴³ then how might speculative practices be generated that take into account and rework the environmental relationships and conflicts encountered through environmental pollution, particularly as it accumulates and is experienced in environments over time?

38 'Would You Like to Taste Environmental Conflict?', <http://www.ymparisto.konfliktisovittelu.fi/en>; and Mediate North, 'Malla, A Rocky Hill', at <https://mediate.north.wordpress.com/2015/09/01/malla-a-rocky-hill>, accessed 20 September 2017

39 Tsing, *The Mushroom at the End of the World*, op cit, p 180

40 van Haluwyn and van Herk, 'Bioindication', op cit, p 48

41 Ibid, p 50

42 Ibid, p 53

43 Isabelle Stengers, *Cosmopolitics I* [1997], Robert Bononno, trans, University of Minnesota Press, Minneapolis, 2010, p 55

A Speculative Bioindicator Garden

One way to pursue this proposition into and for a more-than-human sociality that addresses environmental pollution differently might then be to return to the bioindicator garden discussed at the beginning of this article. The NASA ozone bioindicator garden offers up a series of instructions for cultivating plants to indicate their ozone stress to the observant scientist-in-training. And yet, it might also be possible to propose a speculative bioindicator garden that creates conditions for monitoring and bioindicating from a lichen point of view. I have previously developed work in relation to a ‘moss-eye view’ through a walk in London that attended to the urban exchanges and incorporations that occur ‘under the radar’ through this overlooked set of organisms.⁴⁴ Here, I extend this approach – that works across creative practice, environmental science and political engagement – to consider how these inverted modes of environmental sensing might open up other approaches to environmental conflict by encountering pollution from the point of view of other organisms.

The notion of engaging with organisms through their ‘point of view’ is one that now populates a wide range of environmental theory and practice. In her work on matsutake mushrooms, Tsing considers how to take into account perspectives from fungal points of view, which might recast encounters with forests, where multiple overlooked ‘participants’ begin to have more marked roles in constituting ‘social relations with other beings’.⁴⁵ Similarly, Christelle Gramaglia and Delaine Sampaio da Silva suggest that ‘sentinel organisms’ provide very particular accounts of areas – of a river as a ‘collective entity’, for instance – through abilities to signal pollution.⁴⁶ This, in part, is a process of attending to the communicative exchanges and pathways of other organisms, where sentience, intelligence and even ‘meaning’ unfold through the sense-making operations of multiple organisms.⁴⁷ Yet bioindication through these multiplying points of view also demonstrates how ‘nature’ is not a stable referent, but rather is a realm where diversity multiplies toward a ‘multinaturalism’, where, as Eduardo Viveiros de Castro suggests, organisms might also be approached as persons and as having perspectives as persons.⁴⁸ Rather than indicating how a stable nature might be sensed, or bioindicated, by other organisms, bioindication instead could be expressive of multiple environmental inhabitations that unfold from the perspective of every entity. A lichen point of view, in this case, would take seriously the ways in which this environmental subject is taking account of, and forming experiences of, its world. Such an approach not only expands an approach to environmental subjects, it also suggests that we could re-engage with the worlds that are formed with and through subjects. This has further consequences for how we encounter ‘the ends of the world’ as an environmental event, as well as a remaking of the worlds that we might cultivate and care for.⁴⁹

A speculative bioindicator garden from a lichen point of view would then be a much different type of garden. Less a *hortus conclusus* for containing ‘natural’ entities, this would be a garden that begins in the thick of things, unfolding through the work and connections made across organisms. As extremophiles, lichens are able to thrive on and amongst

44 Gabrys, ‘Becoming Urban’, op cit

45 Tsing, *The Mushroom at the End of the World*, op cit, p 263

46 Gramaglia and Sampaio da Silva, ‘Researching Water Quality with Non-Humans’, op cit, pp 184–185

47 Eduardo Kohn, *How Forests Think: Toward an Anthropology Beyond the Human*, University of California Press, Berkeley and Los Angeles, California, 2013

48 Eduardo Viveiros de Castro, *Cannibal Metaphysics: For a Post-Structuralist Anthropology* [2009], Peter Skafish, ed and trans, Univocal Publishing, Minneapolis, 2014

49 Déborah Danowski and Eduardo Viveiros de Castro, *The Ends of the World* [2014], Rodrigo Nunes, trans, Polity, 2017

almost any substrate, and, as such, could establish their garden on glass or rubber, concrete or limestone, granite or tree trunks. Given a surface, a certain aspect and the collection of bits of nutrient-laden dust and condensing fog, dew or rain, lichens can begin the work of colonising, stabilising and even breaking down their substrates for other organisms. The 'siting' for this speculative garden could then begin less as a tidy plot, and more through a chance encounter that engenders the beginning of a bioindicative engagement: signalling that the site chosen is in fact a vector for some environmental events and resources, and not others.

A further point of complication with this speculative bioindicator garden is that lichens are notoriously difficult for humans to cultivate. The spark of growth would occur through more-than-human alignments. Furrows cannot be ploughed, seeds cannot be planted, and crops cannot be tended, since the very multi-organismal and symbiotic characteristics of lichen (many of which are not entirely well understood by humans) again require that particular environmental conditions be in place both for lichens to take hold, and to continue over extended durations.

This speculative bioindicator garden is, from its outset, already defying the instructional approach to cultivation that the NASA garden so neatly offered. Instead, here is a garden that requires waiting for things to happen, in excess of human intentionality, as indications of the environmental conditions that lichens favour. Already, the establishment of this garden requires not a blank slate from which bioindication will spring up, but rather an established set of conditions in which lichens will be able to prosper. Such conditions would likely require a relative absence of air and water pollution, the presence of other vegetation including trees and forests, the existence of numerous invertebrates that make their homes in lichens and even grow lichens on their backs (as is the case with some weevils, for whom this method provides camouflage), and still other organisms that would distribute lichen matter for reproduction.

One could encounter such a lichen garden in-the-making in the Arctic, for instance, where these organisms are not only pervasive but are also key to the ecologies found there. At the biological field station in Kilpisjärvi, Finland, I found through numerous lichen-based encounters that these organisms were populating granite and shrubs, while also in considerable decline in the form of reindeer lichen due to shifts in land use that restricted reindeer grazing to limited areas, thereby intensifying the impacts on lichens in these zones. Some lichens, the hardy crustose for instance, might then prosper in this speculative garden, clinging to granite boulders, while others continue to decline perhaps for reasons related to air pollution and climate change, but also due to the expansion of resource extraction in the Arctic and its subsequent effects on grazing lands.

As temperatures continue to become warmer due to climate change, lichens that have lived in Lapland for nearly 10,000 years (where the oldest living lichens can be found), might also begin to shift, decline or otherwise disappear as new material-environmental matrices are established.⁵⁰ Other lichens in this speculative garden might flourish or even become new accumulators of toxic events, similar to the accumulation of radionuclides in the food web through lichens, reindeer and indigenous human populations in the Arctic as a result of nuclear testing in the 1950s

50 Oliver Gilbert, *Lichens*, Collins New Naturalist Library, HarperCollins Publishers, London, 2000, pp 88–89

and 1960s.⁵¹ Because substances ‘taken up by lichens may subsequently reach other components of the surrounding biosphere via litterfall, leaching, bacterial incorporation, or non-cellular particle formation’,⁵² lichens in the context of rapid twenty-first century environmental change become pivotal transformers and transducers of pollutants and materials within environments. Yet exactly how lichens cycle and recycle these substances through environments, to other organisms, for how long, and with what effects, remains a further area of speculation.

This speculative bioindicator garden, which begins in the middle of things and resists the usual practices of cultivation, further indicates how the connections made across organisms and environments are continually being remade through the accumulation of pollutants. If this speculative bioindicator garden offers up a proposition for how to engage with the bioindicative capacities of lichens, it might then suggest that this garden is productive of other counter-practices of cultivation that rework relations, entities and environments through shared inhabitations with – and even against – pollution. This is a mode of indication that does not merely ‘signal’ that an event has occurred or is occurring, but rather that materialises the relations and processes that are at stake when pollution accumulates, and when environments change due to extractive or damaging industries.

Bioindication, as materialised through lichens in their ecological microcosms, can instigate a process of collaborative sensing that might also suggest more ecological ways of encountering citizenship. This is a speculative citizenship that, drawing on Tsing, attempts to ‘make common cause with other living beings’ by engaging with more-than-human sensing, listening and noticing as modes of ‘political work’.⁵³ A bioindicator garden in this respect is as much a process of cultivating and decolonising sensing, as it is a working and reworking of earthly territories and relations. Such multi-organismal sensing, which bioindication expresses, reworks the ways in which environments are sensed, and the diversity of perspectives from which this sensing unfolds. It also propels, in a speculative register, possibilities for more expansive environmental politics that account for relations, and that tune in to the world-making projects of other organisms.

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51 T H Nash, ‘Nutrients, Elemental Accumulation, and Mineral Cycling’, in Nash, ed, *Lichen Biology*, op cit, p 234

52 M R D Seaward, ‘Environmental Role of Lichens’, in *Lichen Biology*, ibid, p 288

53 Tsing, *The Mushroom at the End of the World*, op cit, p 254

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