Designing for Cohabitation: Naturecultures, Hybrids, and Decentering the Human in Design

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ABSTRACT
Recent research in urban informatics has presented the city as both a complex technological center and a diverse cultural, social, and political entity. However, there has been little research into the changing role that nature plays in urban space, particularly when it comes to understanding how animals have adapted to life in technological and networked cities. In the wake of urbanization, new kinds of cohabitation, including increased interactions between humans and animals, has resulted in new challenges for those working in urban informatics. We leverage key concepts in the Anthropocene—naturecultures, hybrids, and decentering the human in design—to unpack the entanglements of animal-human-computer interaction in two design cases: The Big Cat Behavioral Tracking Initiative and The Phenology Clock. We contribute to urban informatics and HCI research by reflecting on ways in which design can promote new forms of cohabitation and support a broader conception of the city that sees animals as an essential part of the urban landscape.

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Animal-Computer Interaction; Urban Informatics; Cohabitation; Posthumanism; Anthropocene

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INTRODUCTION
Cities are often described as technological hubs, full of shining skyscrapers, dense networks, flows of people, and home to a diverse range of cultural, social, and political structures. Missing from such a conception of the city are elements such as plants, trees, mountains, water, and animals—the natural world—which has long been conceived of as something relegated to designated spaces such as parks, or more broadly as something "out there" or apart from urban space. However, given the rapid course of urbanization, cities and natural spaces have become geographically entangled—not only do we see more common animals such as our domestic pets, birds, and squirrels in our neighborhoods, but as cities around the world continue to encroach on animal habitats, there is an increasing chance that we may encounter cougars, foxes, monkeys, wolves, or what we might call urban wild things [30]. It is likely that interactions between humans, animals, and technologies will only grow in frequency and complexity in the future, and we see a need for those working in HCI to identify both the ways in which urban animals may be affected by design, as well as the ways these animals may inform interaction design.

Urban informatics research has explored not only the physical and technical characteristics of cities [25, 61] but also the increasingly complex social and cultural aspects [59, 11, 34] of urban spaces. Additionally, recent research in HCI has been conducted on such things as the influence of climate patterns in everyday urban life [60], growing food in the city [41], and even an asocial hiking app [51], all of which have implications for how we think about the relationship between nature and cities. However, there has been little research on the role that animals play in urban space.

As we enter the Anthropocene—the proposed geological epoch in which we now find ourselves—we see new avenues with which we can develop more robust theoretical foundations and actionable design practices regarding the role of animals in cities. Not only does the Anthropocene bring to the fore pressing issues such as climate change and mass extinction, but the Anthropocene, as part of a posthuman discourse, also compels a vision of the world that includes the so-called *end of nature* [52]. Consequently, we see a need to develop new urban design processes that are more equitable for all species; if we are to survive in the conditions of this new epoch, adapting perspectives that decenter the human from design practice will promote new conceptions of cohabitation that help both humans and nonhumans thrive in the future. What is at stake here is not only animal welfare or simply an ethical obligation to support urban wild things, but rather we are presented with an opportunity to build interactive systems that are more sensitive to the environmental and cultural capacities of different cities around the world.

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We situate our work in the intersection of urban informatics and animal-computer interaction to make the following contributions: First, we introduce scientific and cultural research on the Anthropocene and motivate the uptakes for HCI researchers and designers concerned with cities and animal-centered designs. Second, we present a critical analysis of two design cases to explore the productive role the Anthropocene discourse plays in urban informatics/ACI research; in particular, concepts such as *naturecultures, hybrids, and decentering the human* surface issues surrounding the design of behavioral tracking technologies for animals and sensitize us to our role as inhabitants of and actors in technologized cities with other creatures. And finally, we reflect on design and HCI in the Anthropocene, seeing roles for citizen science, everyday design, and a revision of concepts of the city, culture, and design itself.

ANIMAL-COMPUTER INTERACTION

Animals, though not a prominent part of the design discourse, have recently emerged as an important player within HCI. Animal-computer interaction (ACI) is defined as the explicit and systematic application of design principles that place the animal at the center of an iterative development process as a legitimate user and design contributor [43]. ACI researcher Clara Mancini has called for interaction designers to be more explicit in considering animals in their work. She writes, "The negative effects of this lack of animal perspective become obvious when, for example, the behavior and welfare of seals fitted with bio-logging tags and satellite transmitters are significantly affected and data gathered during costly conservation studies risks invalidation, or when cows who do not engage with milking systems are culled and farmers suffer capital losses. But risk mitigation aside, what about the things we could gain from a shift in perspective? What would it allow us to learn about and achieve with interactive technology? How would it influence our reflection on usability, adaptation, appropriation, methodology, and ethics, to name but a few aspects? [44]" In the Anthropocene, these questions are particularly relevant in urban informatics because more than fifty percent of the population now live in cities. Global cities are increasingly entangled human-nonhuman spaces that open up the possibilities for increased interactions among diverse groupings of species. This trend indicates a need to consider alternative understandings of cohabitation and to develop ways in which those working in urban informatics might adopt and promote practices that support the goals of ACI.

Interaction design related to animals generally falls into several key categories: 1) Designing *for* animals 2) Designing technology to *mimic* animal behavior 3) Designing tools to *study* animals 4) Designing animal-technology interactions *for humans.* Designing *for* animals accounts for devices that are created specifically for animal use, such as service dogs who need light switches and door handles that are more paw-friendly. Designing technology to *mimic* animal behavior has become a popular aim within the field of robotics. For example, a team at Harvard has recently developed a robotic bee that may aid in worldwide pollination after the death of millions of bees over the past decade [54]. Designing tools to *study* animals accounts largely for scientific and cultural projects that aim to capture animal behavior. Designing animal-technology interactions that primarily *benefit* humans accounts for a large part of interaction design work related to animals, especially in such fields as farming and medicine. However, we also see novel uses of interaction design, such as HeroRat, a project that trains and utilizes rats to detect land mines that would otherwise pose a danger [1].

In urban informatics, we see significant overlaps in the potential aims of ACI because designing *for* animals in cities is likely benefit humans as well. However, as [44] observes, "The animal perspective has seldom informed the design of animal computing applications, whose development has so far been driven by academic disciplines other than computer science or by other industrial sectors. The design of these technologies remains fundamentally human-centered, and the study of how they are adopted by or affect their users remains fundamentally outside the remit of user-computer interaction research." There are promising opportunities for designers to engage with animal perspectives, and the practical aims of developing technological interventions in urban space require a theoretical foundation upon which to build such design practices. The idea of the Anthropocene, which has not been extensively adopted in HCI, provides a productive resource because it readily suggests new ways of thinking about global change that offer generative possibilities to support the aims and processes of those working in urban informatics.

THE END OF NATURE

The Anthropocene, originally conceived of as a geological epoch in which humans have irreparably changed the Earth, has become a prominent concept in a variety of fields, from the sciences to the humanities [17]. Anthropologist Xuemei Bai and colleagues define the Anthropocene as signifying, "1) the novelty of the time period in which humans find themselves as a result of this [irreparable change]; 2) the novel challenges, opportunities, and uncertainties that awareness of this global potency brings; and 3) the new perspectives required to deal with them [3]." This conception of the Anthropocene suggests a need for those in urban informatics to interrogate the foundations and implications of global change, so that we are better positioned to design systems that support cohabitation in urban contexts.

One of the key concepts associated with the Anthropocene is the so-called *end of nature*. What this means is not that the natural world has ceased to exist, but rather the social construction of "nature" as a concept is no longer tenable in light of human influence in the world. Environmental law professor Jedediah Purdy has captured this phenomenon,

arguing, "The natural and the artificial have merged at every scale. Climate change makes the global atmosphere, its chemistry and weather systems, into Frankenstein's monster—part natural, part made. The same is true of seas, as carbon absorption turns oceans acidic and threatens everything that lives in them. The planet's landscapes, its forests and fields, along with the species that inhabit them, are a mélange of those we have created, those we have cultivated and introduced, and those we let live… […] If Nature were a place, we could not find it. It Nature were a state of mind, we could not attain it. We are something else, and so is the world" [52]. The notion that we are designing after nature has implications in areas of critical making [53], sustainability [57], and collapse informatics [56] among others. We see broad application of these ideas across the field, but in this paper, we will focus in particular on drawing out the connections between the Anthropocene and urban informatics because urbanization is a particularly challenging design concern. In what follows, we highlight three concepts—naturecultures, hybrids, and decentering the human in design—and explore the implications for designing for cohabitation in the city.

Naturecultures

Within urban informatics, cities are often construed as entities that are apart from, or at odds with, nature, as if nature is some green (or brown or blue) space that exists miles outside of urban areas. However, city dwellers are deeply entangled with natural elements, including plant life, animals, dirt, water, and so forth. At the same time, what we tend to think of as "pristine wilderness" is hardly pristine; conserved lands are highly managed by humans. Historian William Cronon has written significantly on the problem with wilderness: "[We must] abandon the dualism that sees the tree in the garden as artificial—completely fallen and unnatural—and the tree in the wilderness as natural—completely pristine and wild. Both trees in some ultimate sense are wild; both in a practical sense now depend on our management and care. We are responsible for both, even though we can claim credit for neither [16]." In the Anthropocene, there is no place on Earth that remains "untouched" by humans; even the pollution we have projected into the air has made its way into the furthest reaches of the planet.

Rigidly distinguishing between natures and cultures poses several problems for designers. First, these foundational perspectives affect the ways in which knowledge is produced in our field; setting up research based in this dualism is unlikely to produce useful conceptions of urban space because cities cannot be separated neatly into natural and cultural elements. Naturecultures, as both a term and a concept, not only provides a useful frame with which to prevent faulty knowledge production, but it also gives us a way to talk about the interconnectedness between natural and cultural elements in an urban setting.

Second, this dualism prohibits us from seeing and understanding the entangled nature of cities because under such a divide, the individual elements of a city are seen as unattached from one another. Urban technologies are deeply embedded in these entanglements. Consider, for example, an interactive kiosk at a bus stop. This tool may provide information for people riding the bus, or for tourists who need to consult a map. But it does not stand alone with a unified function apart from the nonhuman elements of the city. The structure may provide a home for birds (or may perhaps disrupt a previous home for birds). The light from the screen may affect moths and other nocturnal creatures. The kiosk could be designed to support water collection or to allow for a plant to grow on or in it to foster a more harmonious relationship among animals, humans, and technology. There are numerous, and many yet unknown, interactions that may occur at these intersections between technology, humans, and animals. We can see this evidenced in the numerous effects that are currently being uncovered as technology makes its way outside the human world. For example, electrosmog has disrupted orientation in migratory birds [22]. Another consideration within urban informatics, informed by the Anthropocene, is the animal-technology relationship, which may or may not involve humans at all.

In writing about the concept of *natureculture* (a term coined by Donna Haraway) Science and Technology Studies (STS) researcher Joanna Latimer suggests that the term works as "a provocation for collapsing and transgressing the dominant metaphysics that dichotomizes nature and culture, and through which culture and all that is human is constituted as discontinuous with the rest of the world. As Haraway points out, nature cannot stand outside of culture, just as culture cannot stand outside of nature. This is because the meaning of nature—what we identify as natural—is not just determined by culture but is also the result of specific historical, material and political conditions of possibility. [38]." The term natureculture, then, provides us with a useful concept with which to think about design in urban informatics because a shift in thinking towards naturecultures will support a foundation for those in HCI who aim to integrate a wider range of perspectives in practice (both in generating empirical and theoretical work on the topic). By breaking away from this perceived divide between urban space and nature, we are better positioned to investigate cities, not only as technological centers, consisting of buildings, infrastructures, and networks, but as vibrant, living things, teeming with a diverse range of plant and animal life.

Hybrids

One of the perspectives that opens up with the turn to naturecultures is that of *hybridity*. Design researcher and STS scholar Laura Forlano argues that "hybridity offer[s] a way of enabling designers to think and act more critically about their responsibility to design more ethical ways of living and working in cities given socio-technical

complexity [24].” The notion of hybridity helps us to reimagine, in the words of anthropologist Jamie Lorimer, the *category* animal, in order to “recognize the multiple forms of difference it subsumes, and to take seriously the ways in which humans and animals are shaped by their interactions [40].” The implication for HCI research is that such conceptual openings help attune us better to ways that technology does and/or might mediate animal-human interactions. Additionally, hybridity has the capacity to inspire new methodological approaches in urban informatics that promote such attunement and make visible these human-nonhuman interactions.

It has been suggested that the most complex design challenges we face are those related to environmental change [33] and thus, this pathway into HCI is already beginning to happen: methods such as multispecies ethnography, first developed in cultural anthropology [36] have been taken up in HCI to investigate human-dog relationships [42]. Multispecies ethnography advocates for thinking beyond the human and aims to understand the complex ways in which different beings affect one another. Similarly, thing ethnography [23] articulates a nonanthropocentric way of understanding design from a material objects’ perspective.

Hybrid worlds also acknowledge nature as what Haraway might call a *relational achievement* [27]. Lorimer articulates this notion with an example that is productive for us to think with. He refers to Sri Lanka’s elephants as archetypal companion species and suggests that we can “trace their diverse entanglements within multispecies histories and geographies. Elephants have coevolved with people over millennia. Their genetics, anatomies, behaviors, feelings, social groupings, and wider ecologies all bear a human signature. At the same time, the language, culture, religions, agricultures, and economies of their human coinhabitants carry a pachyderm trace. These relations are unequal and frequently fraught and cut across species divides” [40]. Conceiving of humans and animals in a relational perspective prevents us from defining humans as the dominant force, which has been a problematic narrative throughout the proposed time of the Anthropocene.

Decentering the human in design

Naturecultures and hybridity can help us to *decenter* the human from design. This is a crucial shift in thought if we are to develop new technologies for cohabitation because it will help us reframe HCI from a human-centered field and towards holistic practices that are more environmentally and culturally sensitive to global cities. There have been a number of recent proposals advocating for the decentering of the human within HCI [18, 19, 24, 32, 35] and we further this aim by identifying the ways in which engaging with the Anthropocene supports this goal. Those in STS, particularly within the tradition of posthumanism, have long held that human exceptionality is problematic, arguing that humans and nonhuman actors necessarily create intersubjective worlds, where both human and nonhuman perspectives shape interactions [29]. Forlano has recently argued for the decentering of humans in the development and design of cities: “Designers are increasingly engaged in projects that go beyond crafting individual graphics or products and toward the design of services, organizations, systems, platforms, and experiences. As designers take on these roles, they are engaged in the active creation and curation of complex socio-technical networks, constituencies, and alliances that come together around problems, issues, and controversies that have distinct politics, values, and ethics” [24]. As designers are now faced with developing technology that exists within these complex socio-technical networks, new challenges have arisen that require a shift in thinking from traditional design practices that focus on human wellbeing, to more inclusive practices that emphasize a multiplicity of perspectives.

Decentering the human, it should be noted, does not mean *excluding* human perspectives; nor does it mean placing animal, or other, perspectives at the center of design thinking. Rather, a decentering of the human in design blurs the boundaries between people and things, emphasizing the interconnectedness that is inherent in human/nonhuman assemblages; a decentering would promote news ways of approaching technology development that accounts for multiple and heterogeneous standpoints within urban spaces.

REIMAGINING URBAN INFORMATICS IN THE ANTHROPOCENE

One of the issues with the way the Anthropocene is conceived in the natural sciences is as a series of phenomena that has led to global climate change, which is often talked about as a neutral set of occurrences, such as increased global temperatures, ozone depletion, ocean acidification, and decreased biodiversity. On the other hand, those in the humanities rightly call for a need to situate this phenomenon in historical and cultural contexts [46]. For example, it has been demonstrated that climate change is primarily caused by wealthy nations, and disproportionally affects poorer individuals, especially those who rely on the earth for their livelihoods [13]. In other words, climate change cannot be addressed independent of social justice, so design interventions in the one are tied to the other. The kinds of questions this raises for those working in urban informatics include: What kinds of systems or tools might designers develop to address this disparity? How can we conceive of the global nature of technology use and development as something that is tremendously unbalanced across and within different nations? And, most relevant to the present project, how does a broader understanding of issues related to the Anthropocene help designers to conceive of more equitable ways of incorporating other species in the development of urban technologies?

According to [3], “while the concept “Anthropocene” reflects the nature, scale and magnitude of human impacts

on the Earth, its societal significance lies in how it can be used to explore and guide attitudes, choices, decisions and actions that will reverberate far into the future." The Anthropocene is useful to designers, not only as a way to understand the physical changes occurring on Earth, but also as a bridging concept that helps us to engage with issues such as global inequalities, power dynamics, interspecies relationships, and historically and culturally situated systems. [3] continue, "The Anthropocene thus implies a fundamental reconceptualization of the role of individual and collective human agency and its relation to structures, systems and inputs." The implication for urban informatics is evident: It means a fundamental shift in how we conceive of cities, as well as a shift in thinking towards design as an inherent and dynamic part of all naturecultures.

Animals, as part of an urban ecosystem, contribute in surprising (and yet unknown) ways. As Haraway observes, "The constant question when considering systemic phenomena has to be, when do changes in degree become changes in kind, and what are the effects of bioculturally, biotechnically, biopolitically, historically situated people (not Man) relative to, and combined with, the effects of other species assemblages and other biotic/abiotic forces? No species, not even our own arrogant one pretending to be good individuals in so-called modern Western scripts, acts alone; assemblages of organic species and of abiotic actors make history, the evolutionary kind and the other kinds too [28]." Here, again, we can see an articulation of the relationship between animals and humans that moves away from dualism and supports a more ecological perspective. No species, as Haraway suggests, acts alone. The same can be said of technology, which always already exists within and among other urban elements.

DESIGNING FOR COHABITATION

We critically analyze two examples of interaction design to further illustrate how engaging with the Anthropocene can play a productive role in urban informatics research and identify ways this idea can be more robustly integrated into practice in order to promote design for cohabitation. We present analysis of two design cases informed by Bardzell's conception of interaction criticism [5]. Interaction criticism entails "rigorous interpretive interrogations of the complex relationships between (a) the interface, including its material and perceptual qualities as well as its broader situatedness in visual languages and culture and (b) the user experience, including the meanings, behaviors, perceptions, affects, insights, and social sensibilities that arise in the context of interaction and its outcomes." It has also been argued that knowledge is unfolded in the interpretation of objects. Importantly, for our purposes, this takes seriously the idea that "reading and interpretation of complex design objects provides resources to support research through design. Designers are tasked with understanding the relationships between present and near-future technological possibility and future ways of being, such that design solutions can be introduced" [4]. Methodologically, this allows us to critically examine these designs and place them within socio-technical systems with the aim of identifying the characteristics of non-human centered design and the ways in which designers can explicitly develop work that supports animal life. Such criticism enhances our sensitivities to how particular design decisions, materials, and processes can help us realize our values and goals.

We selected two design cases—the Big Cat Behavioral Tracking Initiative and the Phenology Clock Project—primarily because they point towards novel conceptions of cohabitation in urban space, revealing and also proposing ways of understanding urban wild things in order to design systems that support complex city entanglements. Additionally, they represent tremendous diversity in terms of their functionality and aesthetic qualities. We see these two designs as operating at different ends of the spectrum in terms of what cohabitations might mean, but they compliment one another because they both highlight different needs that designers may have when considering animal-human-technology interactions.

The Quantified Cat

Tracking the behavior of animals in urban space has a long history in fields related to animal science, such as biology and ecology, as well as in fields such as anthropology and cultural studies, which are interested in understanding the social and cultural implications of animal behavior in relation to human life [50]. Digital technologies allow us new ways of tracking, observing, and learning about animal movement, patterns, interactions, and lifestyles. These technologies have been applied extensively in the context of domestic pets, such as The Paw Tracker [47], PetPace [48], Nuzzle [45] and others, but we are especially interested in the way these tracking tools are used to study urban wild things, and what implications this data has for developing future cohabitation technologies.

In support of conservation efforts, tracking devices, such as GPS collars are often used to follow the movements of big cats, such as leopards, jaguars, lions, and tigers. These tracking devices provide scientists, conservationists, and NGO workers insight into big cat behavior and habitat needs. For example, the Snow Leopard Trust, a conservation organization that has been conducting long-term ecological study on snow leopards since 2008, utilizes tracking devices and research cameras to gain insight into questions such as: How much space does a snow leopard typically use? Where do snow leopards hunt and find water? Where are the biggest threats to snow leopards located [55]? This data reveals aspects of how snow leopards cohabit with humans, including conflicts with mining companies whose land acquisition often cuts through snow leopard territory, and local herders whose cattle sometimes become snow leopard prey.

To capture this information, GPS-enabled trackers are implanted in collars that are attached to the leopards (the leopards are not harmed during this process) and the collars

are programmed to release one to two years after placement so that researchers can collect them. The data captured in these trackers includes location information and have been deployed in long-term studies in China, Mongolia, India, Pakistan, and Kyrgyzstan [55]. Snow Leopards are shy, often elusive animals, and tracking devices helps researchers to gain valuable insight into their lives. That said, as human development encroaches on animal habitats, big cats have begun to lose their shyness around humans in order to adapt to urban life, as increasingly common news stories about cougars in Los Angeles attest.

Sub-Saharan Africa and India are home to the two largest populations of leopards in the world, and in cities such as Mumbai, with a population of 21 million, leopards can be found living alongside the expansive neighborhoods of the city. About 35 leopards are known to live in Sanjay Gandhi National Park, 40-square-miles of green space in central Mumbai. Environmental writer Richard Conniff, who specializes human and animal behavior, has explored this phenomenon and he observes: "That's an average of less than two square miles of habitat apiece, for animals that can easily range ten miles in a day. These leopards also live surrounded by some of the world's most crowded urban neighborhoods, housing 52,000 people or more per square mile. (That's nearly twice the population density of New York City.) And yet the leopards thrive. Part of their diet comes from spotted deer and other wild prey within the park. But many of the leopards also work the unfenced border between nature and civilization. While the city sleeps, they slip through the streets and alleys below, where they pick off dogs, cats, pigs, rats, chickens, and goats, the camp followers of human civilization. They eat people too, though rarely [15]." As cities grow, one of the ways in which humans have tried to address urban wild things is simply to remove them from cities. As the thinking goes, we worry that leopards might attack humans, so we tranquilize them, take them to areas that are far outside the limits of the city center with the hope that they will not pose a danger to people. However, recent studies have suggested that this can actually cause *more* human attacks because the cats are dropped off in an unfamiliar location, which can be disorienting and alarming for the cat, who finds itself in a rural area with little food and water. When the cat does come across a rural family, they are more likely to attack than they would have if they had simply been left free to roam in the city where they have ample access to other food sources [2].

The cohabitation of humans and big cats in major cities around the world presents us with a concrete example of hybridity described earlier; in particular that ecosystems are relational achievements. This has both technical and ethical implications for urban informaticists: From a human-centered perspective, in which only people have interests and value, the meaning we create is subjectively based on *our* perception, however we are not the only ones that perceive the world around us and create meaning. Purdy argues, "This exclusively human-centered outlook would wipe out a great swath of experience, perception, and relationships—to places, other living things, and practices such as wilderness pilgrimages and eco-pastoral farming—that would have formed environmental imagination. The obliteration would take away, make unsayable, much of what has mattered in powering environmental politics, and seems likely to matter just as much or more in Anthropocene politics [52]." A posthumanist perspective encourages alternative conceptions of possible ways of being, beyond the human-defined sense of existence. To put that another way: when we begin to think like a leopard, we can also design environments that support leopard behavior. Technologies such as trackers, which give us insights into their behavior, help us do this work.

One such design intervention that has resulted in the data gathered from both observation, and later tracking devices, is the *Wildlife Crossing*, a commonly used design solution that provides alternative paths for animals to cross high-traffic roads [8, 21, 39].

Figure 1. Wildlife Crossing, Alberta, Canada. ©Maggie Tacheny

Wildlife Crossings are designed to functionally support the movement of animals, while minimizing the chance of accidents from moving vehicles. If a road runs through a cohabitated area, between areas of shelter and access to water, for example, a wildlife crossing supports animals' abilities to safely cross to access a water source. Wildlife Crossings take numerous shapes and sizes; they may go over, under, or around a road, and generally aim to utilize natural elements, such as grasses, trees, and plants that already exist in the area. This encourages animals to move through the crossing, rather than to cross the road because the environment is more familiar to them.

Wildlife Crossings exemplify the posthuman hybrid notion that we are not entities but ecologies [10]. Humans, it is argued, are made up of more nonhuman than "human" material including significant amounts of bacteria and other kinds of matter. We see this idea reflected in the environment as well; it is a complex entanglement of human and nonhuman elements, impossible to divide into neat categories. The bridge creates a path that benefits both

animals and humans without disrupting the ecosystem, but at the same time it breaks down the perceived divide between nature and culture. It is, quite literally, human-designed nature, and it is based on the cultural norm of protecting both animal and human life from highway accidents. Is a Wildlife Crossing a cultural artifact or a natural one? We would be hard-pressed to define it as either one, and urbanization suggests that this kind of design will necessarily become more common as a result of increased cohabitation between humans and animals.

Tracking the movements and behavior of big cats helps us to develop design interventions such as the Wildlife Crossing. This is just one example of what may emerge from the collection of this kind of data, and it suggests that quantification will be an increasingly important tool for understanding animal behavior and its changes in the Anthropocene.

The Phenology Clock

Quantified cat initiatives show how technology helps conservationists develop new awareness of how humans and apex predators already cohabit, where the points of friction are (e.g., highways that cut through territory and rural herders whose livelihoods become prey animals), and new ways of "thinking like a leopard." But humans are not only acquiring new facts about apex predators; we are also changing our self-understanding as inhabitants of and actors on planet Earth. Designs that support reflection are one means of doing this work [9]. We turn now to a design that arguably does such work: the Phenology Clock.

Phenology is the centuries-old practice of tracking and identifying the natural rhythms of the planet—when birds migrate, when cherry trees blooms, when bears hibernate, and so forth. We could say that phenology is the study of the Earth's calendar. This "calendar" is deeply affected by climate change and as we move away from stable Holocene conditions into the yet unknown conditions of the Anthropocene, phenology allows us a way to track, monitor, and record the inevitable changes in natural phenomena. Recent advances in technology have advanced the capabilities of this practice; what was once done by careful human observation can now be augmented with remote sensors that can track air, water, soil, and other natural conditions.

The London Phenological Clock (part of The Phenology Clock Project [49]) designed by Natalie Jeremijenko's Environmental Health Clinic, is a clock that displays when local plants and animals emerge, bloom, or migrate throughout the year. This design was originally displayed as part of the "All of This Belongs to You Exhibition" at the Victoria and Albert Museum, and also functions as an interactive website that can be publically accessed. The clock displays data recorded in London from 2000-2014. The data was collected and managed by the Woodland Trust as part of its Nature's Calendar project run in partnership with the Centre for Ecology and Hydrology. This data is gathered by citizen scientists, or volunteers, who are interested in observing and recording phenomena in their neighborhood; it is then collected by The Centre and can be used as a way to understand natural phenomena and as evidence of the effects of climate change.

Figure 2. The London Phenological Clock ©Natalie Jeremijenko, Jake M Richardson, Tega Brain, and Blacki Li Rudi Migliozzi

The Phenology Clock (see Figure 2) visually alludes to a traditional clock—round with a face, dials, and hands that reflect information. However, it is more complex than a clock that keeps track only of time. In the Phenology Clock we see not only the information displayed in a central circular infographic, but it sits atop an X-Y axis—the X displays the different species that have been tracked: trees, plants, mammals, birds, amphibians, flowering perennials, grasses, fungi, and soil microbes. The Y-axis displays the individual species within a given category. For example, if you select trees, the vertical axis will reflect: Oak, Sycamore, Silver Birch, Rowan, Chestnut, Holly, Hazel, and so forth. There is an option to choose "all species" which will reflect data from all of the categories. Spans of time are selected by rotating the "hands" of the clock to choose specific dates; time selections include aggregated information during each of the tracked months over the course of 2000-2014.

The clock allows for a tremendous amount of data to be efficiently and elegantly visualized and organized by assigning specific colors to each species; hovering over trees illuminates a ring of different shades of green, while hovering over birds shows us a variety of pinks, light and dark, depending on which species appear in the data set. At the same time, we can drill even deeper into the data by hovering over a specific colored ring in the clock. For example, Figure 3 shows data for Bramble, also known as Rubis Fruitcosus. There were 1,721 observations of the first ripe fruit between October and June, which gives us an accurate sense of when this fruit first appears. In order to understand ecological connections, other animals who may eat the berries, such as birds, may also be tracked during the same period to see if they appear around the Bramble. There are some challenges in interacting with this design in

part because of the constraints of a screen, which limits the amount of data that can be seen at once. Additionally, some of the connections between animals and plants are not as intuitive as might be suggested. For example, it is unclear *which* animals might feed off certain fruits or plants and how we might know this without trial-and-error clicking.

Based on the data presented in the Phenology Clock, there are numerous interpretive possibilities for developing technologies that work in consort with the natural phenomena that occurs in urban space. The clock inherently accounts for a wide variety of species and their diverse entanglements, and it visualizes data that would be otherwise unavailable to laypersons who don't study animals. Not only is it a tool for capturing data about the planet, but, if we consider this a tool to help us think about natural patterns, it also works as a pedagogical tool for those interested in environmental design. We can also imagine alternative expressions of the phenology clock, such as one that that also tracks the human-based patterns of a city, including light, noise, traffic, and pollution.

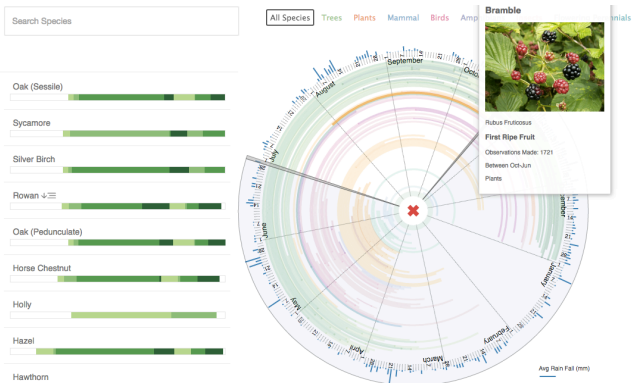

Figure 3. The London Phenological Clock, Bramble. ©Natalie Jeremijenko, Jake M Richardson, Tega Brain, and Blacki Li Rudi Migliozzi

Whereas the Wilderness Crossings present an example of concrete intervention inspired by collected data on animal movement, the Phenology Clock works as an object for us to think with and a learning device that helps us to plan and shape such interventions. The Phenology Clock has important implications in the Anthropocene because we are currently undergoing a time of great change in which Holocene conditions are irreparably damaged. But the exact nature and scale of the changes are difficult to grasp, and designs like the Phenology Clock propose different *rhetorics*—self-led, interactive, graphic—than what we more standardly experience in the media (e.g., statistics and verbal warnings from scientists). This design has the capacity to inspire those interested in learning about the natural world to go out and explore their own neighborhoods and observe and track the phenomena in their own backyards.

Moreover, a phenology clock could help us to record and learn about these emerging patterns in a more participative way than traditional science affords. One thing we do know is that there is no possible return to the conditions of the Holocene [26]. This means that we will have to conceive of a future world that has conditions—climate, temperature, air quality, biodiversity, and so forth—that are significantly different than any that came before. This design not only accounts for those changes, but also has the potential to help future designers to create with these planetary shifts in mind. Consistent with the reasoning in collapse informatics regarding designing for scarcity, [56] this also supports the idea of developing designs that are more adaptive to the changing blooming or migrating patterns of the various plants and creatures on the planet, rather than fixed designs that function the same way year-round.

We can see in this design one of the requirements of living in this new geological epoch, or what has been articulated to as "the ability to think and act beyond human experience [26]." The Anthropocene forces us to reconsider the role that humans play in shaping the Earth. No longer can we see ourselves as exceptional, but in this new geological era we are confronted with a need for hybrid thinking that helps us to learn how to work with and for other experiences on the planet. The Phenology Clock promotes nonhuman understanding by illustrating the behaviors, characteristics, and patterns of plant and animal life in a given place. It suggests that as humans increasingly experience life in cohabitation with urban wild things, we can develop digital tools that give us insight into the lives of these other creatures.

What might some of those design interventions look like? We see three key characteristics promoted by the Phenomenology Clock: biodiversity, time, and location specificity. Design in the Anthropocene requires us to carefully consider each of these factors, and one challenge for urban informaticists is that we don't necessarily have the tools or abilities to investigate and understand the biodiversity that exists in a given city. One option is to draw from other fields such as biology and ecology, which can help shape our knowledge development; the other option is to develop technologies that gather this kind of data and make it accessible to those without advanced environmental scientific training—which, incidentally, includes most designers. (This is also fundamental to the quantified self movement, which allows non-experts to collect and analyze data on their own bodies.) At the same time, this clock critiques traditional notions of time that humans have constructed and lived with for centuries. Although we have calendars based on the seasons and the path of the Earth around the sun, animals don't necessarily adhere to these demarcations in the way that humans do. This is especially true as we consider global cities with natural environments that are as wide ranging as hot, humid Mumbai summers and the icy winters of St. Petersburg. Similarly, we now must contend with artificial light that

upends our associations to the patterns of the sun. Of particular importance to those working in urban informatics is the need to understand not only global patterns of urbanization, but also the situated, idiosyncratic characteristics within each city and region in the world. The Phenology Clock advocates for such a sensibility because the data presented within can be specific to individual cities, although it has broader global implications for understanding climate change.

Design in the Anthropocene

Critiquing these particular designs helps us to ground the theoretical concepts that we have explored in order to highlight possible ecological interventions. Big Cat Tracking presents us with an example of how data collection tools are used to study animals; in turn, this data can be used to support cohabitation as evidenced by the emergence of Wildlife Crossings. The creation of the Wildlife Crossing, as something that employs natural elements, has proven to be significantly more effective than other animal bridges that simply emulate human bridges (e.g. those made of cement and steel), as animals are less likely to cross. Informed by the concept of hybridity, and explicitly situated in the Anthropocene, we can see the Wildlife Crossing as an example that supports cohabitation because it purports to design from an animal perspective.

Similarly, in the Phenology Clock, we are able to engage with the concept of natureculture in a way that grounds the theory in a functional design. This design captures information that is vital to designing spaces of cohabitation, but it does more than simply capture and present data; it also engages information in a way that challenges typical presentation of global change phenomena. Our engagement with these designs in combination with key concepts from the Anthropocene are likely to lead to more appropriate design solutions in the future because they promote a non-human centered approach, and we can see concrete takeaways informed by notions such as naturecultures and hybridity. Big Cat Tracking and the Phenology Clock are unique in their approaches towards animal technology. The Big Cat Tracking Initiative is one example of a larger class of projects related to data tracking, while the Phenology Clock is a singular, more artistically-driven instance and in both of these designs, we see material trajectories for future work in developing technologies for cohabitation.

DESIGNING [WITHIN/FOR] COHABITATION

Within Urban Informatics, we see a vision of the city that has evolved from a more technology-centered hub towards a more socio-cultural conception with unique manifestations in different global cities. At the same time, we can see that research across the natural and social sciences has identified the Anthropocene as a locus for research related to global change phenomena, including climate change, mass extinction, loss of biodiversity, air and water pollution, and other concerns related to urbanization. Key concepts, such as naturecultures and hybridity, inform our understanding of the Anthropocene have been explored here with the aim of decentering the human from design and promoting new forms of urban cohabitation. If the Anthropocene brings about the *end of nature*, we can no longer think of culture and nature as separate entities, but rather as deeply entangled concepts that shape our urban experiences. Given that HCI agendas are increasingly taking responsibility for urban experiences, and given that the end of nature is shaping such experiences now, then it follows that this shift in our conception of nature is, or should be, part of HCI's concern. Cohabitation both describes the present and anticipatable future, and also is a goal—yet a goal that HCI as a field has not yet systematically pursued.

Current research in ACI has tended to focus on animals such as pets, guide dogs, and farm animals; however, if we are to extend the practices of ACI into urban informatics, we see a need to include urban wild things in this agenda. Animals of all kinds inhabit all cities around the world, even apex predators such as leopards that many of us tend not think about as urban animals. Moreover, we have seen that all different kinds of animals are needed for a healthy ecosystem, urban or otherwise. By considering big cats, we have shed light on the kinds of animals that tend to be neglected in the ACI discourse. At the same time, considering big cats can also help us to think about the overall species diversity of any major city. The existence of cougars in Los Angeles presents unique concerns for the inhabitants of that area, whereas, the presence of cougars in Boise or Denver may present other needs and opportunities for design interventions. Similarly the presence of leopards in Mumbai makes visible yet *another* set of concerns for the residents of that city. While we can see connections across world cities in the work we have presented here, more precise data captured in individual locations will reveal that animal-human interactions are idiosyncratic in each locale—shaped by the numbers and behaviors of relevant animal species, urban geographies, and human cultures. Such a conception is in-line with and contributes towards the arguments already prevalent in urban informatics that challenge the notion of "the city" as a monolithic concept.

One of the implications surfaced by the present work is an increased understanding of how global change might be addressed in the future by those who have no scientific training. Although the Anthropocene exhibits natural phenomena that is observed, measured, and studied by those in the natural sciences, we will require design sensibilities and approaches from those who have little or no scientific training at all. As shown earlier, the data gathered for the Phenology Clock was collected by ordinary citizens who tracked the plant and animal behavior in their own backyards. Similarly, the Snow Leopard Trust relies on crowd-sourced data analysis to sift through the huge amount of images collected through camera traps. In both cases, it is not only highly trained scientists who are involved in such initiatives, but anyone who is concerned

with conservation and the environment. Addressing issues such as climate change and mass extinction necessitates the collaboration of all—policymakers, government officials, researchers, designers, technologists, and citizens alike—towards possible solutions. This raises important questions about how knowledge is generated and who has the capacity to contribute towards addressing climate change. The two designs we have explored in this paper reveal ways different stakeholders with varying expertise can work in concert with one another for interventions.

Designs like the Phenology Clock are useful as a way to make data accessible to anyone interested in engaging with ecological data related to the natural patterns of the earth, but through our analysis we can see that it does *more* than simply present information. It challenges basic human assumptions about time and space. The information presented in the Phenology Clock assumes the entangled nature of space in that it accounts for a multitude of species and recognizes the fact that none of these species exists on its own without the others. The Clock also promotes a time scale that may be at odds with human-defined time. One of the challenges with developing urban technologies is the fact that all the creatures in a given city don't adhere to the same structures of time, nor to the same patterns of movement. Designs like the Phenology Clock make this multiplicity visible and inspire a design approach that necessarily privileges the notion of cohabitation as a guiding characteristic of the city.

CONCLUSION

Urban informatics/urban computing has been evolving from a techno-centric vision of the city (i.e., a city with sensors) towards a physical-social-cultural assemblage. In the meantime, research in the natural sciences helps us understand the emergence of the Anthropocene—climate change, mass extinction, and the fact that cities have grown to a scale that they now encroach on what was previously considered animal habitat. Indeed, the long-held nature-culture dualism is fast collapsing. The Anthropocene has become a key concept of our time because it has captured a strong sense of urgency around what humans have done to the Earth; however, the Anthropocene, and its associated concepts and concerns, is only just beginning to be taken up into HCI.

As shown in our analysis of two design cases, the Anthropocene challenges us to rethink our conceptions around the relationship between animals and humans and the different ways in which we perceive and act in the world. Moving forward, we can build on the implications of the Anthropocene to develop design strategies that refigure human-animal relations to support cohabitation and presumably even redefine cohabitation. As the transdisciplinary research agenda around the Anthropocene continues to develop, there are opportunities for further dialogues between HCI researchers and designers interested in issues of global change, and especially those concerned with urbanization and animal-centered designs, which are also of concern to both scientific and cultural scholars of the Anthropocene.

ACI researcher Mancini (cited earlier) challenges us to shift our animal perspective and provocatively asks what would happen if we did. The Phenology Clock revealed the ways that our conceptions of time—which we think of as objective and external—are actually human-defined and human-centric. A similar distinction is made between space and place, where the one is said to be external and objective and the other is human-meaningful. Perhaps designing for cohabitation might decenter the human in our conceptions of space, helping us perceive and therefore design for new spatialities.

Purdy's reflections on Anthropocene futures leads him to conclude, "Whatever innovation brings, people will continue to shape the earth by inhabiting it, changing everything from its atmospheric cycles to its soils and habitats. It is much too late to imagine that any technology could enable humanity to 'stop disturbing' the earth. Instead, every technology will become part of the joint human-natural system in which we make and remake the world just by living here [52]." That joint human-natural system might be our greatest—and most urgent—design challenge.

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