Architectural Succession: A Multi-Species Approach to the Built Environment

by

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Architectural Succession

A Multi-Species Approach to the Built Environment

Catherine Daigle

Abstract

A novel approach to single-species design is urgently required. Urban expansion is directly impacting global biodiversity, increasing habitat-threatened species reliance on human infrastructure. Whereby recognizing the architect's responsibility to provide habitat for additional species, the built environment can be utilized for multi-species inhabitation. Derived from the natural cycle of ecological succession, Architectural Succession outlines the process of change occurring for a built environments program and user over time. Informed by this framework, a Research Creation process examines the at-risk Chimney Swift and its food source within a successional multi-species structure. Further enhancing Sudbury, Ontario's, Regreening efforts, barren outcroppings offer significant opportunity for multi-species built intervention, encouraging habitat recovery and the return of species at-risk. A wildlife observation pavilion explores the successional opportunities of traditional light wood frame construction undergoing the decomposition process to support the regrowth of the forest.

Keywords: Multi-species design; Habitat restoration; Species at-risk; Chimney Swift; Regreening; Sudbury, Ontario; Ecological succession; Architectural succession

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PREFACE

A book for those who are willing to go where others won't.

- H. D. S. Lane

Introduction

With human expansion impacting the quality and quantity of natural habitats globally, habitat-threatened species have no choice but to cling to the built environment as an attempt at survival. By looking at the Chimney Swift's story of resilience and ability to adapt to human conditions, we can begin to understand the challenges all other species are facing globally. The Chimney Swift is a bird of the eastern North American forest that once found its home in the hollow old growth trees, however due to human influence is suffering from a lack of adequate food source and habitat loss, resulting in its adaptation to seeking shelter within anthropogenic structures.[1] These structures have provided adequate habitat for the Swifts for as long as they deemed useful to the owner, however, with renovations, capping, screening, lining, demolishing, and the lack-of accessible new builds, the Chimney Swift is once again facing population decline due to human intervention.[2]

1 Christian Artuso, C-Jae C. Breiter, Laura D. Burns, Nicole Firlotte, Stephen D. Petersen, Timothy Poole, and Barbara E. Stewart, "First Use of Purpose-built Artificial Chimney Swift Habitat in Manitoba,"*Blue Jay* 78, no. 3 (2020): 30-33; "Chimney Swift Life History: Distribution and Migration," Landbird Species at Risk in Forested Wetlands, accessed October 17, 2022, https://landbirdsar.merseytobeatic.ca/chimney-swift-distribution-and-migration/.

2 "Media Release: Birds Canada and Partners Launch Major New Fund to Help Conserve The Chimney Swift," Birds Canada, February 14, 2022, https://www.birdscanada.org/birds-canada-and-partners-launch-major-new-fund-to-help-conserve-the-chimney-swift.

Canada has a current total of 600 species classified as at-risk, 234 of which are located within Ontario, and 50 can be found in the City of Greater Sudbury.[3] Known for its intensive exploitation of the natural environment, Sudbury Ontario is of special interest to the study of species at-risk and their recovery, where 84,000 hectares of barren rock were exposed by heavy metal extraction and smelting, leaving a once forested region a barren landscape.[4] However, in 1978 the region recognized these environmental impacts and began the Regreening process, liming and seeding over 3,400 hectares of land and planting 10 million trees thus far.[5] As a result, much of the region is in environmental recovery, however areas such the Maley Conservation area remain ecologically barren due to the inability to maintain adequate soil structure on rocky outcroppings.

As conservation efforts have long been recognized as necessary in preserving the natural environment, even more recently, ecologically intact ecosystems have become key in understanding what areas require additional resources.[6] Where currently, as little as 20% of the earth's surface remains unoccupied by human anthropogenic influence, and in response to the increasing numbers of species at-risk, efforts must now be focused on recovering habitat within the built environment.[7] By examining Ecological Succession, the process of change that occurs in species structure within an ecological community over time, Architectural Succession has been derived for the purpose of this thesis addressing the process of change that occurs for a built environment and its inhabitants over time.[8] Where this thesis seeks to question how architects can approach the built environment as a multi-species design through the process of architectural succession.

Various cultural, religious, and environmental groups support bioethical arguments that every species has the fundamental right to exist independently of human material benefits, however, the largely Western centric dominated world of architecture actively practices in opposition of this mindset.[9] The Philosopher Michel Serres summarizes this theoretical shift through the notion of a 'Natural Contract' to symbiosis, highlighting how the key to survival lies in our ability to recognize our dependance on the health of the planet in

3 "Species at risk in Ontario," Government of Ontario, last modified April 01, 2022, https://www.ontario.ca/page/species-risk-ontario.

4 Oiva W. Saarinen, *From Meteorite Impact To Constellation City: A Historical Geography of Greater Sudbury* (Wilfrid Laurier: University Press, 2013), 50-62; "Barren Rings," City of Greater Sudbury Open Data Portal, City of Greater Sudbury, last modified May 21, 2019, https://opendata.greatersudbury.ca/datasets/7692463b600846e0816ae8e70d438f4b_0/explore?location=46.517297%2C-80.933900%2C11.62.

5 John M. Gunn, *Restoration and recovery of an Industrial Region: Progress in Restoring the Smelter Damaged Landscape near Sudbury Canada* (New York: Springer-Verlag, 1995), 109-120; "Regreening Program," City of Greater Sudbury, accessed September 29, 2022, https://www.greatersudbury.ca/live/environment-and-sustainability1/regreening-program/.

6 Baisero, Daniele et al., "Where Might We Find Ecologically Intact Communities," *Frontiers: In Forests and Global Change*, 4, no. 626635 (April 2021): 2, https://doi.org/10.3389/ffgc.2021.626635; Courtney Le Roux and Joseph J. Nocera. "Roost sites of chimney swift (Chaetura Pelagica) form large-scale spatial networks," Ecology and Evolution 11, (2021): 3820.

7 Baisero et al.,"Where Might We Find Ecologically Intact Communities," 2; Courtney Le Roux and Joseph J. Nocera. "Roost sites of chimney swift (Chaetura Pelagica) form large-scale spatial networks," *Ecology and Evolution* 11, (2021): 3820.

8 "Ecological Succession," Ecological Succession Definition, Biology Dictionary, last modified October 4, 2019, https://biologydictionary.net/ecological-succession/.

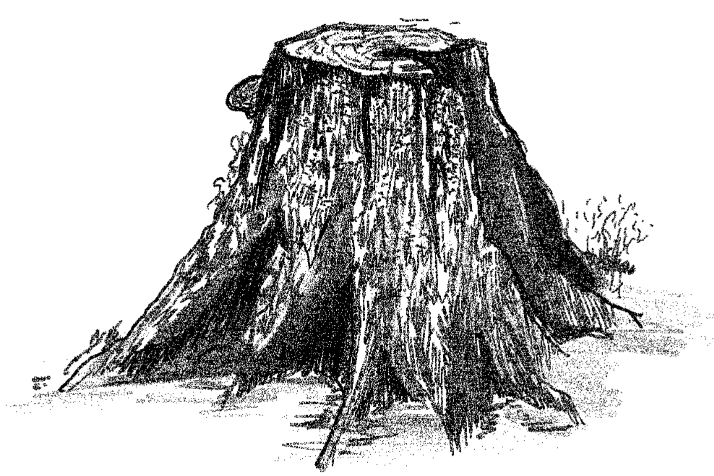
9 E Szűcs, R Geers, T Jezierski, EN Sossidou, DM Broom, "Animal welfare in different human cultures, traditions and religious faiths," *Asian-Australas J Anim Sci.* (2012): 1499, https://doi.org/10.5713/ajas.2012.r.02.

its entirety.[10] And addressing culturally and environmentally sensitive perspectives on multi-species relationships, feminist theorist and biologist Donna Haraway urges that the sixth greatest extinction is actively driven by human activities.[11] Drawing attention to how architects are not only designing for a single species but consciously and unconsciously designing for all species on earth, it is now the responsibility of the architect to integrate multiple species into the built environment.

At present there is no comprehensive literature detailing an architectural framework intended for multiple-species design, and as such, through the analysis of a tree, we can begin to comprehend multispecies habitation on a fundamental level. A Research Creation project explores the relationship between the at-risk Chimney Swift, its primary food source of aerial insects, and the human participant within a built structure located on the McEwen School of Architectures rooftop garden in Sudbury Ontario. The act of questioning and making providing insight into multi-species design and Architectural Succession to be applied to that of the ecological recovery of Sudbury Ontario's remaining barren outcroppings. An iterative design process creates a series of precedents on multi-species habitat pavilions and observation pavilions informing the proposed wildlife monitoring and observation program of Maley hill. Offering habitation to some of the region's 50 at-risk species, the project establishes temporary habitats during the forest recovery period, by following the process of Architectural Succession.

10 Michel Serres, *The Natural Contract*, trans. Elizabeth MacArthur, and William Paulson (Ann Arbor: The University of Michigan Press, 2011), 27-50.

11 Donna Jeanne Haraway, *Staying with the Trouble: Making Kin in the Chthulucene* (Durham: Duke University Press, 2016).



Chapter 1: Human Intervention

As of 2022, the human population has exceeded 8 billion.[12] This increase is projected to reach 9.7 billion in 2050 and 10.4 billion by 2100.[13] Particularly troubling, the encroachment of the built environment into ecologically sensitive regions is reflective of this growing population. Human actions of expansion, alteration, destruction, pollution, extraction, and the introduction of invasive and non-native species are among the contributing factors of modern days depletion of global biodiversity, meaning that, these ecological issues should more than concern us.[14]

The spatial rejection of non-human species from the built environment has negatively impacted global biodiversity, forcing other species to either retreat or adapt to human built conditions.[15] Currently, less than 20% of the earth's surface remains unoccupied by human anthropogenic influence, and as little as 2.9% of land area remains ecologically intact, leaving little to no space for non-human species to exist comfortably (Fig. 01).[16] As architecture seeks to create a comfortable built environment for its user(s), it can be utilized as a tool in supporting biodiversity as a whole, rather than for a single species, i.e., human.

12 "World Population to Reach 8 Billion on 15 November 2022," Department of Economic and Social Affairs, last modified November 15, 2022, https://www.un.org/en/desa/world-population-reach-8-billion-15-november-2022.

13 "World Population to Reach 8 Billion on 15 November 2022," Department of Economic and Social Affairs, last modified November 15, 2022, https://www.un.org/en/desa/world-population-reach-8-billion-15-november-2022.

14 John M. Gunn, *Restoration and recovery of an Industrial Region: Progress in Restoring the Smelter Damaged Landscape near Sudbury Canada* (New York: Springer-Verlag, 1995), 144; Thom van Dooren, and Deborah Bird Rose, "Storied-places in a multispecies city," *Humanimalia* 3, no.2 (2012): 2, https://doi.org/10.52537/humanimalia.10046.

15 Megan Stokes, and Rajjan Man Chitrakar, "Designing 'Other' Citizens into the City: Investigating Perceptions of Architectural Opportunities for Wildlife Habitat in the Brisbane CBD" *QUThinking Conference: Research and Ideas for the Built Environment,* (2012): 6.

16 Daniele Baisero et al., "Where Might We Find Ecologically Intact Communities," *Frontiers: In Forests and Global Change*, 4, no. 626635 (April 2021): 2, https://doi.org/10.3389/ffgc.2021.626635.

Figure 01 | **Human Influence**
The first in a series of narrative sketches, this drawing of a tree stump represents both the influence of human intervention within the natural environment and natures ability to foster new life with its decay.

Chimney Swift [Chaetura Pelagica]

Existing in more than 10,000 different species variations ranging from the small bee hummingbird of 2 grams upwards the ostrich at 140,000 grams, birds have long been recognized as one of the most diverse species of land vertebrates in modern day.[17] Early scientific study has focused on birds and their ability to adapt to changing environments ever since the development of evolutionary thought at the forefront of paleontology.[18] Evolving some 165–150 million years ago, persisting through the advances and retreats of continental ice sheets and the mass extinction of many large reptiles and mammals, now facing their most recent testament within the last million or so years being that of their adaptability to the introduction of the human species.[19]

Humans, although short in presence compared to the existence of other species on earth, have both directly and indirectly impacted the livelihood of many species. Inherently an environmental crisis, habitat loss is gaining attention by the designers of the built environment, where despite conservation efforts, ecologies continue to be altered and significant wildlife habitats are exponentially being lost.[20] The agricultural and urban expansions into delicate forests, shrublands, prairies, and coastal marshes are one of the main causes for habitat loss alongside Climate Change and the burning of fossil fuels damaging the quality and livelihood of food sources.[21]

With human expansion impacting the quality and quantity of natural habitats, habitat-threatened species have no choice but to cling to human infrastructure as an attempt at survival. A clear example of this would be that of the Chimney Swift [Chaetura Pelagica], (Fig. 02). The Chimney Swift is an aerial insectivorous bird species of the swift family breeding in central and eastern North America and winters in the Amazon basin of South America (Fig. 03). It can be identified by its brown body, gray throat, long wings, and tail feathers extending into a spiny tip.[22] Its nest structure is constructed with small twigs and cemented to a vertical surface, typically 3.5-4.5 inches in size.[23] Spending the majority of its day in flight, the Chimney Swift feeds on insects in air, and nests and perches by clinging to vertical surfaces within hollow trees, and anthropogenic structures such as chimneys, abandoned houses, barns, air vents, garages, lighthouses, and silos.[24]

Figure 02 | **Chimney Swift**
The second in a series of narrative sketches, this drawing represents the physical features and dimension of the Chimney Swift [Chaetura Pelagica] as a playful approach to merging botanical themed drawings with architectural language. The Chimney Swift will serve this thesis as an analogy for the experiences all other species face due to human influence.

17 Luis M. Chiappe, and Gareth J Dyke, "The Early Evolutionary History of Birds," *Journal of the Paleontology Society of Korea* 22, no. 1, (January 2006): 133; Stephen L Brusatte, Jingmai K. O'Connor, and Erich D. Jarvis, "The Origin and Diversification of Birds," *Current Biology Review* 25, no. 19 (October 05, 2015): 889, https://doi.org/10.1016/j.cub.2015.08.003; John M. Marzluff, *Welcome to Subirdia,* (Yale University Press, 2014), preface.

18 Chiappe and Dyke, "The Early Evolutionary History of Birds," 134; Brusatte, O'Connor, and Jarvis, "The Origin and Diversification of Birds," 889, 890.

19 Brusatte, O'Connor, and Jarvis, "The Origin and Diversification of Birds," 890; Marzluff, Welcome to Subirdia, 888.

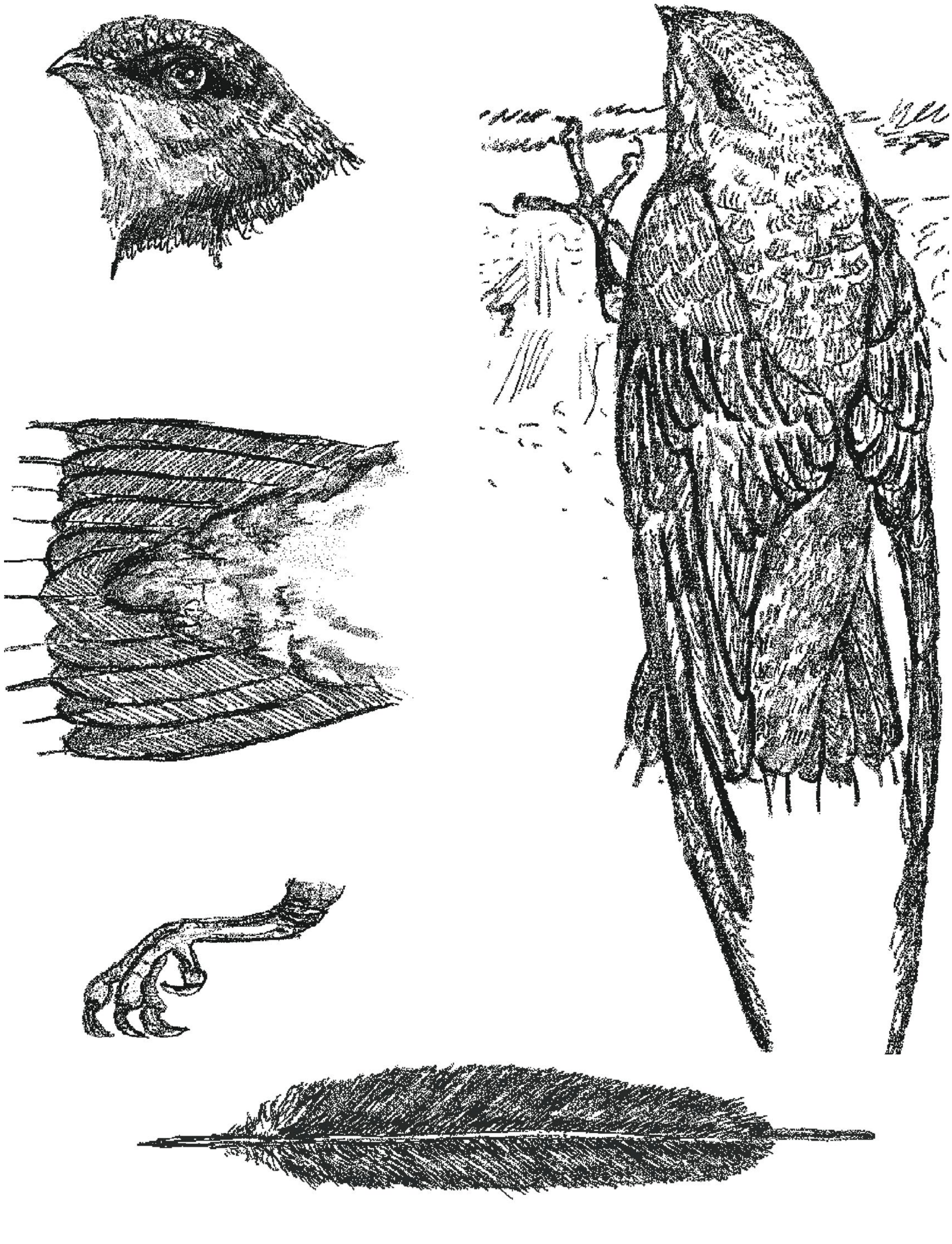
20 Courtney Le Roux and Joseph J. Nocera, "Roost sites of chimney swift (Chaetura pelagica) form large-scale spatial networks," Ecology and Evolution 11, (2021): 3821.

21 Le Roux and Nocera, "Roost sites of chimney swift (Chaetura pelagica) form large-scale spatial networks," 3820.

22 Environment and Climate Change Canada, "Recovery Strategy for the Chimney Swift (Chaetura pelagica) in Canada [Proposed]," S*pecies at Risk Recovery Strategy 3 Series* (2022): 2.

23 Gary R. Graves, "Avian commensals in Colonial America: when did Chaetura pelagica become the chimney swift?" *Archives of Natural History* 31, no. 2 (2004): 301, http://dx.doi.org/10.3366/anh.2004.31.2.300.

24 Christian Artuso, C-Jae C. Breiter, Laura D. Burns, Nicole Firlotte, Stephen D. Petersen, Timothy Poole, and Barbara E. Stewart, "First Use of Purpose-built Artificial Chimney Swift Habitat in Manitoba," *Blue Jay* 78, no. 3 (2020): 33; "Chimney Swift Life History: Distribution and Migration," Landbird Species at Risk in Forested Wetlands, accessed October 17, 2022, https://landbirdsar.merseytobeatic.ca/chimney-swift-distribution-and-migration/.



Experiencing an increase in environmental disruption, the Chimney Swifts survival is deeply rooted in its resilience and ability to adapt to human conditions. Historically nesting in hollow old-growth species of white pine, yellow birch, cypress and sycamore trees, the introduction to human dwellings and old growth deforestation in eastern North America during the pre-Colonial era influenced a dramatic change in the ecology of Chimney Swift's breeding, roosting, and feeding sites.[25] Historical depictions of the species nesting behaviour and the change in vernacular name suggest that the Chimney Swifts began nesting in human structures, particularly chimneys as early as 1672, and by the late eighteenth century almost exclusively nesting in wood heated open-hearth fireplace chimneys (Fig. 04).[26] The stone and brick of these chimneys offered shelter more secure than that of natural cavities and hollowed trees, and the brick mortar provided exceptional opportunity to directly attach the structure of their nests.[27] These new nesting structures were rapidly inhabited and due to the Chimney Swifts adaptations, it is now a rare phenomenon for this species to inhabit natural cavities or hollowed trees.

Although it is hypothesized that the Chimney Swifts have benefited from nesting in human structures, the species is now experiencing drastic population declines. Traditionally associated with dense forests and rural agricultural areas, Canada currently hosts approximately one quarter of the Chimney Swifts breeding range within its urban and suburban areas of Saskatchewan, Manitoba, Ontario, Quebec, New Brunswick, and Nova Scotia.[28] However, the Chimney Swift's long-term population has declined 95% from 1968 to 2005 within rural regions, in addition to a substantial reduction over the

Figure 03 | **Chimney Swift Range**
This map illustrates the Chimney Swifts breeding, migration, and wintering ranges across North and South America.

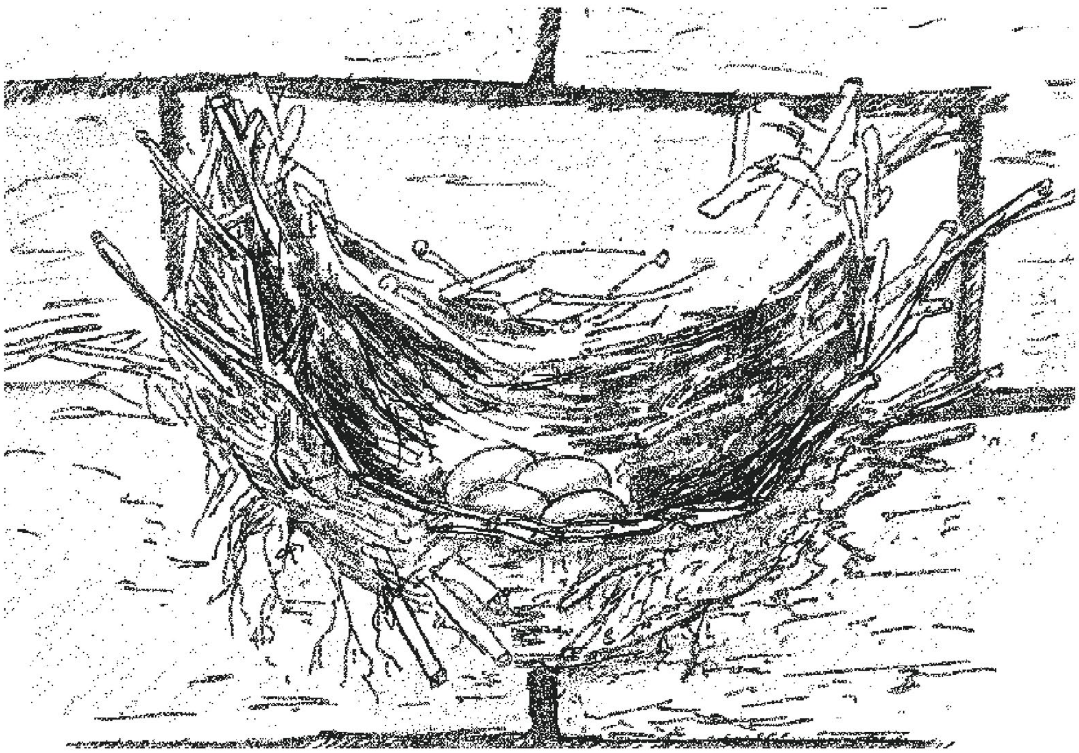
Figure 04 | **Chimney Swift Nest**
The third in a series of narrative sketches, this drawing shows in front and side elevation the physical features of the Chimney Swift [Chaetura Pelagica] nest attached to the interior of a brick chimney.

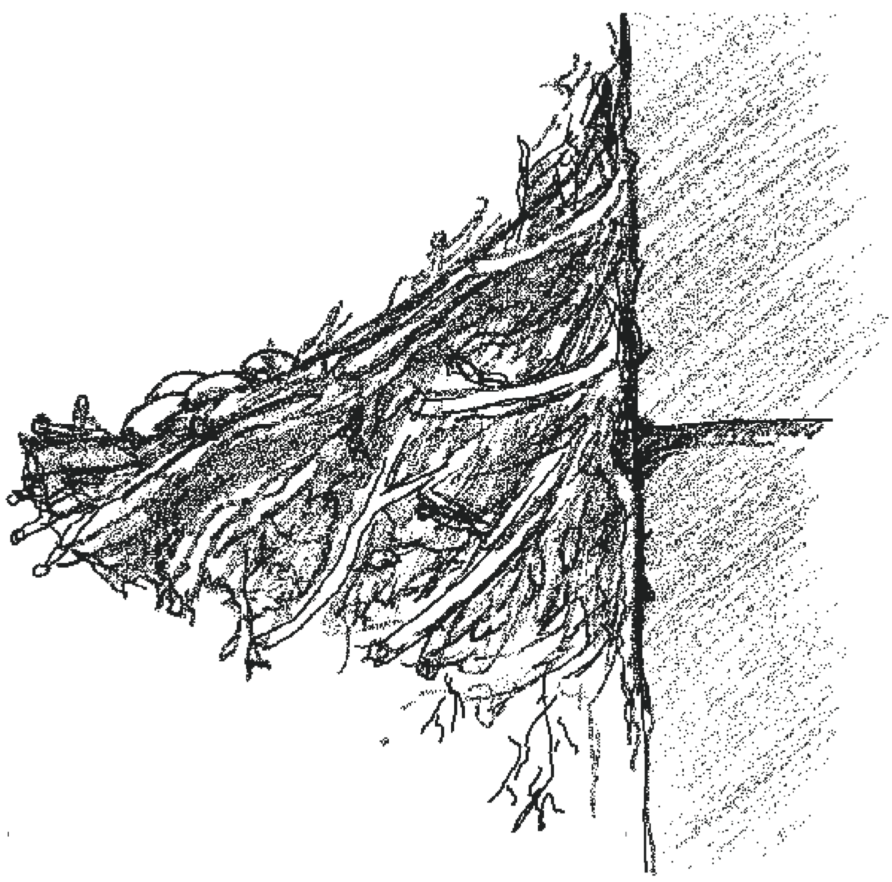
25 Graves, "Avian commensals in Colonial America: when did Chaetura pelagica become the chimney swift?" 300.

26 Leah Finity, "The Role of Habitat and Dietary Factors in Chimney Swift Population Declines," (M.Sc., Trent University, 2011), 2.

27 Graves, "Avian commensals in Colonial America: when did Chaetura pelagica become the chimney swift?" 301.

28 Environment and Climate Change Canada, "Recovery Strategy for the Chimney Swift (Chaetura pelagica) in Canada," 1, 3.





past three generations (14 years) of 49%, with its most dramatic decline geographically within northern and eastern North America.[29] Both nationally (Canada) and provincially (Ontario) threatened under the Species At Risk Act, 2009 and Endangered Species and Ecosystems Act 2007, the Chimney Swift is of significant concern.[30]

Due to the species habitat being dependent upon access to adequate food source of aerial insects and suitable nesting sites, it is difficult to associate it with a single habitat type. However it is suggested that the main cause of threat to the species is identified as the decline in its food source due to the use of pesticides, urban expansion, change in climatic conditions due to climate change, and the lack of suitable natural and human structured habitat.[31] In Canada, chimneys have not been constructed to the same degree as trees were felled, and in Ontario the majority of old growth forests were removed for agriculture and logging purposes, causing habitat disruptions for both the Chimney Swift and its food source. With the increase of electric heating in the 1950s and eventual transition to natural gas, suitable chimneys are few and far between. Typical new buildings are no longer constructed with chimneys or have metal flues preventing Chimney Swifts from entering. Any remaining chimneys are often renovated with metal liners as fire prevention measures, required by bylaws to install spark arresters effectively blocking entry, or capped and/or demolished if no longer in use.[32] As such, suitable chimney habitats have been in constant decline due to renovations, capping, screening, lining, demolishing, and the lack-of accessible and adequately designed shelter in new builds.[33] Where the Chimney Swifts are now facing population decline due to human intervention.

The Recovery Strategy for the Chimney Swift in Canada outlines how potential threats to the species and its habitat can be mitigated, aiming to promote long-term population and distribution of the Chimney Swift by stopping the decline within a 10 year period to maintain its current extent of occurrence.[34] Current efforts are being directed towards the conservation and protection of existing nesting and roosting sites through legal and stewardship outreach, however the homeowner desire to modify, renovate, or remove decommissioned chimneys poses a continued threat to the species recovery. With the loss of old growth forests and short timber harvesting cycles it is suggested that preserving forested nesting and roosting sites within Canada will be unlikely, as trees will not be capable of growing large enough to develop cavities suitable for habitation by the Chimney Swifts. The insect populations the Swifts feed on are threatened primarily by pesticide use and climate change. The reduction in the use of pesticides could help mitigate this decline, however unfavourable weather conditions are less likely to resolve soon enough.[35] By understanding the Chimney Swift's struggle and adaptation due to human influence, we can begin to understand the challenges all other species are facing globally. With the loss

29 Finity, "The Role of Habitat and Dietary Factors in Chimney Swift Population Declines," 1-2.

30 Environment and Climate Change Canada, "Recovery Strategy for the Chimney Swift (Chaetura pelagica) in Canada," 1.

31 COSEWIC, "Assessment and Status Report on the chimney Swift in Canada," *Committee on the Status of Endangered Wildlife in Canada,* (2017): 32.

32 COSEWIC, "Assessment and Status Report on the chimney Swift in Canada," 10.

33 Ibid,11, 12.

34 Environment and Climate Change Canada, "Recovery Strategy for the Chimney Swift (Chaetura pelagica) in Canada," 16.

35 Ibid, 16.

of their natural and human-built environments, the responsibility to provide new habitats for these other species is now positioned upon the designers of the built environment in going forward.

Key Biodiverse Areas

The global database on the conservation status of species states that there are currently more than 41,000 species threatened with extinction globally, totaling 28% of all species assessed.[36] Within Canada, under the federal Species at Risk Act (SARA) there are over 600 plant and animal species at-risk and an additional 150 species currently under threat of being listed.[37] Ontario houses 234 of these species at-risk, with 51 species being of special concern, 55 threatened, 113 endangered, and 12 extirpated.[38] According to the Endangered Species Act 2007, a species is classified as special concern if it "may become threatened or endangered because of a combination of biological characteristics and identified threats," threatened if it is "likely to become endangered if steps are not taken to address factors threatening to lead to its extinction or extirpation," endangered if "facing imminent extinction or extirpation," and extirpated if it once lived in Ontario but currently exists elsewhere in the world.[39] This classification system emphasizes the urgency of these species at-risk and suggests an opportunity to provide further protection.

In response to the increasing number of species at-risk, global conservation efforts focus primarily on identifying Key Biodiversity Areas and providing efforts to manage and preserve them. These Key Biodiverse Areas are crucial to preserving global biodiversity, however few environments remain ecologically intact are eligible of receiving support.[40] The ecologically intactness of a site refers to an ecosystems composition, structure, and function remaining within historical and natural ranges of variation.[41] The current Standard of Assessment of a site's Ecological Intactness uses the measurement of anthropogenic impacts on an area rather than an ecosystem's overall biodiversity as the determining scale, limiting human influenced areas from receiving ecological support. [42]Additionally, these efforts primarily focus on habitats within conservation areas, making it difficult to determine significant environmental conditions within urban, suburban, and even rural areas.[43] Efforts are now being made to challenge this standard of assessment. Rather than determining key biodiverse areas by their anthropogenic impacts, they are instead measured by its contribution and recovery of biodiversity, allowing for more areas to qualify as Key Biodiverse Areas eligible of conservation support.

36 "The IUCN Red List of threatened Species," The IUCN Red List, IUCN Red List, last modified 2022, https://www.iucnredlist.org/.

37 "Understanding Species Status Listing," Endangered and threatened Species, WWF, last modified 2022, https://wwf.ca/wildlife/.

38 "Species at risk in Ontario," Government of Ontario, last modified April 01, 2022, https://www.ontario.ca/page/species-risk-ontario.

39 "Endangered Species Act, 2007, S.O. 2007, c. 6," Government of Ontario, last modified October 19, 2021, https://www.ontario.ca/laws/statute/07e06.

40 Daniele Baisero et al., "Where Might We Find Ecologically Intact Communities," Frontiers: In Forests and Global Change, 4, no. 626635 (April 2021): 2, https://doi.org/10.3389/ffgc.2021.626635.

41 Baisero et al.,"Where Might We Find Ecologically Intact Communities," 2.

42 Ibid.

43 Le Roux and Nocera, "Roost sites of chimney swift (Chaetura pelagica) form large-scale spatial networks," 3820.

Sudbury Ontario, Canada

The City of Greater Sudbury is the largest urban centre in Northeastern Ontario, Canada, and commonly known for being home to one of the world's largest smelting complexes, industrial barrens, moon like landscape, and acidic lakes, housing 50 of the provinces at-risk species (Fig. 05).[44] A standard assessment of the region's ecological intactness would determine high levels of anthropogenic impact, labeling it as a non-Key Biodiverse Area. However, through decades of ecological stewardship in the implementation of the cities Regreening Program it has become a globally influential story of environmental rehabilitation, making it of special interest to the study of species and their recovery.[45] By examining the process in which Sudbury was formed, exploited, and Regreened, the potential for successful human intervention on biodiversity can be better understood.
Approximately 7700 years ago Sudbury's landscape began to vegetate with native boreal forest species after the great glacial advances eroded and deposited debris throughout the landscape, trapping meltwater within its craters and forming many of the 330 lakes located within the city limits.[46] This forest structure began to evolve and later became largely populated by species of the Great Lakes - St. Lawrence Forest, making up the region's natural forest today.[47]

Although the series of events that shaped the formation of Sudbury date back millions of years, its human history spans less than 1000 years.[48] The Anishinaabe people first sparsely populated the region, being it was an area on an outer periphery of their Sault Ste. Marie, Manitoulin Island, the French River, and North Bay communities.[49] As the Hudson Bay Company's fur trade began activity in the area in 1824, it was around 1871 with the introduction of selective logging to the region that human impacts on the landscape began (Fig. 06).[50] The large red and white pine trees of the Sudbury Region were felled and floated down stream to Georgian Bay and Lake Huron where they were then rafted into the northern United States (Fig. 07).[51] As selective logging of the region's larger pines continued, the impact on the forest's structure and biodiversity remained minimal, allowing for quick successional species such as white birch and aspens to colonize.[52]

Sudbury was still largely unknown at this point, and it was not until the passing of the Public Lands Act allowing for the construction of colonization roads into unsettled lands that the emergence of the north truly began.[53] In 1883 human impacts on the environment

44 Gunn, *Restoration and recovery of an Industrial Region*, vii; Autumn Watkinson, Myra Juckers, Liana D'Andrea, Peter Beckett, and Graeme Spiers, "Ecosystem Recovery of the Sudbury Technogenic Barrens 30 Years Post-Restoration," *Eurasian Soil Science* 55, no.5, (December 30, 2021): 663.

45 City of Greater Sudbury, "Greater Sudbury Natural Heritage Report," *Official Plan Officiel,* (May 2013): 30; Baisero et al.,"Where Might We Find Ecologically Intact Communities," 2.

46 David Pearson, John Gunn, & Bill Keller, "The Past, Present and Future of Sudbury's Lakes," In *The Physical Environment of the City of Greater Sudbury*, ed. D.H. Rousell and K.J. Jansons (Ontario Geological Survey, 2002), 195.

47 Gunn, Restoration and recovery of an Industrial Region, 17; Watkinson, Juckers, D'Andrea, Beckett, and Spiers, "Ecosystem Recovery of the Sudbury Technogenic Barrens 30 Years Post-Restoration,"663.

48 Gunn, *Restoration and recovery of an Industrial Region*, 17.

49 Ibid, 17.

50 Ibid.

51 Ibid.

52 Ibid, 18.

53 Oiva W. Saarinen, From *Meteorite Impact To Constellation City: A Historical Geography of Greater Sudbury* (Wilfrid Laurier:

became evident as the Canadian Pacific Railway was rerouted north, blasting through the region's igneous complex and uncovering the rich deposits of metals in Sudbury.[54] Sudbury's lumber production increased dramatically to support the railways wood burning locomotives, rail ties, and pit timbers, increasing forest fires within the region.[55] This process of logging began to alter the forest structure much differently than that of minimal or natural disturbances (Fig. 08). Where natural disturbances enhance a regions heterogeneity whereas rapid logging and burning 'salvages' timber before it becomes compromised by other species and natural processes, reducing the forests biodiversity and altering its natural cycles (Fig. 09).[56]

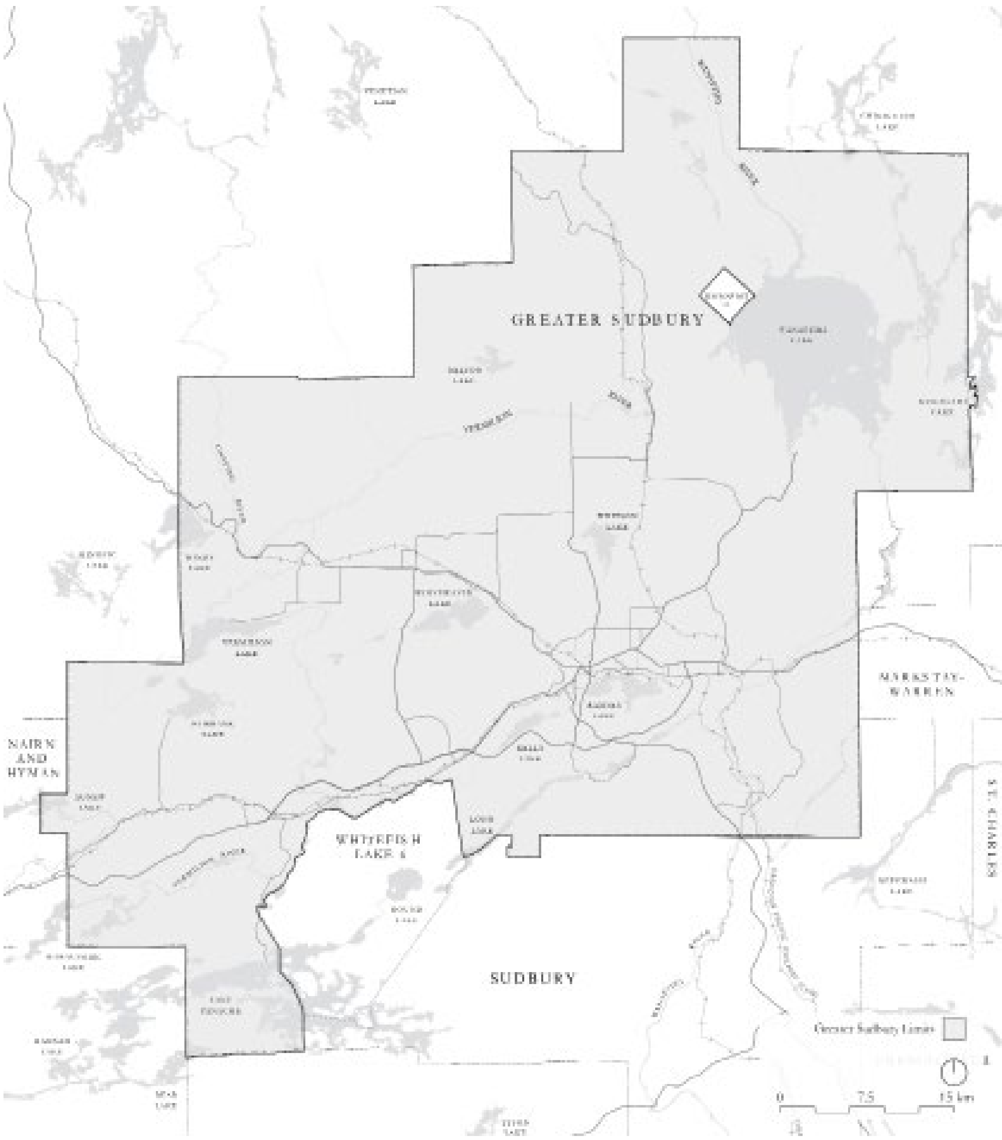


Figure 05 **| The City of Greater Sudbury Aerial Map**
This map identifies the relationship between the City of Sudbury and its surrounding landscape and industrial context.

University Press, 2013), 38.

54 Saarinen, *From Meteorite Impact To Constellation City,* 50.

55 Gunn, *Restoration and recovery of an Industrial Region*, 18..

56 "Ecological Succession," Ecological Succession Definition, Biology Dictionary, last modified October 4, 2019, https://biologydictionary.net/ecological-succession; Simon Thorn, et al., " Impacts of salvage logging on biodiversity: A meta-analysis," J*ournal of Applied Ecology* 55, no.1 (January 2018): 279, doi: 10.1111/1365-2664.12945.

The first successful mining company opened in Sudbury in 1885, serving as the area's first smelter in 1888.[57] These early mines functioned as open pit operations, using roasting yards to process ore. Approximately 3.3 million m3 of wood was harvested from the region between 1888 and 1929, removing nearly all surrounding vegetation to support the open pit operations.[58] Crushed ore was piled on top of beds of wood and ignited for months on end, releasing sulfur dioxide into the atmosphere damaging any remaining vegetation (Fig. 10), generating 20 000 hectares of barren and 80 000 hectares of semi-barren land (Fig. 12).[59] Over the next century Sudbury would experience over 100 mines in operation, smelt 28 million tons of ore, and release 10 million tons of sulphur dioxide at the ground level resulting in mass vegetative expiration and habitat loss (Fig. 11).[60]

Without the protective covering of vegetation soil quickly eroded, exposing bedrock that became blackened by smelter emissions, entering Sudbury into an ecologically barren landscape capable of only supporting very few terrestrial plants and animals tolerant of extreme conditions. Damage to terrestrial ecosystems reached their apex in the 1960s, fragmenting and destroying the region's forested habitats, forcing the retreat of many of the region's terrestrial species. Although the most visually prominent damages occurred

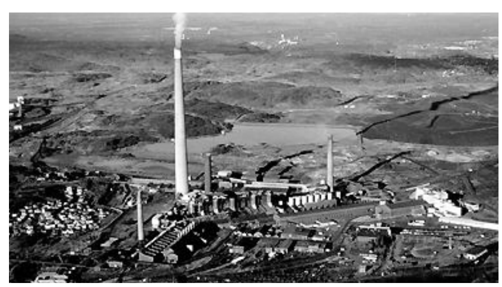


Figure 06 | **Sudbury, Ontario Selective Logging**
[Top left]

Figure 07 | **Sudbury, Ontario Felled Pines**
[Top right]

Figure 08 | **Sudbury, Ontario Increased Logging**
[Middle left]

Figure 09 | **Sudbury, Ontario Altered Landscape**
[Middle right]

Figure 10 | **Sudbury, Ontario Open Pit Operations**
[Bottom left]

Figure 11 | **Sudbury, Ontario Mining Complex**
[Bottom right]

57 Saarinen, *From Meteorite Impact To Constellation City*, 50.
58 Gunn, *Restoration and recovery of an Industrial Region*, 21.
59 Gunn, *Restoration and recovery of an Industrial Region*, 21; Watkinson, Juckers, D'Andrea, Beckett, and Spiers, "Ecosystem Recovery of the Sudbury Technogenic Barrens 30 Years Post-Restoration," 663.
60 Bill Bradley, "Digging Through the Sudbury Soils Study," Republic of Mining, last modified June 13, 2008, https://republicofmining.com/2008/06/13/digging-through-the-sudbury-soils-study-by-bill-bradley/.

with the barren rings, remote areas northeast and southwest of Sudbury contain the majority of 7000 lakes damaged by smelter emissions.[61] The atmospheric deposition of emissions covered over 17,000 km2 up to 120 km away, leaving approximately 134 local strains of fish extirpated, the absence or extreme scarcity of molluscs, amphipods, mayflies, crayfish and organisms at various aquatic trophic levels, such as zooplankton, phytoplankton, and benthic invertebrates.[62] In addition, the acidification of Sudbury's waterways posed a serious threat to waterfowl and amphibian species, as changes in the composition, abundance and nutrition of food sources significantly reduced the quality of their nesting and feeding habitats.[63]

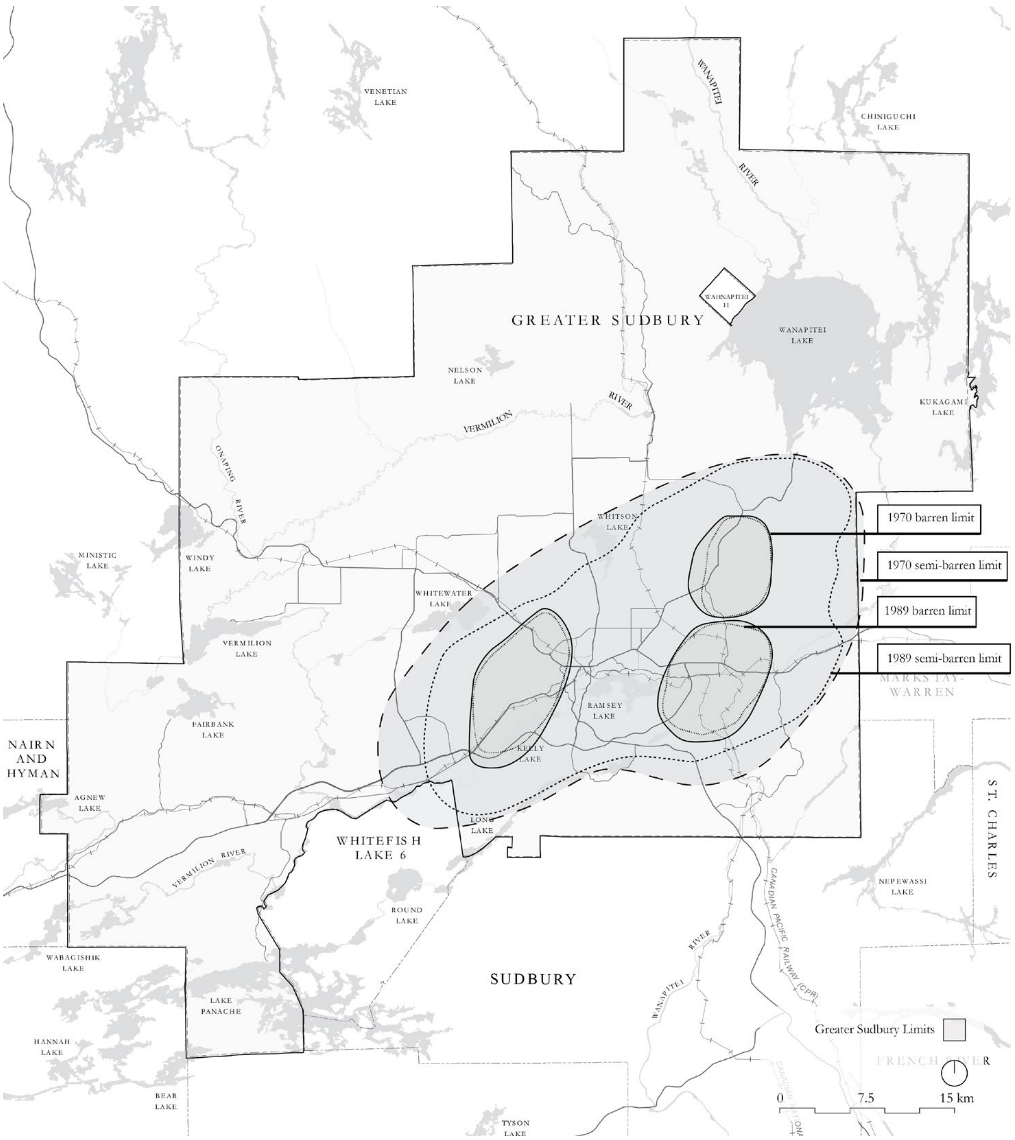


Figure 12 | **Sudbury Barren Rings**
This map indicates the barren and semi-barren land impacted by the mining operations within the Greater Sudbury region.

61 Gunn, *Restoration and recovery of an Industrial Region*, 67.

62 Ibid, 30, 143; Bill Keller, Jocelyne Heneberry, and John Gunn, "Effects of emission reductions from the Sudbury smelters on the recovery of acid- and metal-damaged lakes," *Journal of Aquatic Ecosystem Stress and Recovery* 6, no.3 (1999): 189, http://dx.doi.org/10.1023/A:1009975116685; Bill Keller, Jocelyne Heneberry, John Gunn, Ed Snucins, George Morgan, and Julie Leduc, "Recovery of Acid and Metal - Damaged Lakes Near Sudbury Ontario: Trends and Status," *Cooperative Freshwater Ecology Unit,* (July 1, 2004): 26, www.coopunit.laurentian.ca/sudlake.pdf.

63 Gunn, *Restoration and recovery of an Industrial Region*, 205.

The severe toxicity of the region generated conditions that were unlikely to develop into rapid natural recovery, and in 1974 the Regional Municipality of Sudbury began addressing the need for human intervention through the implementation of a city wide Regreening effort.[64] The Regreening program directed its focus towards the recreation of a viable and functional ecosystem made up of healthy soils, waters, plants, and animals; restoring the chemical makeup of the environment, creating ecosystems that are capable of growing and self-sustaining, and restoring the biological diversity of the area.[65] This developing field of restoration; restoration ecology, kickstarted Sudbury's recovery process by gradually restoring the integrity of its damaged ecosystem.

Initial restoration experiments of liming, seeding, and planting of various reclaimed sites determined that the process of liming using crushed dolomitic limestones was the first step needed to detoxify the region's acidic soils by increasing pH content to habitable levels.[66] The first few years after treatment showed no sign of coniferous tree growth and only quick successional species such as birch and poplar. Any early attempts to plant saplings were largely unsuccessful, however with continued liming and seeding of herbaceous species providing shade and soil moisture, the planting of conifers and other species became possible (Fig. 13).[67]

[Limed, fertilized and seeded in 1979]
[Trees planted in 1987]

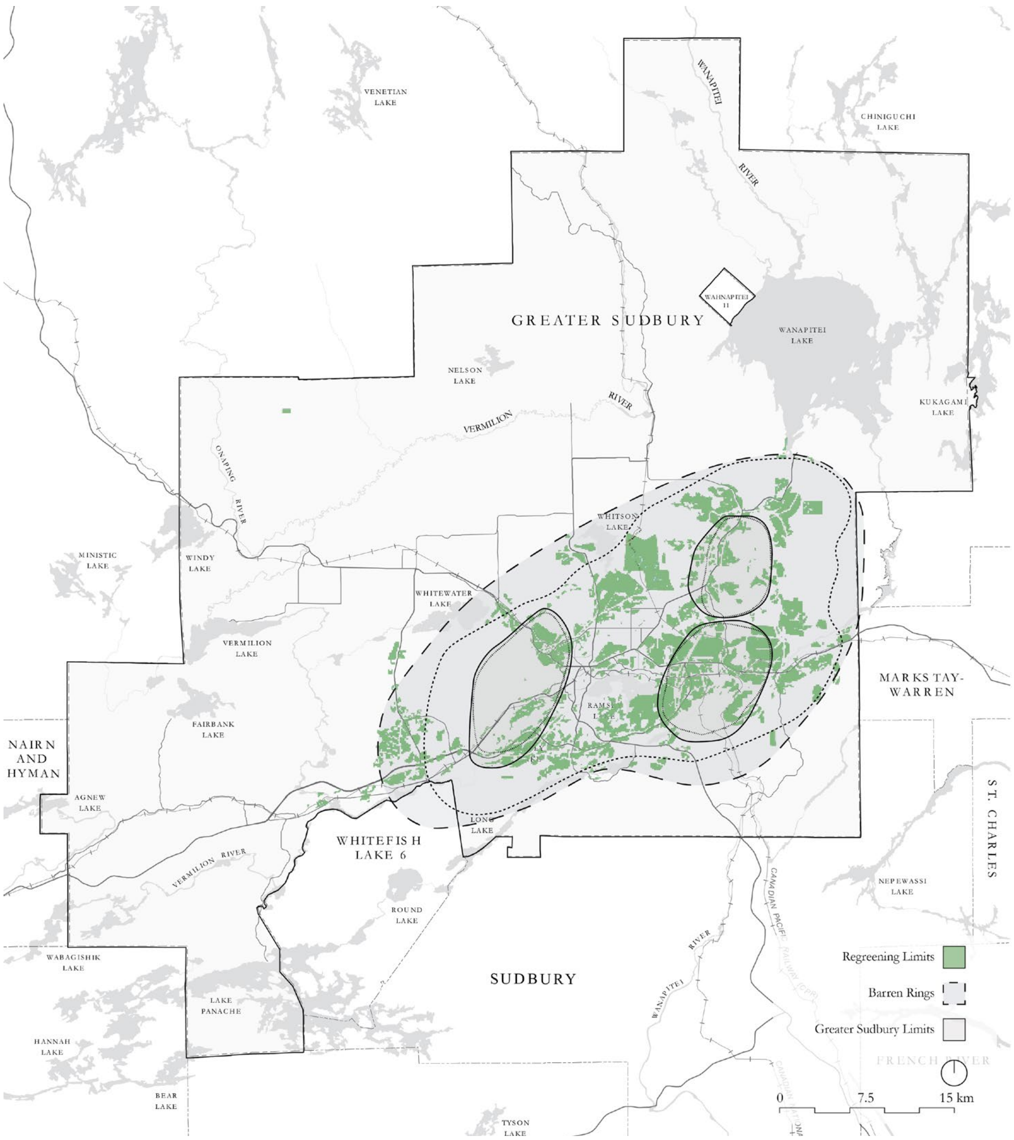
[Untreated]

[Limed in 1997]

Figure 13| S**udbury Regreening**
This photo showcases the success of Sudbury's Regreening program in ecological recovery. Three barren hilltops have received separate treatments in an effort to monitor their recovery; the barren site receiving lime, fertilizer, seeding, and tree planting demonstrating the most recovery.

64 Ibid, 109.
65 Ibid, 106.
66 M. McKergow, R. Narendrula-Kotha, P. Beckett, and K. K. Nkongolo, "Microbial Biomass and Activity Dynamics in Restored Lands in a Metal Contaminated Region," *Ecotoxicology*, (December 30, 2021): 1958, https://doi.org/10.1007/s10646-021-02464-9.
67 Gunn, *Restoration and recovery of an Industrial Region,* 113.

In 1983 the first large scale tree planting season planted 228 000 trees, and since then, the Regreening program has limed and seeded over 3,400 hectares of land and planted 10 million trees, resulting in the gradual return of biodiversity to the Sudbury area (Fig. 14).[68] To date, by means of successful human intervention, restoration efforts have allowed for approximately 250 vascular plant species, 20 moss species, 50 lichen species, 16 mammals, and 80 bird species to return to the region.[69] However, there is still much work to be done.



68 Gunn, *Restoration and recovery of an Industrial Region*, 109, 113, 120; "Regreening Program," City of Greater Sudbury, accessed September 29, 2022, https://www.greatersudbury.ca/live/environment-and-sustainability1/regreening-program/.
69 The Vermilion Forest Management Company Ltd, "2020-2030 Sudbury Forest Management Plan," *Ministry of Natural Resources and Forestry's Sudbury District,* (April 1, 2020): 15; Peter Beckett, "Over 40 years of creating restored ecosystems on a smelter impacted landscape of Sudbury, Ontario, Canada," *Regreening Reverdissement*, (June, 2022): 72.

Figure 14 | **Sudbury Regreening Map**
This map indicates the areas of land recieving Regreening treatments in response to the barren rings within the Greater Sudbury region.

Architectural Practice

The United Nations Convention on Biodiversity defines Biological Diversity as "the variability among living organisms from all sources including, inter alia, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species and of ecosystems."[70] Where Ecosystem "means a dynamic complex of plant, animal and micro-organism communities and their non-living environment interacting as a functional unit."[71] Coinciding with this definition, architecture seeks to create these non-living environments, otherwise known as the built environment, for a single species, i.e., humans. However, the developing global biodiversity and climate crisis demand further ecological advancements within the architectural discipline.

The built environment is inextricably bound to the ecologies that it inhibits and therefore must function as an extension of its ecosystem rather than a contributor to its depletion. By recognizing our responsibility as contributors to the greater ecology, it is here that we can begin to question how the built environment can be rethought as an architectural and ecological space where humans, nature, and other species mutually coexist. Contending a greater attention be directed toward supporting ecology directly within the built environment itself, the paradigm shift from single-species to biodiverse built environments begins.

While the built environment has been shown to significantly contribute to the loss of biodiversity, approaching it as the extension of an ecosystem we are now provided with the greatest potential to support ecologies.[72] Prioritizing multi-species design to address ecological depletion, this shift in thinking enables the majority of architectural practices who have not yet considered nor have the vocabulary to address these pressing issues. Ecological Succession is a fundamental concept in ecology to refer to the way in which healthy ecosystems function; as the non-linear process of change that occurs for a species structure within its environment over time, where different communities generate conditions that subsequently allow for other communities to develop.[73] Existing in two main successions, ecological succession begin as either entirely new environments being created and colonized by pioneer species for the first time (primary succession), or resulting from disturbances which restart the cycle of succession to where soil and nutrients are still present (secondary succession).[74]

70 "Article 2. Use of Terms," Convention Text, The Convention on Biological Diversity (CBD), last modified February 11, 2006, https://www.cbd.int/convention/articles/?a=cbd-02#:~:text=%22Biological%20diversity%22%20means%20the%20variability,between%20species%20and%20of%20ecosystems.

71 The Convention on Biological Diversity (CBD), "Article 2. Use of Terms."

72 Alex Opoku, "Biodiversity and the Built Environment: Implications for the Sustainable Development Goals (SDGs)," *Resources, Conservation and Recycling* 141, (February 1, 2019): 2, doi:10.1016/j.resconrec.2018.10.011.

73 "Ecological Succession," Definition, Britannica, last modified Nov 28, 2022, https://www.britannica.com/science/ecological-succession.

74 Biology Dictionary, "Ecological Succession."

Where by this definition, the built environment is created as a result of disturbances to an existing environment resulting in the halt and decline in ecology, and rather should seek to follow a third, tertiary succession, where human intervention builds upon existing ecologies to further accelerate the successional process.

By rethinking the built environment as an extension of ecologies, this thesis mobilizes the new concept of Architectural Succession to address the process of change occurring for a built environment and its inhabitants over time. This fluid state of designing challenges static design approaches for a single-species, and encourages the collaboration and inhabitation between species. This thesis seeks to question how architects can design for Architectural Succession by approaching the built environment as a multispecies collaboration.

Chapter 2: Single-Species Design

The human population does not exist in isolation. On a biological, cultural, and social level, Human existence is forever entangled with all other species as part of the larger planetary ecosystem. As active contributors to the ecosystem, human actions hold the potential to cause vast consequences or great benefits for all biotic and abiotic entities.[75] Where now the ability to respond to global biodiversity loss stands as the responsibility of the designers of the built environment, reframing our contributions to this environment as ecologically significant.

As architecture provides the space in which the human species exist, the concept of other species in the built environment should come as no surprise, however up until the 21st century non-human species studies as a subfield in cultural spatial inquiry was often overlooked.[76] Animal Studies have recently begun rejecting the long-standing Western philosophical concepts of human non-human separation, and began encouraging encounters with other species as opposed to existing in separation from them.[77] Where the human-centered utilitarian justification for conserving ecological biodiversity often focuses on the materialistic benefits the environment can offer, such as raw material extraction, the biological purpose of ecosystems provide air and water quality, the generation and protection of soil, climate control, nutrient cycling, food source, and protection for all levels of biological communities.[78] Various cultural, religious, and environmental groups support bioethical arguments that every species has the fundamental right to exist independently of human material benefits.[79] However, the largely Western centric world of architecture actively practices in opposition of this mindset.

75 Michel Serres, *The Natural Contract*, trans. Elizabeth MacArthur, and William Paulson (Ann Arbor: The University of Michigan Press, 2011), 4.

76 "Animal Infrastructures: Building across Species," *Architectural Review*, Bushra Tellisi, February 3, 2022, https://www.architectural-review.com/essays/keynote/animal-infrastructures-building-across-species.

77 Tellisi, "Animal Infrastructures: Building across Species."

78 "Article 2. Use of Terms," Convention Text, The Convention on Biological Diversity (CBD), last modified February 11, 2006, https://www.cbd.int/convention/articles/?a=cbd-02#:~:text=%22Biological%20diversity%22%20means%20the%20variability,between%20species%20and%20of%20ecosystems.

79 E Szűcs, R Geers, T Jezierski, EN Sossidou, DM Broom, "Animal welfare in different human cultures, traditions and religious faiths," *Asian-Australas J Anim Sci.* (2012): 1499, https://doi.org/10.5713/ajas.2012.r.02.

Theory, Philosophy & Gaps

The French humanities Philosopher Michel Serres in the age of posthuman culture accurately summarizes the theoretical shift in approach towards the agency of the natural world in the 21st century. Highlighting the crises and paradoxes of human participation and separation from the environment, Serres offers the notion of a 'Natural Contract' to symbiosis, where the key to human survival lies in the ability to recognize our dependance on the health of the planet in its entirety. Suggesting that we have forgotten nature, Serres states that humans are no longer speaking meaningfully of the environment and only making decisions about it and transforming it into our own commodities, which is highly reflective of modern Western societies materialistic motives towards the environmental crisis.[80] Serres argues that civilization is working negatively towards damaging a system (ecosystem) that has functioned for millions of years without us, only to be interrupted by us, where the total sum of harm inflicted on the world outweighs the damage a world war could have possibly produced.[81]

Serres bases his theory on the Social Contract, a concept that philosophers of law suggest guided humans away from nature and into society, and the Natural Law, existing outside society to govern all.[82] As for humans, nature has been reduced to human nature, and human nature to history or reason, where from the social contract derives Serres' 'Natural Contract' of symbiosis and reciprocity. This Natural Contract is proposed as the grounds in which human material value matters less in comparison to that of the health of the ecosystem as a whole. Recognizing that all species and environmental relationships are interwoven, with even the smallest of actions human influence can cause vast consequences for all entities. Serres argues that Western cultures have positioned themselves at the center of the earth, to which all other communities of ecosystems revolve around, and proposes the removal of this hierarchy of human order over nature-animal-environment, for a wider ecological integration to be achieved (Fig. 15).[83]

Serres speaks in response to the rising environmental crisis as the damage to a system of order and law between human and non-human communities, uniting only through the single sided signing of the Natural contract. However, not once referencing the biological

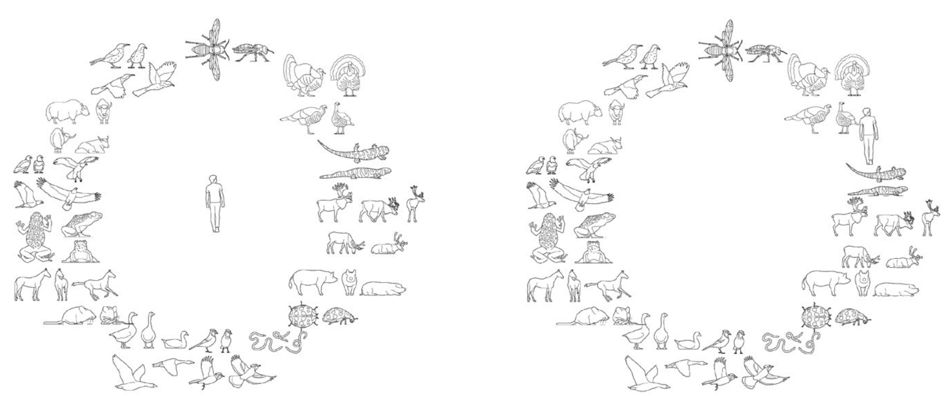


Figure 15 | **Natural Contract**
This diagram synthesizes Michel Serres Natural Contract, where the first diagram represents Western cultures positioning of humans significance at the centre of all other species, and the second diagram represents the removal of this hierarchy where human is acknowledged as only one of the many species on earth.

80 Serres, *The Natural Contract,* 33.
81 Ibid, 32.
82 Ibid, 34.
83 Ibid, 33.

sciences, ecology or ecosystem, to describe humans' existence within nature. By excluding this fundamental and biological relationship, Michel Serres Natural Contract is in many ways representative of the past and present challenges in shifting theoretical and systematic approaches to include both ecology and humans within the built environment.

In line with culturally and environmentally sensitive perspectives on human non-human relationships, multispecies feminist theorist and biologist Donna Haraway has combined her knowledge of biology with philosophy to offer new and provocative ways of reconnecting human relations to the earth and all its species. Haraway urges humans that the sixth greatest extinction, unlike previous extinctions caused by natural phenomena, is actively driven by human activities of unsustainable land use, water and energy use, climate change, etc., urging humans to rethink our relationships with non-human beings by 'making kin' to construct a heterogeneous multispecies community for all.[84]

Haraway's theory falls within the post-humanistic perspective, responding to the presence of the anthropocene and addressing how Western-centric societies' idea of humans, both in their being and species are the superior entity, has essentially removed all liability for human action on biological, chemical, physical and organic lives and habitats.[85] These 'inherited' hierarchies place humans over other species, whereas other environmentally sensitive and ecologically grounded cultures have recognized the importance in the sharing of this ecosystem. Addressing concerns not only for the contemporary life sciences but as well for the biological sciences, Haraway attempts to move away from our currently limited vocabulary focused solely on the individual and into a more encompassing way of thinking and practicing.[86] This collective call for action towards human driven ecological devastation reframes the 'Anthropocene' as the 'Chthulucene.' Chthulucene critiques the limitations of linear solution narratives of a 'self-making' mindset into a more tangible and constantly evolving method of 'making-with,' in order to describe the ways more accurately in which human and non-human are interconnected (Fig. 16).[87]

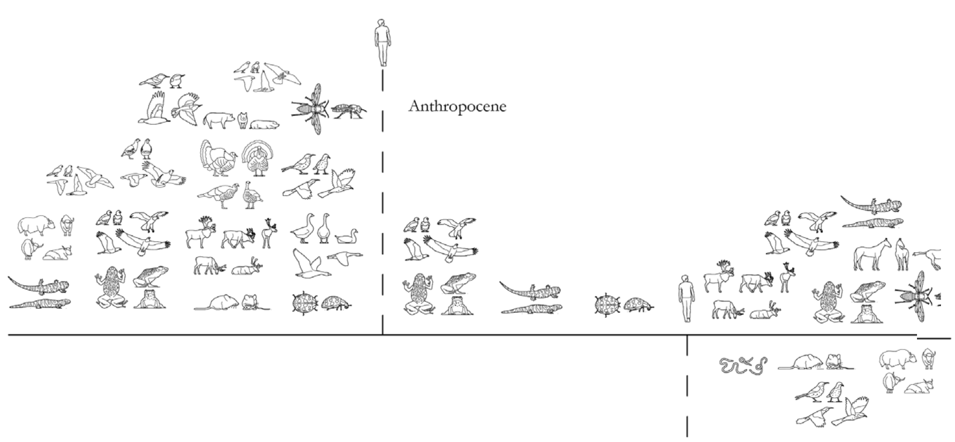


Figure 16 | **Anthropocene Towards Chthulucene**
This diagram represents Haraways post-humanistic perspective where through the introduction of human influence and the anthropocene, species have been impacted, and it is through the chthulucene that a new way of existing in harmony can begin to emerge.

84 Donna Jeanne Haraway, *Staying with the Trouble: Making Kin in the Chthulucene* (Durham: Duke University Press, 2016) 99; "What is the sixth mass extinction and what can we do about it?" World Wildlife Fund, last modified March 15, 2022, https://www.worldwildlife.org/stories/what-is-the-sixth-mass-extinction-and-what-can-we-do -about-it.
85 Haraway, S*taying with the Trouble: Making Kin in the Chthulucene,* 100.
86 Ibid,102.
87 Ibid, 101.

Shifting this theoretical notion of the 'other' into a physical place, the built environment, calls upon a new approach to design. As architects and designers of the built environment are, of course, already familiar with the need to design for sensitive inclusive spaces that respond to a community's needs, the necessity to design heterogeneous multispecies communities falls somewhere within the upper boundaries of their expertise. Situating theory into practice, the built environment can offer the space in which biologically diverse ecologies can develop, where humans are not only designing for themselves, but unconsciously and now very consciously designing for all ecologies.

Single-Species

While in recent decades there has been increasing attention to sustainable design, current design strategies primarily focus on a building's performance toward the reduction of its carbon footprint.[88] The terminology surrounding Sustainable Design has been adopted by many buildings due to their ability to lower environmental impact to some degree, however that is not enough to be deemed sustainable. Sustainable buildings are often designed as merely highly efficient technologies to sustain their performance at the benefit of a single species (humans), rather than to support a greater ecology.[89] Terms more suitable for describing designs that are ecologically sustainable would be restorative or ecological design which seek to maximize the quality of the built environment and minimize the effects on the natural environment. However, even these best practices only seek to minimize ecological damages, rather than provide opportunities to continue an environment's natural successional process.

With the growing movement of green and sustainable practices, it is essential to question the intentions in which we design our buildings, communities, and cities in order to achieve an ecological approach. By choosing to neglect the need for a sustainable design practice that both benefits the ecological community as well as its primary intended users, a gap in the logic of sustainability has been created, and it is through the altering of design practices to follow an ecological led approach that we can begin to question how to design a built environment for both.

The relatively new branch of ecology, Reconciliation Ecology, examines the different ways of encouraging a cultural and theoretical shift in biodiversity within ecosystems dominated by humans.[90] As a practical solution, this form of ecology proposes a third field of sustainability which modifies and diversifies anthropogenic habitats to support a more diverse range of species while maintaining land use and function, particularly within dense urbanized environments.[91] Differing from the process of setting aside land to form a landscaped and ecological friendly environment separate from the overall site program, and separate from ecological restoration or rehabilitation which restore previous ecosystem conditions, this approach applies bottom-up techniques for improving urban

88 Jason F. McLennan, *The Philosophy of Sustainable Design* (Kansas City: Ecotone Publishing, 2004), 2, 3.
89 McLennan, *The Philosophy of Sustainable Design*, 2.
90 Robert A. Francis and Jamie Lorimer, "Urban reconciliation ecology: The potential of living roofs and walls," J*ournal of Environmental Management* 92, no.6 (2011):1429, https://doi.org/10.1016/j.jenvman.2011.01.012.
91 Francis and Lorimer, "Urban reconciliation ecology: The potential of living roofs and walls," 1432.

biodiversity through the implementation of living roofs and walls to new and existing infrastructure.[92]

This field of study begins to recognize the necessity for human participation to actively provide these ecological habitats within the built environment. However, it provides only surface level solutions. As the density of biodiversity required within an ecosystem to achieve a healthy biodiverse area is far more complex than what can be supported by merely living roofs and walls.[93] Nonetheless, Reconciliation Ecology is a positive step towards an ecological diverse built environment.

Barns, Sheds, & More

Architecture, traditionally the practice of designing and constructing structures intended for the use by a single user, humans, is in a critical moment of transition. Where in order to sustain current architectural practices and reduce climate change, unsustainable land-water-energy use, and global ecological depletion, a change in approach is drastically needed to address how to design for multiple species in the built environment. As other species are gradually approaching the forefront of design conversation, designers have begun to question how to provide habitat for them in an environment that is no longer providing adequate conditions for their survival.

Entire ecosystems are now influenced by human activity, structuring the formation of the natural environment by lines drawn by roadways, walls, fences, and chicken wire, where even interventions designed to support them are in a sense, to support us.[94] Trends in recent urban and regional planning suggest that issues on depleting biodiversity are becoming increasingly prominent as human infrastructures encroach further and further into the habitats of other species.[95] As seen by the increased implementation of migration corridors for wildlife within areas separated by human activities such as roads and various infrastructures, the necessity to maintain species circulation paths as well as reduce injuries and fatalities are both caused and resolved by human intervention.[96] By providing infrastructure intended for the physical use by other species, fragmented ecosystems can begin to relink and limit the depletion of ecologies, however to what degree are these interventions actually intended to support other species rather than to support us?

Animal activists, environmentalists, and select architects have begun to explore strategies to increase the social and political awareness of biodiversity loss by providing species specific built habitats and architectures to draw attention to this matter.[97] The phrase 'animal architecture' refers to a wide variety of structures built by or for another species,

92 Ibid, 1429.

93 World Wildlife Fund, "What is the sixth mass extinction and what can we do about it?"

94 Mollard, Manon, Eleanor Beaumont, Max Zarzycki, and Ellen Peirson, "Animal Crossing," *Architectural Review,* (February 1, 2022), https://www.architectural-review.com/essays/letters-from-the-editor/editorial-animal-crossing.

95 "Living Among Pests," Ants of The Prairie, last modified 2022, https://www.antsoftheprairie.com/?page_id=1589.

96 Mollard, Manon, Eleanor Beaumont, Max Zarzycki, and Ellen Peirson, "Animal Crossing."

97 Megan Stokes, and Rajjan Man Chitrakar, "Designing 'Other' Citizens into the City: Investigating Perceptions of Architectural Opportunities for Wildlife Habitat in the Brisbane CBD" *QUThinking Conference: Research and Ideas for the Built Environment,* (2012): 3.

such as nests, burrows, dens, roosts, coops, houses, barns, semi-detached structures, towers, among others.[98] These animal architectural structures take into account a wide range of complex species types, behaviors and requirements to support a specific single species habitation.[99]

Traditional typologies of animal architecture consist of designs such as bird houses or beehive boxes where specific species or colonies are targeted and provided with shelter within the human-built environment, typically removed from human dwellings and functioning as some additional use or purpose for Humans. Additionally, surrogate habitats such as chimney swift towers and insect hotels have been directed at providing critical habitats for select at-risk species (Fig. 17, 18). In recognizing the need to provide additional habitats within the built environment, designs have begun to integrate other species architecture into the facades of buildings, such as bee bricks, nesting shingles, and bat boxes (Fig. 19, 20, 21). Whereby examining architecture's current relationship with non-human design, specific species parameters and social expectations can be determined.

Figure 17 | **Chimney Swift Tower**
[Top left]

Figure 18 | **Insect Hotel**
[Top right]

Figure 19 | **Birdhouse Shingle**
[Bottom left]

Figure 20 | **Bee Brick**
[Bottom center]

Figure 21 | **Bat Box**
[Bottom right]

98 Tom Wilkinson, "Typology: Buildings for Animals," *Architectural Review*, (April 16, 2018) https://www.architectural-review.com/essays/typology/typology-buildings-for-animals.

99 Mike Hansell, "The Builders," in *Built by Animals: The Natural History of Animal Architecture*, (Oxford: Oxford University Press, 2009), 5.

Non-human designs such as architect Joyce Hwang's Bat Tower explore strategies for increasing the awareness of bats as crucial members of ecosystems, as well as providing habitat to endangered species by constructing large scale prototypes of a series of bat habitation installations (Fig. 22).[100] As bats are crucial members of ecosystems, this structure is located within a moderately foot trafficked greenspace to contribute to the greater ecology of the region as well as provide access to the bats primary food source near the wetland.[101] Designed as a vertical cave with a series of grooved interior wooden panels, this installation mimics the natural habitats of bats, while simultaneously furthering the design of small scale bat boxes (Fig. 23, 24). Addressing the need for architecturally driven habitats, this installation demonstrates how a single species can greatly benefit from human intervention by design.

Figure 22 | **Bat Tower Interior**
This photo shows the structures slatted plywood material intended to be inhabited by the bats.
[Top]

Figure 23 | **Bat Tower Exterior**
[Bottom left]

Figure 24 | **Bat Tower Above**
[Bottom right]

100 "Bat Tower," Ants of the Prairie Architecture, last modified 2022, http://www.antsoftheprairie.com/?page_id=203.
101 Ants of the Prairie Architecture, "Bat Tower."

Similarly, other species at risk of habitat loss have been provided with surrogate structures such as the University at Buffalo School of Architecture and Planning's Elevator B project. Elevator B is a design intervention relocating a colony of honeybees occupying a grain elevator in an industrial area into a permanent habitat structure (Fig. 25).[102] Designed using a honeycombed steel structure and cladded in perforated stainless steel, this choice in unnatural materials provides extended protection from the elements, as well as allows for solar gain and shading (Fig. 26).[103] Taking into consideration an aesthetic gesture, the design visually regenerates the brownfield site for human purposes, including the opportunity for human observation of the bee colony through a glass bottom.[104]

It can be noted that undistributed and ecologically diverse environments continue to provide the highest levels of biodiversity and success rates, however as the built environment expands into these regions, human intervention and habitat structures are gradually providing additional support.[105] Determining both the practical and behavioral

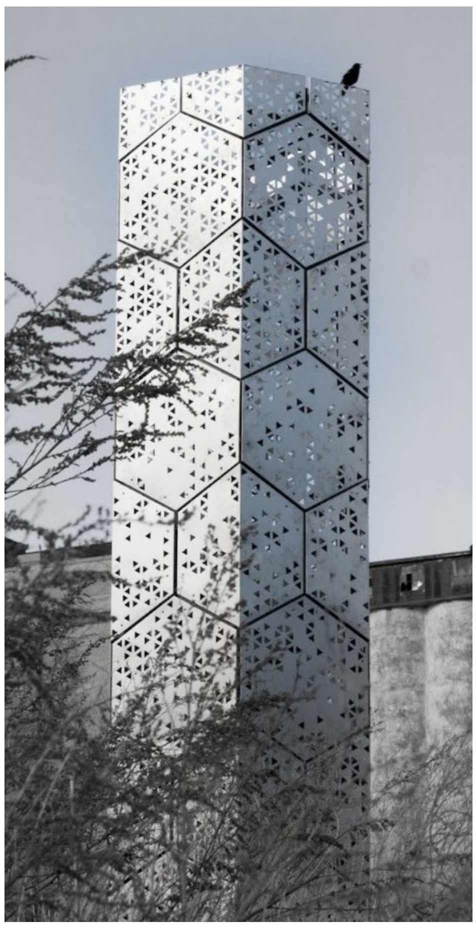


Figure 25 | **Elevator B Exterior** [Left]

Figure 26 | **Elevator B Interior** [Right]

102 "A B/a+p design competition," Hive City, last modified 2013, https://hivecity.wordpress.com/about/.
103 Hive City, "A B/a+p design competition."
104 Ibid.
105 Stokes, and Chitrakar, "Designing 'Other' Citizens into the City: Investigating Perceptions of Architectural Opportunities for Wildlife Habitat in the Brisbane CBD," 8.

requirements of species-specific habitats is an essential approach to designing ecological extensions of the built environment. The active and passive involvement of human participation in this process forms positive connections that drive environmental stewardship surrounding a specific species or site.[106] The social activism aspect of these designs, either through interaction or aesthetics, draws attention to the ecological concerns of a community and increases knowledge surrounding the individual's contribution.

The choice to use natural and or unnatural materials in a design brings forward the conflict of human aesthetics, order, and permanence versus the fundamental environmental processes of function, decay, and succession. Each design, given that it has been intentionally created, uniquely conveys an individual perspective and creative approach completed by human order, and as such is challenging - if not impossible - to remove all sense of aesthetic purpose. In addition to these examples, various precedents focus on a single species approach, meaning that the intended user is but one species rather than to support a greater ecology (see Appendix A for information regarding additional Case Studies). Where as architects, we are unconsciously taught to think and to design for a single occupant, whether it be for humans or beginning to lend our knowledge to other species, and even with our best efforts, we are still encountering the same issue; a single species design.

106 Stokes, and Chitrakar, "Designing 'Other' Citizens into the City: Investigating Perceptions of Architectural Opportunities for Wildlife Habitat in the Brisbane CBD," 7; E Ryang, "Eco-Revelatory Design: An Approach You Can Bank On," *Environmental Sustainability in Transatlantic Perspective. Energy, Climate and the Environment Series*, (2013): 213, https://doi.org/10.1057/9781137334480_13.

Chapter 3: Multi-Species Design

Once constructed, all structures immediately begin to deteriorate.[107] As organic matter experiences decomposition in the physical form, its breakdown serves a critical role in maintaining species diversity through successional processes.[108] When analyzed through an architectural lens, decomposition suggests the breaking down of structures, materials, function, and matter into identifiable elements of the greater whole. This occurrence exists with both the natural and built environment, however unlike the fallen tree's ability to sustain multiple forms of life throughout its lifecycle, human structures serve as static environments only capable of supporting a single species.

107 D. Brendan Nagle, *The Ancient World: A Social and Cultural History* (Boston: Pearson Education, 2014), 96.

108 Anna-Liisa Sippola and Pertti Renvall, "Wood-Decomposing Fungi and Seed-Tree Cutting: A 40-Year Perspective," *Forest Ecology and Management* 115, no. 2-3 (1999): 183, https://doi.org/10.1016/s0378-1127(98)00398-3; Pertti Renvall, "Community Structure and Dynamics of Wood-Rotting Basidiomycetes on Decomposing Conifer Trunks in Northern Finland," *Karstenia* 35, no. 1 (1995): 1, https://doi.org/10.29203/ka.1995.309.

Multi-Species

In order to design for complex multiple species habitats, we must first turn to nature as the primary source; examining the case study of a tree. A single tree offers habitation to hundreds of species throughout varying stages of its life (Fig. 27, 28, 29, 30). The outer rings alone, the bark and cambium layer, are hosts to hundreds of different species of microscopic bacteria, insects, microbes, lichens, algae, fungus, birds, small mammals, among many others.[109] This community structure within a tree varies in successional pathways depending on the species type, size, stage of growth or decay, climate, and the interactions between contributing species in its environment.[110]

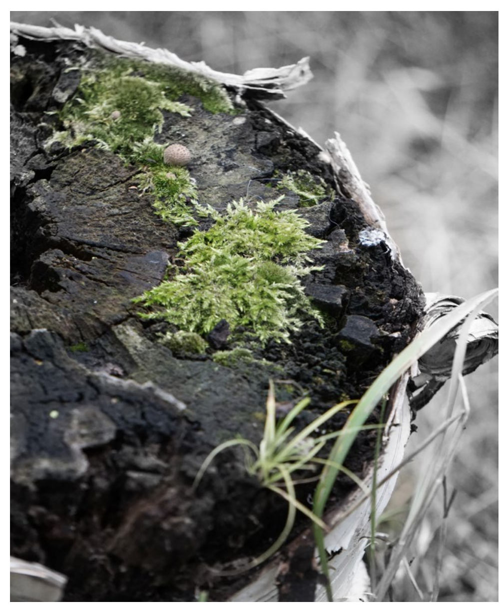


Figure 27 | **Birch Tree Mature**
[Top left]

Figure 28 | **Birch Tree Snag**
[Top right]

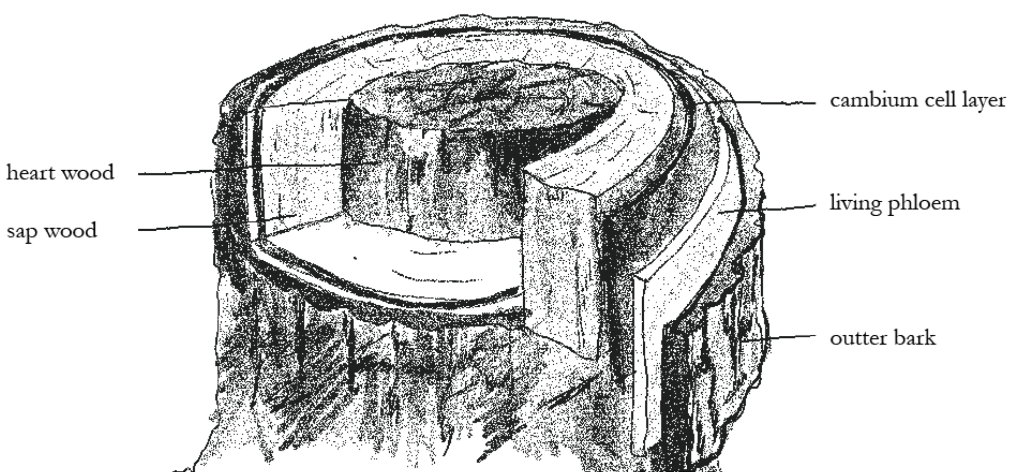
Figure 29 | **Birch Tree Fallen**
[Bottom left]

Figure 30 | **Birch Tree Decomposition**
[Bottom right]

109 Dipanjan Ghosh, "Living on the Bark," *Resonance* 18, (January 2013): 53.
110 Sippola and Renvall, "Wood-Decomposing Fungi and Seed-Tree Cutting: A 40-Year Perspective," 184.

A tree's outer bark differs depending on the species, however, it provides similar functions; serving as a protective external layer for the plant, provides structural support, acts as a conductor for nutrients to travel, protects from dehydration, and provides nutrient source and habitat for external species of microbes, insects, worms, fungi, etc, (Fig. 31).[111] When bark becomes loose and lifts away from the body of the tree, it provides habitat for smaller species to seek shelter such as mites, lice, aphids, wood borers, beetles, wasps, snails, spiders, worms, and others.[112] Bark crevices are used by a large number of insects and spiders as resting, hiding, hunting, breeding and hatching grounds.[113] Some larvae, beetles and other insects sometimes tunnel deeper beneath the bark, leaving behind engravings on the outer tree ring layers in order to seek shelter.[114]

Many species such as butterfly caterpillars, mites, mealybugs, zorapterans and bark-lice feed on the bark of inhabiting trees, whereas other insects such as aphids and ants feed on the secretions and gums produced by the underlying phloem tissues of flowering trees.[115] This sometimes develops into the positive interspecies exchange of myrmecophily, where species such as ants benefit from a plant's nutrients and shelter, whereas the plant benefits from protection and seed dispersal.[116] Larger species of animals such as rabbits, porcupines, squirrels, beavers, deer, among others, feed on the branches, leaves, inner and outer bark of plants as a primary food source, especially within the winter months.[117]



111 Dipanjan Ghosh, "Living on the Bark," *Resonance* 18, (January 2013): 51.
112 Ghosh, "Living on the Bark," 58, 59.
113 Ibid, 59.
114 Ibid, 58, 59.
115 Ibid, 60, 61.
116 Ibid, 60.
117 Ibid, 62.

Figure 31 | **Tree Ring Layers**

Beyond the interior layers, trees offer shelter to a variety of animal and vegetative species, providing coverage, microclimates, look out posts, access routes, nesting sites, burrows, hollows, among other habitat conditions.[118] These habitats, both external and internal of the tree's main structure are dependent on the tree's maturity and size.[119] Habitats provided by young trees exist only temporarily and are rapidly changing, whereas large mature trees provide extended qualities of habitation, however the presence of all stages of plant growth at a given time promote the most biodiverse habitat source.

Decomposing wood plays a crucial role in developing high species diversity in forests, forming a physical-chemical link between successional stages of a forest structure.[120] A decomposing tree provides a constantly changing spectrum of nutrient source for multiple species over the course of decades to centuries, harboring a dynamic number of fungi, insects, birds, small mammals, and serve as a substrate for bryophytes among other vegetation.[121] Varying according to ecological conditions such as species type, climate, phase of decomposition, dimensions, infection, intact bark and stem conditions, etc., each individual piece of decaying wood has a unique successional process.[122]

The process of decomposition begins first in a standing tree, resulting from a variety of causes such as heart rot, pathogens, wounds and infections, dead wood, invasive species, as well as fungi latently present in functional sapwood.[123] However a newly fallen tree is not immediately a viable habitat for most species, interacting with its environment through internal surface area.[124] Organisms need to first gain access through entry points to the interior of the tree to begin consuming and breaking down wood cells and fibers, making way for larger organisms like mites, collembolans, spiders, millipede, centipedes, amphibians, and small mammals to enter these internal spaces, the amount of diversity increasing as decomposition develops.[125] Small species help facilitate the process of decomposition and the microbial colonization of fallen trees by activities such as boring, tunneling, and exciting to provide additional points of entry into the wood.[126] Additionally, plant roots colonize decaying wood, further splitting and compressing openings as it grows.

118 Fred L. Bunnell and Isabelle Houde, "Down wood and biodiversity — implications to forest practices," *Environmental Reviews* 18 (2010): 398, http://www.jstor.org/stable/envirevi.18.397.
119 Chris Maser, Robert F. Tarrant, James M. Trappe, and Jerry F. Franklin, "From the forest to the sea: a story of fallen trees," *U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station*, (1988): 44, https://doi.org/10.2737/PNW-GTR-229.
120 Lynne Boddy, "Fungal Community Ecology and Wood Decomposition Processes in Angiosperms: From Standing Tree to Complete Decay of Coarse Woody Debris," *Ecological Bulletins,* no. 49 (2001): 44, http://www.jstor.org/stable/20113263.
121 Anna-Liisa Sippola, and Pertti Renvall, "Wood-Decomposing Fungi and Seed-Tree Cutting: A 40-Year Perspective." *Forest Ecology and Management* 115, no. 2-3 (1999): 1-3; Pertti Renvall, "Community Structure and Dynamics of Wood-Rotting Basidiomycetes on Decomposing Conifer Trunks in Northern Finland," *Karstenia* 35, no. 1 (1995): 1-2.
122 Renvall, "Community Structure and Dynamics of Wood-Rotting Basidiomycetes on Decomposing Conifer Trunks in Northern Finland," 2.
123 Boddy, "Fungal Community Ecology and Wood Decomposition Processes in Angiosperms: From Standing Tree to Complete Decay of Coarse Woody Debris," 44.
124 Maser, Tarrant, Trappe, and Franklin, "From the forest to the sea: a story of fallen trees," 42.
125 Ibid, 42.
126 Ibid, 45.

Apart from its ability to self-sustain while providing multiple species nutrients and habitation, the tree provides raw materials for human use. The plant and bark provide fibers capable of producing rope, cordage, papers, dyes, clothing, medicines and building and construction materials.[127] Notably, in typical building practice, the outer rings of felled trees are removed to square the lumber and remove any trace of life; physically and metaphorically removing other species from the way in which our buildings are constructed (Fig. 32). Unlike the tree's ability to sustain multiple forms of life throughout its entire lifecycle, current architectural methods seek to only complement a single species; humans, whereas Architectural Succession seeks to design for multiple species throughout a cycle.

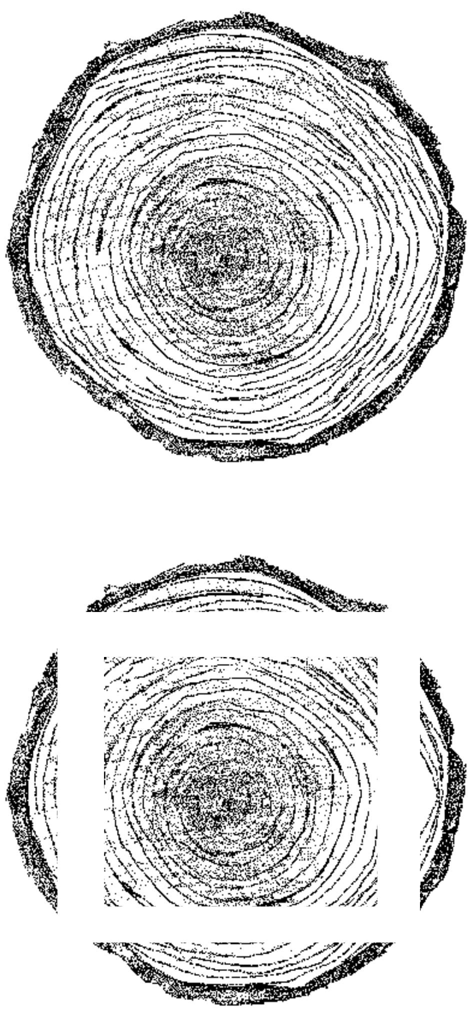


Figure 32 | **Sawmill Log**
This image identifies the outer tree ring layers removed in typical building practice. The bark and sapwood is discarded from construction material, further displacing other species from the built environment.

127 Ghosh, "Living on the Bark," 62.

Research Creation

Often lacking the resources to restore damaged and altered ecosystems, environmental conservation efforts primarily focus on preserving areas that are already capable of supporting biodiversity through the designation of conservation areas and biologically significant areas. It is within the architectural discipline that the creation of new built environments exists, however as of yet, these environments have only been designed to primarily support human habitation. As such, there is no comprehensive literature or design framework outlining an architectural approach for multiple-species design. In response, the methodological approach for this thesis explores the interrelationships between Sudbury Ontario's at-risk Chimney Swift and its primary food source of aerial insects through a design build Research Creation project.

The Chimney Swift [Chaetura Pelagica], as previously discussed, is a small bird at-risk in Sudbury, Ontario that has been displaced from both its natural habitat of hollow old growth trees as well as its anthropogenic habitat within residential and industrial chimneys. Given its dramatic population decline over the past 50 years, conservation efforts are directed towards conserving any remaining nesting and roosting sites through legal and stewardship outreach, and have begun introducing artificial habitats to encourage population growth.[128] However, out of more than 60 known artificial swift towers across five Canadian provinces, there are currently no known instances of an occupied artificial Habitat in North America.[129] This design exercise explores the need to further examine the species-specific requirements in relation to its specific northern context, notably the decline in its food source population of arial insects.

The Chimney Swifts are approximately 127mm in length and have an extended wingspan of 304mm. Their nest structure is constructed with small twigs and pine needles cemented with saliva to a vertical surface, typically 90mm – 114mm in width, 25mm-50mm inches height, and 25mm-75mm from the wall.[130] Spending the majority of its day in flight, the Chimney Swift feeds on flying insects less than 5mm in length.[131] Nesting and perching by clinging to vertical rough surfaces, the Chimney Swifts continue to use their roost from spring to fall occupied for 6 to 8 months out of the year in North America, nesting May through August.[132] Chimney Swifts began nesting in wood heated open-hearth fireplace chimneys as early as 1672, and by the late eighteenth century almost exclusively migrated from forests into human structures.[133] To date, in Ontario chimney structures occupied by swifts were typically constructed prior to 1960s, and what few are remaining, are

128 Environment and Climate Change Canada, "Recovery Strategy for the Chimney Swift (Chaetura pelagica) in Canada," 1.

129 Winifred Wake, "Loss of Chimneys Used by Chimney Swifts in London Ontario, 2004-2013," *The Cardinal* 243 (May 2016): 36, https://www.mbchimneyswift.com/Documents/Wake2016_cardinal.pdf.

130 Gary R. Graves, "Avian commensals in Colonial America: when did Chaetura pelagica become the chimney swift?" *Archives of Natural History* 31, no. 2 (2004): 301, http://dx.doi.org/10.3366/anh.2004.31.2.300; Paul Kyle and Georgean Kyle, Chimney Swift Towers: New Habitat for America's Mysterious Birds, A Construction Guide, (Texas A & M University Press, 2005), 79, Kindle.

131 Kyle and Kyle, *Chimney Swift Towers: New Habitat for America's Mysterious Birds, A Construction Guide*, 112.

132 Christian Artuso, C-Jae C. Breiter, Laura D. Burns, Nicole Firlotte, Stephen D. Petersen, Timothy Poole, and Barbara E. Stewart, "First Use of Purpose-built Artificial Chimney Swift Habitat in Manitoba," *Blue Jay* 78, no. 3 (2020): 33; "Chimney Swift Life History: Distribution and Migration," Landbird Species at Risk in Forested Wetlands, accessed October 17, 2022, https://landbirdsar.merseytobeatic.ca/chimney-swift-distribution-and-migration/.

133 Leah Finity, "The Role of Habitat and Dietary Factors in Chimney Swift Population Declines," (M.Sc., Trent University, 2011), 2.

becoming lost due to renovations, capping, lining, or demolishing.[134] These chimneys vary in size and construction from small residential, to larger industrial or institutional chimneys consisting of exposed brick, stone or concrete block structure, as well as constructions lined with terracotta tile.[135] Given the wide range of chimney dimensions and materials, typical measurements for artificial chimneys rely on a chimney's elevation from the ground being 7000mm - 25000mm and distance from top of building to chimney top of 1000mm – 3000mm.[136] The minimum recommended interior diameter of a nesting chimney is based on small chimneys of 63.5mm x 63.5mm brick at 304mm diameter.[137]

The earliest documented artificial Chimney Swift tower was built in 1915 by ornithologist Althea Sherman, constructing a 8534.4mm tall, 2743.2mm square wooden structure to attract and observe the nesting and roosting of Chimney Swifts in Iowa.[138] The artificial chimney had an interior staircase to provide opportunities for observation, and enclosed a 609.6mm square artificial chimney at the top for the habitation (Fig. 33, 34).[139] Althea has collected the most extensive study known to the Chimney Swifts, noting in one of her journals that "no evil has been detected in its relations with its own or with other species... it appears to be a paragon of perfection—the bird that properly might be chosen as the emblem of peace."[140] Indicating that the Chimney Swifts are a suitable species for exploring a multispecies design approach.

134 Wake, "Loss of Chimneys Used by Chimney Swifts in London Ontario, 2004-2013," 34.; COSEWIC, "Assessment and Status Report on the chimney Swift in Canada," *Committee on the Status of Endangered Wildlife in Canada*, (2017): 11, 12.

135 Wake, "Loss of Chimneys Used by Chimney Swifts in London Ontario, 2004-2013," 33.

136 Manitoba Chimney Swift Initiative, "Guidelines for Creating Chimney Swift Nesting or Roosting Chimneys in Manitoba," Manitoba Chimney Swift Initiative (April 17, 2016): 12, https://www.mbchimneyswift.com/Documents/artificialstructures2016.pdf.

137 Manitoba Chimney Swift Initiative, "Guidelines for Creating Chimney Swift Nesting or Roosting Chimneys in Manitoba," 12.

138 "Sherman, Althea Rosina," The Biographical Dictionary of Iowa, Boyle, Barbara, accessed November 2, 2022. http://uipress.lib.uiowa.edu/bdi/DetailsPage.aspx?id=340.

139 Boyle, "Sherman, Althea Rosina; "Kyle and Kyle, Chimney Swift Towers: New Habitat for America's Mysterious Birds, A Construction Guide, preface.

140 Boyle, "Sherman, Althea Rosina,"

Figure 33 | **Earliest Chimney Swift Tower Exterior**
[Left]

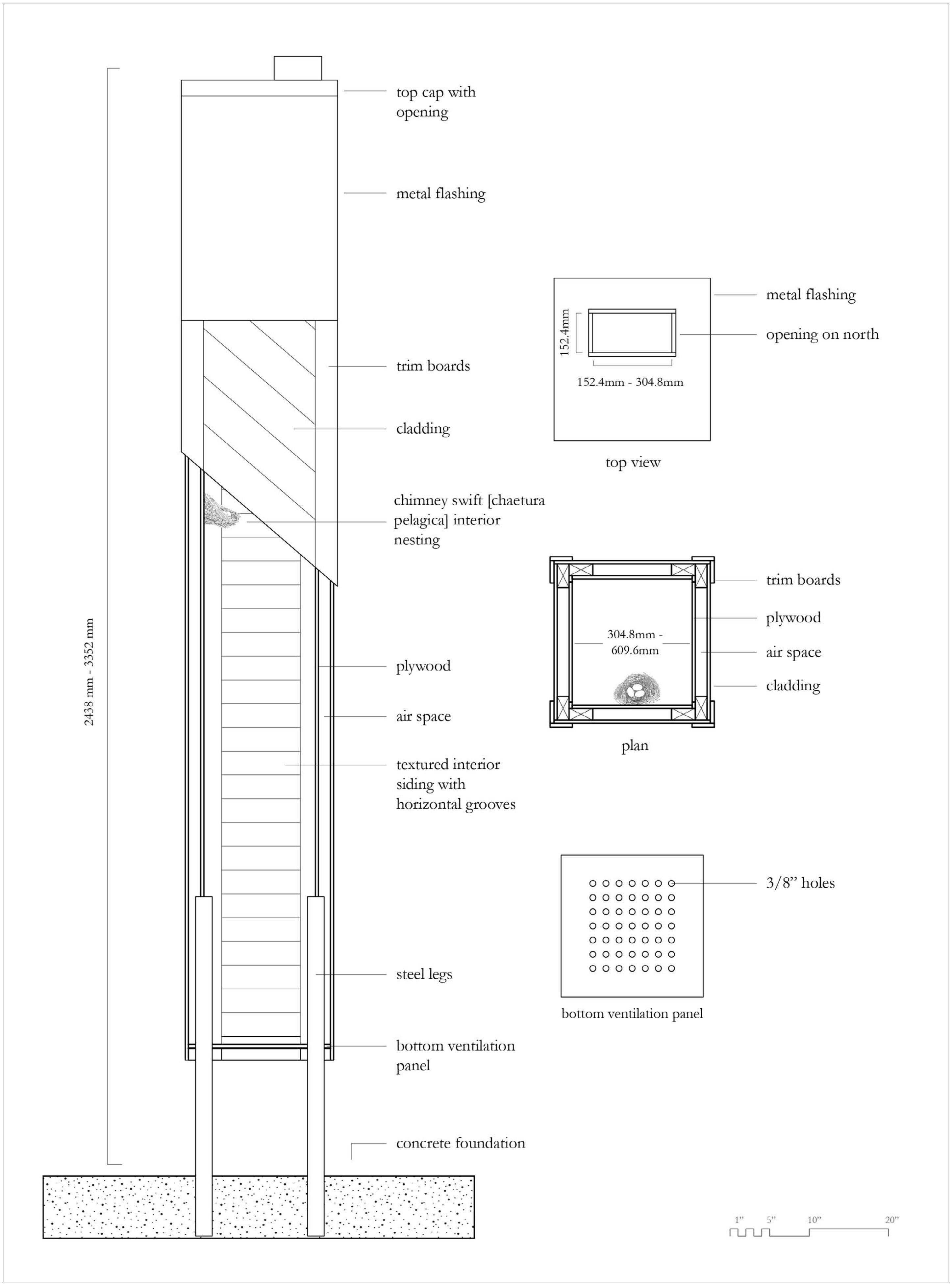
Figure 34 | **Earliest Chimney Swift Tower Interior**
[Right]

Current artificial Chimney Swift towers have been designed to mimic these residential and industrial chimney conditions that the Chimney Swifts have become accustomed to (Fig. 35). Accounting for the Chimney Swift's wingspan, 304.8mm to 355.6mm interior diameters are preferable, and a height of 2438.4mm - 3352.8mm is recommended to provide protection from direct sunlight.[141] The top opening should be no more than half of the tower's interior diameter, and be located on the north to further protect the interior.[142] Artificial towers have been designed to include bottom ventilation to prevent the structures overheating with a grid of holes no larger than 9.525mm.[143] The interior surface shall be of rough texture to allow for the swifts to be able to cling to the vertical surface.[144]

The design approach when constructing a Chimney Swift tower to house the nesting and roosting of the Swifts has ultimately been designed to function as a single species design. However, by recognizing the Chimney Swifts habitat loss as only one of the factors in their population decline, a new design approach that provides habitat for the Swifts in addition to their declining food source of aerial insects can be developed through a multi-species design.

Figure 35 | **Standard Chimney Tower Design**

141 Kyle and Kyle, Chimney Swift Towers: New Habitat for America's Mysterious Birds, A Construction Guide, 157.
142 Ibid, 157.
143 Ibid, 168.
144 Ibid.


top cap with
opening
metal flashing
trim boards
cladding
chimney swift [chaetura
pelagica] interior
nesting
plywood
air space
textured interior
siding with
horizontal grooves
steel legs
bottom ventilation
panel
concrete foundation
2438 mm - 3352 mm
metal flashing
opening on north
152.4mm
152.4mm - 304.8mm
top view
trim boards
plywood
air space
cladding
304.8mm -
609.6mm
plan
3/8” holes
bottom ventilation panel
1”
5”
10”
20”

By examining the Swift's behaviour and habitat requirements, key considerations for its location within the Northern Ontario context led to the site of Laurentian University's School of Architectures rooftop garden in Sudbury Ontario (Fig. 36, 37). The site offers adequate grounds for creation and research exploration, elevation from public access and predators, and direct proximity to rooftop greenspace within the urbanized downtown core. The rooftop garden is within its early successional phase where complex biodiversity within its soil and species structure is not yet present, currently supporting various vegetative species of reed grass, ferns, clover, and flowering species such as bird's-foot-trefoil, evening-primrose, common yarrow, vetch, among others (Fig. 38-46). The rooftop is provided with a drip irrigation system maintaining soil moisture during the summer months and is best suited for low growing horizontally spreading ground coverage with a maximum height of 406.4mm to 609.6mm.

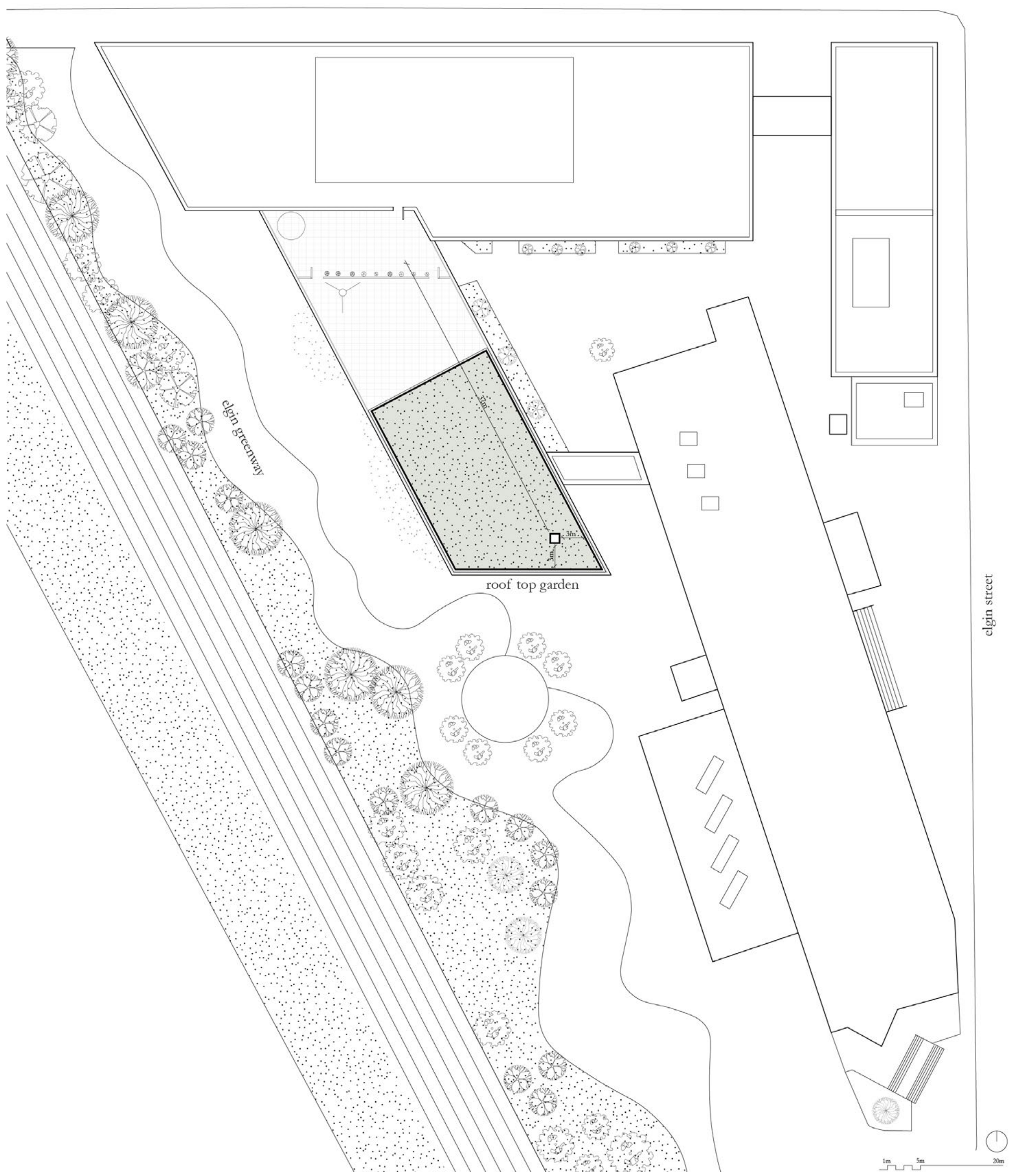
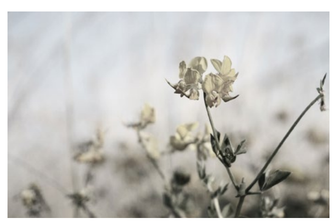
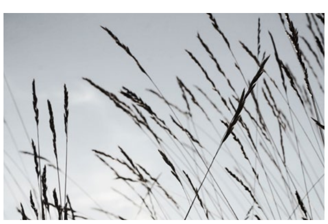
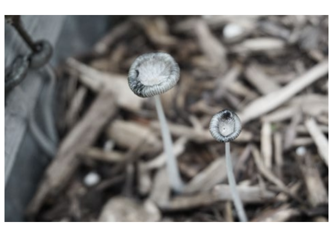


Figure 36 | **Laurentain University McEwen School of Architecture Rooftop Garden Plan**

As Chimney Swifts are an aerial insectivorous species feeding on flying insects less than 0.2 inch in length such as mosquitoes, midges, flies, spittlebugs, aphids, winged ants, tiny bees and wasps, mayflies, moths, spiders, stoneflies, and termites.[145] These insect species live in a variety of habitat conditions (see Appendix B), where given the rooftops grassy conditions, Spittlebugs, Aphids, Bees, Wasps, Moths, and Spiders are most likely to be present, however the populations would not be sufficient to support the Chimney Swifts diet. This allows for the introduction of multispecies to the design where the Chimney Swifts food source will be the secondary occupants.







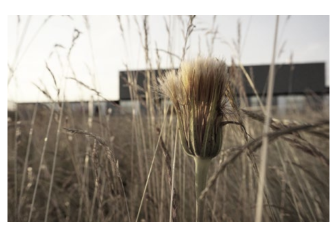


Figure 37 | **Laurentian University McEwen School of Architecture Rooftop Garden**
[1st row]

Figure 38 | **Rooftop Garden Species Evening Primrose**
[2nd row left]

Figure 39 | **Rooftop Garden Species Clover**
[2nd row middle]

Figure 40 | **Rooftop Garden Species Birds-foot-trefoil**
[2nd row right]

Figure 41 | **Rooftop Garden Species Various Grasses**
[3rd row left]

Figure 42 | **Rooftop Garden Species Vetch**
[3rd row middle]

Figure 43 | **Rooftop Garden Species Common Yarrow**
[3rd row right]

Figure 44 | **Rooftop Garden Species Fern**
[4th row left]

Figure 45 | **Rooftop Garden Species Spores**
[4th row middle]

Figure 46 | **Rooftop Garden Species Vegetation**
[4th row right]

145 Ibid, 148.

Much like a tree's ability to sustain multiple forms of life throughout its lifecycle, the intention of this multi-species Chimney Swift tower is to explore how to support multiple species throughout architectural succession. As previously discussed, the outer layers of a tree serve as hosts to hundreds of species of bacteria, microbes, lichens, algae, fungus, insects, birds, and small mammals, and are often regarded as waste material in building construction. In an effort to encourage multiple species habitation within this design framework, these sawmill offcuts serve as the main structure for the multi-species tower.

Figure 47 | **Sawmill Lumber**
Various maple and walnut logs have been cut on the sawmill and its multi-species rich cutoffs salvaged to construct the Research Creation Chimney Swift tower.

Figure 48 | **Weathered Sawmill Lumber**

Figure 49 | **Scaled Model (1)**
[Facing page - top left]

Figure 50 | **Scaled Model (2)**
[Facing page - top right]

Figure 51 | **Scaled Model (3)**
[Facing page - bottom left]

Figure 52 | **Scaled Model (4)**
[Facing page - bottom right]

Each offcut has been upcycled from the School of Architecture, precut at approximately 1651mm in length (Fig. 47). In examining the offcuts, due to their weathering much of the bark is absent, revealing traces of species inhabiting the wood through its many entry points. (Fig. 48).

Scaled models explore the porosity between exterior and interior facades, inverting the offcuts creates an interior cavity while exposing the inner tree ring layers to the exterior that encourage multi-species entry (Fig. 49). The interior cavity exposes vertical surface that mimic the hollow tree and chimney conditions that Chimney Swift have become accustomed to nesting (Fig. 50, 51). Additionally, although the Chimney Swifts have adapted to nesting in masonry chimneys, their saliva, the glue medium in which they attach and build their nests, is best suited for gluing natural, untreated, and unpainted wood.[146] Whereby the use of biodegradable materials for the structure, its connection details further encourages the successional opportunities of this project (Fig. 52).

146 Ibid, 237.

Figure 53 | **Multi-species Chimney Swift Tower (1)**
[Facing page - Top left]

Figure 54 | **Multi-species Chimney Swift Tower (2)**
[Facing page - Top right]

Figure 55 | **Multi-species Chimney Swift Tower (3)**
[Facing page - Bottom left]

Figure 56 | **Multi-species Chimney Swift Tower (4)**
[Facing page - Bottom right]

Figure 57 | **Multi-species Chimney Swift Tower (5)**
[page 47 - top left]

Figure 58 | **Multi-species Chimney Swift Tower (6)**
[page 47 - Top right]

Figure 59 | **Multi-species Chimney Swift Tower (7)**
[page 47 - 2nd row left]

Figure 60 | **Multi-species Chimney Swift Tower (8)**
[page 47 - 2nd row right]

Figure 61 | **Multi-species Chimney Swift Tower (9)**
[page 47 - 3rd row left]

Figure 62 | **Multi-species Chimney Swift Tower (10)**
[page 47 - 3rd row right]

Figure 63 | **Multi-species Chimney Swift Tower (11)**
[page 47 - 4th row left]

Figure 64 | **Multi-species Chimney Swift Tower (12)**
[page 47 - 4th row right]

Figure 65 | **Multi-species Chimney Swift Tower (13)**
[page 48]

Figure 66 | **Multi-species Chimney Swift Tower Plan**
[page 49]

Figure 67 | **Multi-species Chimney Swift Tower Section**
[page 50]

Due to the organic nature of the offcuts, they are inconsistent in size and shape. In an effort to maintain the natural conditions of the wood, connection details between each piece have been explored through experimentation with biodegradable rope. The drilling of holes in each of the cutoffs 50.8mm from top and bottom provides opportunity for additional entry points to the wood, as well as a consistent edge condition for assembly without compromising the organic corner conditions (Fig. 53).

The rope pattern chosen intentionally wraps around the interior of each cut off piece, mimicking the jutted mortar within chimneys that the Chimney Swifts use to attach their nests (Fig. 54). Each cutoff was first assembled side by side attached by rope, however the interior dimension was below the required 304.8mm diameter for the Chimney Swifts entry due to the rope pulling together each of the corners, revealing gaps in each of the edges due to the offcuts organic shape.

The corner conditions were then explored as an opportunity to house insulative materials that would encourage insect populations to inhabit the structure, while simultaneously closing the edge gaps (Fig. 55, 56). However, once tightened, the insulative material was pulled towards the interior and reducing the required interior dimensions, identifying the need for an additional supporting structure.

Cross dowels were explored as a means of maintaining this interior dimension while providing structural support to the tower (Fig. 57, 58). Three out of the four cutoffs were planed revealing a smooth finish representing the human intervention required to provide such habitat, leaving one cutoff with its weathered edge to express the next phase condition the structure will endure throughout its succession (Fig. 59). Rather than filling in each open corner with substrate or closing it off with additional material, a second row of holes have been cut out of the wood to allow for the twine to wrap continuously up each edge (Fig. 60), creating 4 vertical channels that will house the organic insulative material consisting of grasses, wood shavings, and sawdust (Fig. 61, 62).

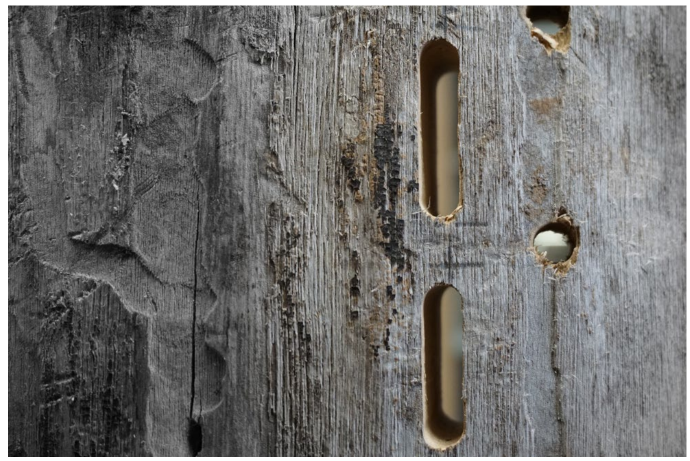
Standing approximately 1645.92mm off the ground, the structure has been lifted an additional 381mm onto a base to provide enough height to attract the Chimney Swifts (Fig. 63, 64). The base condition invites species of vegetation to grow around and through its frame, as well as provides a microclimate condition beneath the structure suitable for other species to take shelter. Capped with a net of twine, the base prevents any large species from entering from the bottom and potentially damaging the nests, allowing for air to flow through the structure preventing it from overheating in the summer months.

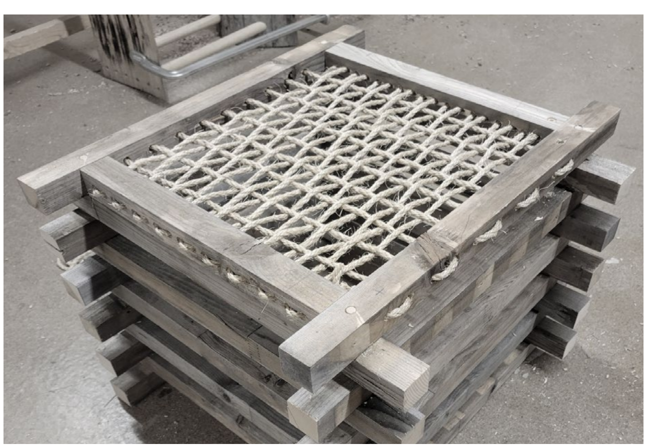
Given the rooftop condition, to prevent wind loads from overturning the structure, it will be positioned in response to prevailing winds and tied down from each corner to varying stages of decaying logs (Fig. 65). Intended to eventually decompose into organic material to further enrich the biodiversity of the site (Fig. 66, 67), these logs begin to explore temporary soil retention methods by utilizing the hollow's to hold soil for plantings.

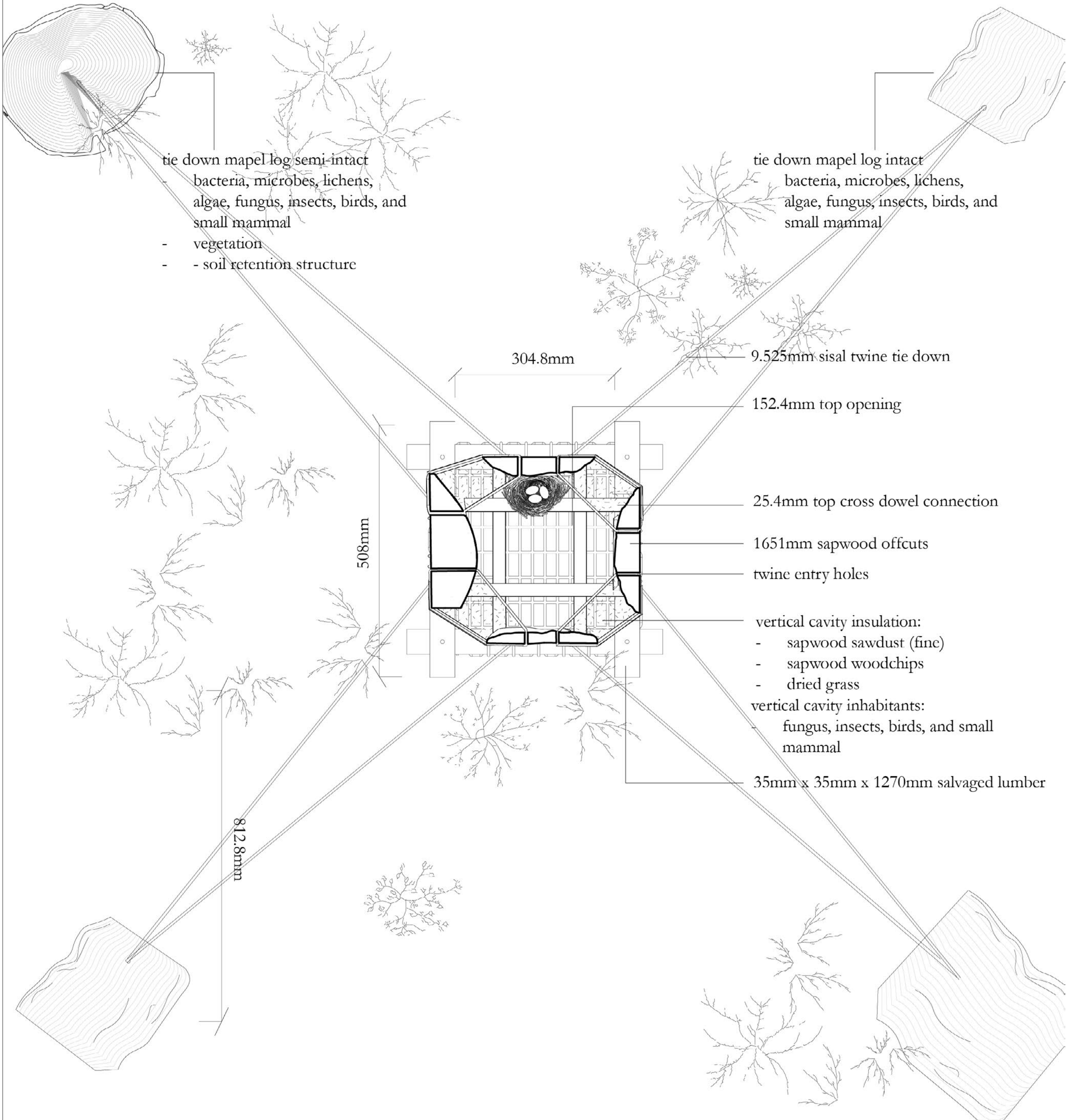


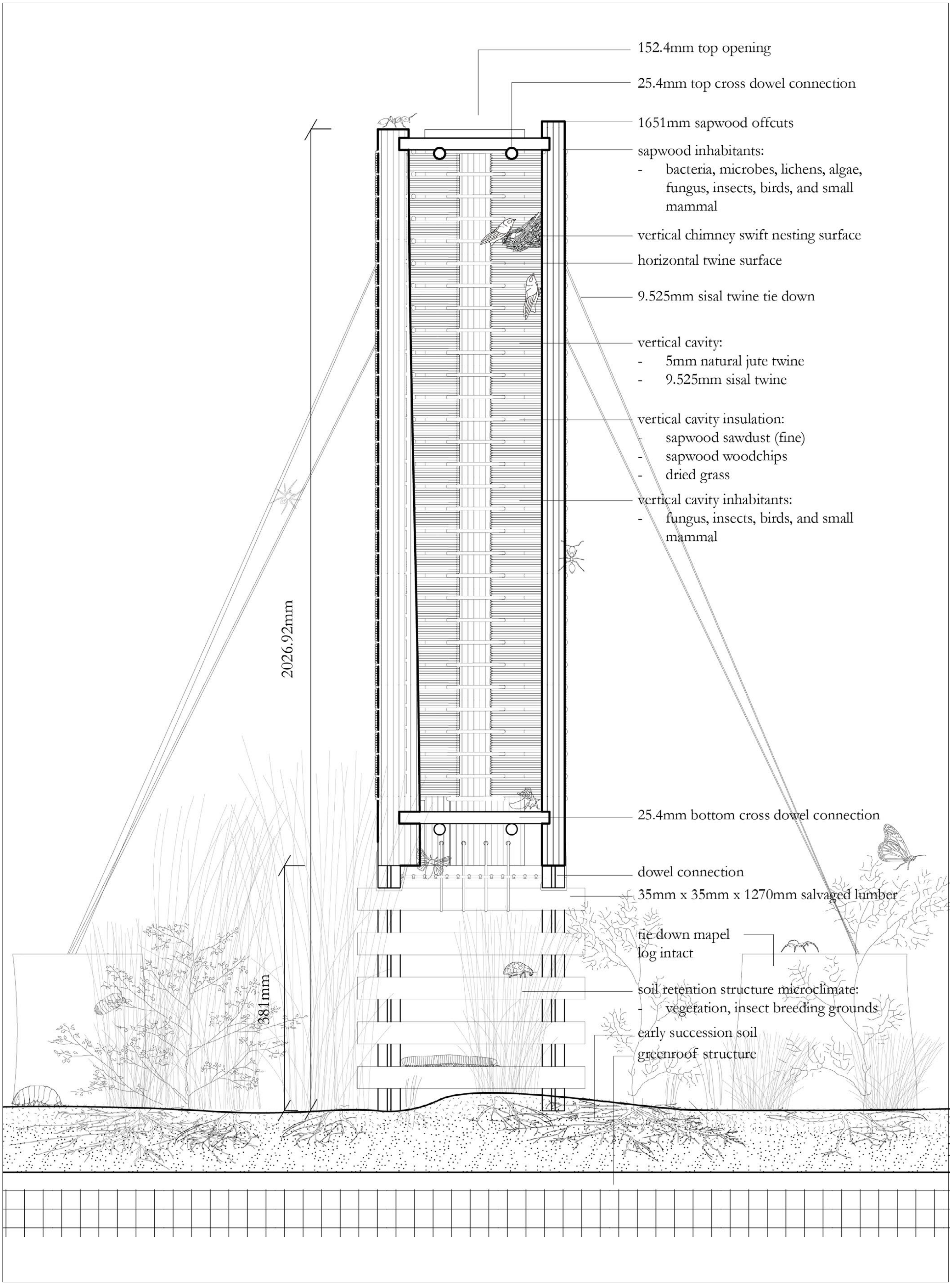








tie down mapel log semi-intact
- bacteria, microbes, lichens, algae, fungus, insects, birds, and small mammal
- vegetation
- - soil retention structure
tie down mapel log intact
- bacteria, microbes, lichens, algae, fungus, insects, birds, and small mammal
304.8mm
9.525mm sisal twine tie down
152.4mm top opening
25.4mm top cross dowel connection
508mm
1651mm sapwood offcuts
twine entry holes
vertical cavity insulation:
- sapwood sawdust (fine)
- sapwood woodchips
- dried grass
vertical cavity inhabitants:
- fungus, insects, birds, and small mammal
35mm x 35mm x 1270mm salvaged lumber
812.8mm


152.4mm top opening
25.4mm top cross dowel connection
1651mm sapwood offcuts
sapwood inhabitants:
- bacteria, microbes, lichens, algae, fungus, insects, birds, and small mammal
vertical chimney swift nesting surface
horizontal twine surface
9.525mm sisal twine tie down
vertical cavity:
- 5mm natural jute twine
- 9.525mm sisal twine
vertical cavity insulation:
- sapwood sawdust (fine)
- sapwood woodchips
- dried grass
vertical cavity inhabitants:
- fungus, insects, birds, and small mammal
2026.92mm
25.4mm bottom cross dowel connection
dowel connection
35mm x 35mm x 1270mm salvaged lumber
tie down mapel log intact
soil retention structure microclimate:
- vegetation, insect breeding grounds
381mm
early succession soil
greenroof structure

The monitoring of its inhabitation atop Laurentian University's School of Architecture rooftop garden provides critical insight into the process of Architectural Succession and multi-species built environments (Fig. 68-74). The cut off pieces provide a time sensitive substrate interacting through exposed surface area, encouraging the growth of organisms to begin breaking down wood cells and fibers. As these fibers begin to break down, burrowing species begin making additional entry points feeding on the cellulose. The woven channels provide shelter from the elements for smaller species. The hollow base condition provides a microclimate where vegetative nesting species may make their breeding ground.

This small-scale test case of multi-species inhabitation identified key opportunities for expanding ecologies through built intervention: First, by recognizing the ability to address multiple species by first understanding the biodiversity surrounding a single species ecological requirement. Next, ensuring a conscious attention to material choice, in particular the microbiome of sapwood. Recognizing that a structure's form, scalability, and location directly inform its ability to attract and support broad ranges of species. Experimentation in porosity between habitat typologies, such as sapwood, interior, exterior, and insulative edge conditions, provide insight into the various habitat typologies required to support an ecosystem. Resulting in the anticipated Architectural Succession; referencing a fallen tree, where its decay serves as a resource to be utilized by a variety of species throughout its succession (Fig. 75).

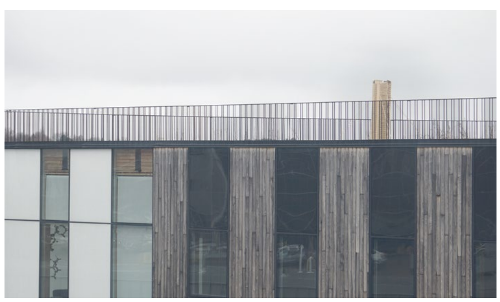





Figure 68 | **Multi-species Chimney Swift Tower (14)**
[top left]

Figure 69 | **Multi-species Chimney Swift Tower (15)**
[top right]

Figure 70 | **Multi-species Chimney Swift Tower (16)**
[2nd row left]

Figure 71 | **Multi-species Chimney Swift Tower (17)**
[2nd row right]

Figure 72| **Multi-species Chimney Swift Tower (18)**
[3rd row left]

Figure 73| **Multi-species Chimney Swift Tower (19)**
[3rd row right]

Figure 74| **Multi-species Chimney Swift Tower (20)**
[facing page]

Figure 75| **Multi-species Chimney Swift Tower Architectural Succession**
[page 53-54]

Succession Phase: 1

Bark: trace

Texture: intact

Connections: intact

Colour: original

Location: elevated on support points

Entry Points: by deisgn, lifted bark

Primary Inhabitant: Chimney Swift

Secondary Inhabitant(s): early successional insects, wintering bird

Vegetation: existing

Succession Phase: 2

Bark: absent

Texture: intact to partly soft

Connections: intact to partly failed

Colour: original to faded

Location: elevated on support points

Entry Points: by deisgn, tunneling, cracking

Primary Inhabitant: Chimney Swift

Secondary Inhabitant(s): microscopic bacteria, insects, microbes, lichens, algae, fungus, wintering birds

Vegetation: existing

Succession Phase: 3

Bark: absent

Texture: intact to partly soft

Connections: primarily failed

Colour: faded

Location: elevated on support points with additional ground conntact

Entry Points: by deisgn, tunneling, cracking, softening

Primary Inhabitant: birds, wintering birds, insects

Secondary Inhabitant(s): microscopic bacteria, insects, microbes, lichens, algae, fungus

Vegetation: existing to early succession

Succession Phase: 4

Bark: absent

Texture: intact to primarily soft, large pieces

Connections: failed

Colour: faded

Location: partial ground conntact

Entry Points: by deisgn, tunneling, cracking, softening

Primary Inhabitant: microscopic bacteria, insects, microbes, lichens, algae, fungus

Secondary Inhabitant(s): birds

Vegetation: early succession

Succession Phase: 5

Bark: absent

Texture: primarily soft, small blocky pieces

Connections: failed

Colour: faded

Location: partial to full ground conntact

Entry Points: by deisgn, tunneling, cracking, softening, organic material

Primary Inhabitant: microscopic bacteria, insects, microbes, lichens, algae, fungus

Secondary Inhabitant(s): vegetation

Vegetation: early succession

Succession Phase: 6

Bark: absent

Texture: soft and powdery, total decomposition

Connections: failed

Colour: faded

Location: full ground conntact

Entry Points: organic material

Primary Inhabitant: microscopic bacteria, insects, microbes, lichens, algae, fungus

Secondary Inhabitant(s): vegetation

Vegetation: early successional

Chapter 4: Architectural Succession

By means of human intervention, Sudbury, Ontario's Regreening program has successfully limed, seeded, and planted over 3,400 hectares of land, allowing for the gradual recovery of its ecologically disrupted landscape.[147] These Regreening efforts have supported the return of over 250 vascular plants, 20 moss species, 50 lichen species, 16 mammals, and 80 bird species to the region thus far.[148] However despite these improvements, large areas within Sudbury's landscape remain ecologically barren due to the inability to maintain adequate soil structure. In approaching this issue, the Regreening program directs their attention toward the areas surrounding these barren outcroppings to gradually build up the landscape over time. However, the rate in which species at risk are in decline requires immediate attention, positioning regions such as rocky outcroppings with the greatest potential in providing additional support during the early successional periods of Sudbury's recovering landscape.

147 John M. Gunn, *Restoration and recovery of an Industrial Region: Progress in Restoring the Smelter Damaged Landscape near Sudbury Canada* (New York: Springer-Verlag, 1995), 109-120; "Regreening Program," City of Greater Sudbury, accessed September 29, 2022, https://www.greatersudbury.ca/live/environment-and-sustainability1/regreening-program/.

148 Peter Beckett, "Over 40 years of creating restored ecosystems on a smelter impacted landscape of Sudbury, Ontario, Canada," *Regreening Reverdissement,* (June, 2022): 45.

Maley Hill

Located within the Junction Creek sub-watershed and home to more than half of the region's species at risk, the Maley branch has been documented as actively eroding copper, nickel, cadmium and zinc concentrations into Sudbury's watershed (Fig. 76).[149] Maley consists of a fragmented conservation area considered to be of significant interest to the biodiversity of Sudbury given its large early successional forest primarily unconfined by human development, surrounded by Open Space Recreation, and undeveloped Rural and Mining Industrial zones (Fig. 77).[150] Having received multiple Regreening efforts between 1984 and 2021, large portions of Maley remain ecologically barren due to exposed bedrock where lime and seed sediments are constantly washed away by weathe events.[151] The recent Maley Drive Highway development (2019) runs along its southern edge, acquiring twenty percent of its land from the conservation area, further fragmenting the landscape and cutting through a documented and ecologically significant habitat of two of Sudbury's at-risk species of Blanding's turtle and Whippoorwill.[152]

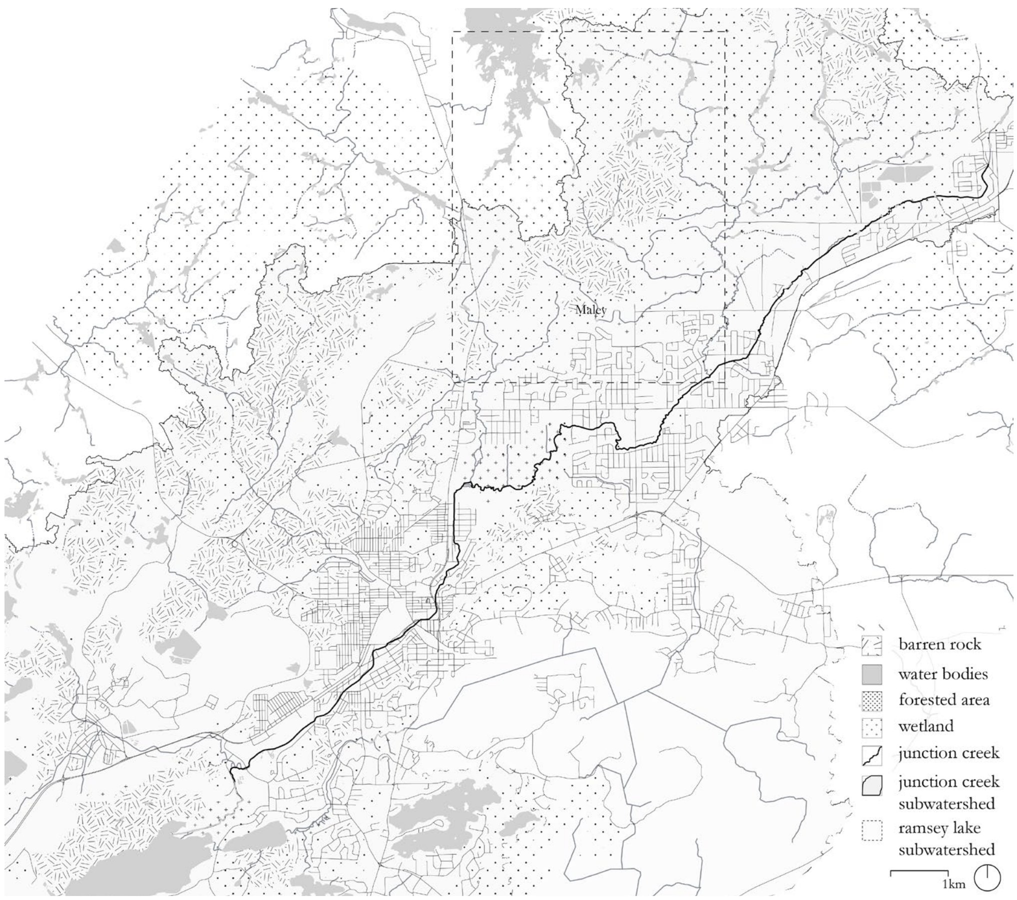


Figure 76 | **Sudbury Watershed**

Figure 77 | **Maley Zoning Map** [facing page]

149 Wood Environment & Infrastructure Solutions a Division of Wood Canada Limited, "Junction Creek Subwatershed Study and Stormwater Master Plan," *City of Greater Sudbury, Junction Creek Subwatershed Study*, (December 20, 2019): 4, 25, 26, 70. https://junctioncreek.com/wp-content/uploads/2021/01/Junction-Creek-Subwatershed-Study-and-Stormwater-Master-Plan-2019.pdf.

150 "Regreening Sudbury," ArcGIS web application, accessed November 15, 2022, https://sudbury.maps.arcgis.com/apps/webappviewer/index.html?id=73fcef8187864784a3a6aad98eb9c1ba; *Wood Canada Limited*, "Junction Creek Subwatershed Study and Stormwater Master Plan," Wood (December 2019): 70.

151 "Regreening Sudbury," ArcGIS web application, accessed November 15, 2022, https://sudbury.maps.arcgis.com/apps/webappviewer/index.html?id=73fcef8187864784a3a6aad98eb9c1ba.

152 AECOM -Sudbury, "Maley Drive Extension - Phase 1 Business Case Report," City of Greater Sudbury, (February 2016): 22. https://pub-greatersudbury.escribemeetings.com/FileStream.ashx?DocumentId=11749

M4
RU
MALEY CONSERVATION
RU
RU
OSR
OSC
M4
RU
M4
Maley Hill
OSR
OSC
OSC
OSP
R
NICKLEDALE CONSERVATION
OSC
path
road
electric poles
barren rock
forest area
ground cover
wet lands
golf course
100m
500m
1000m

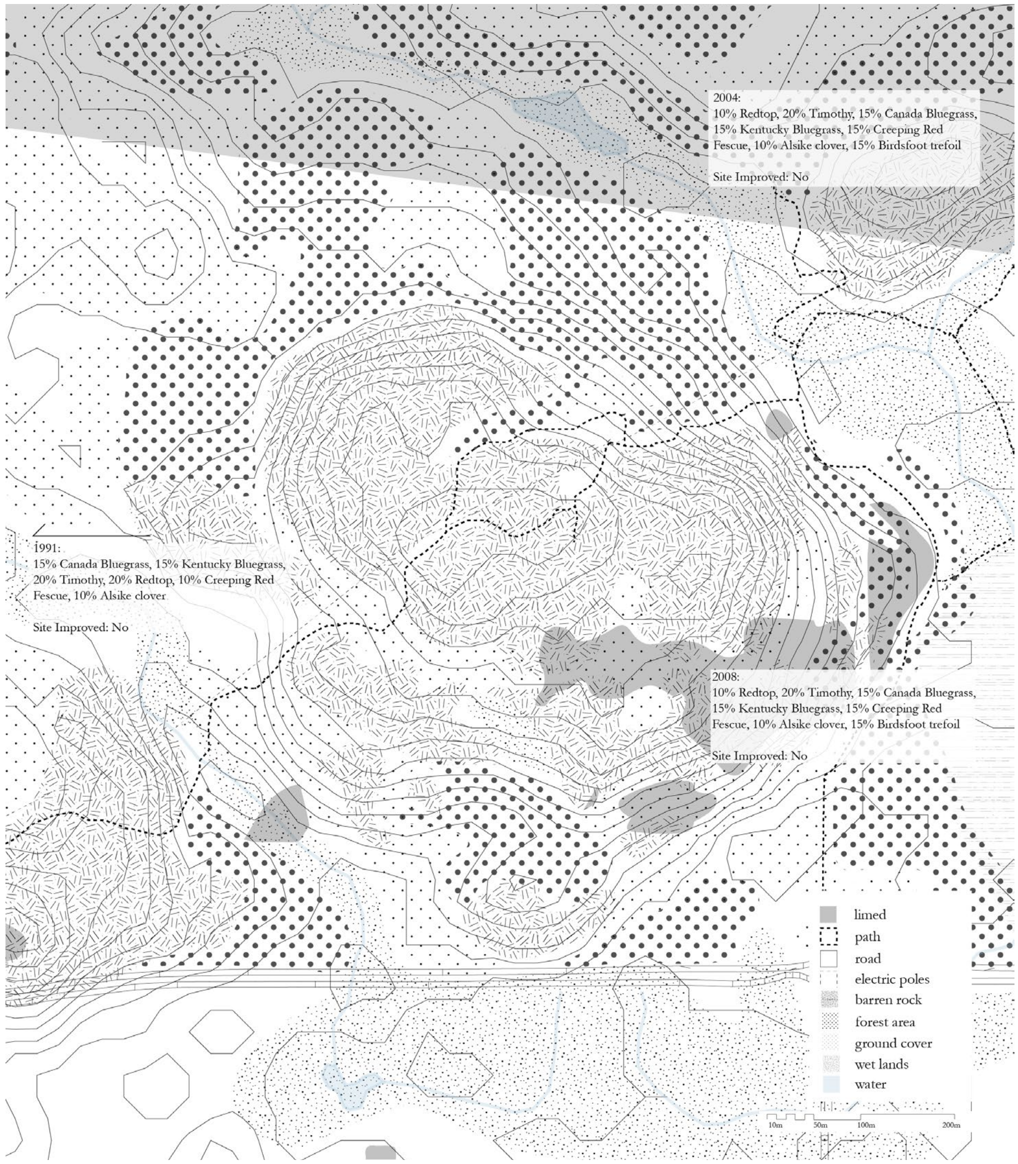
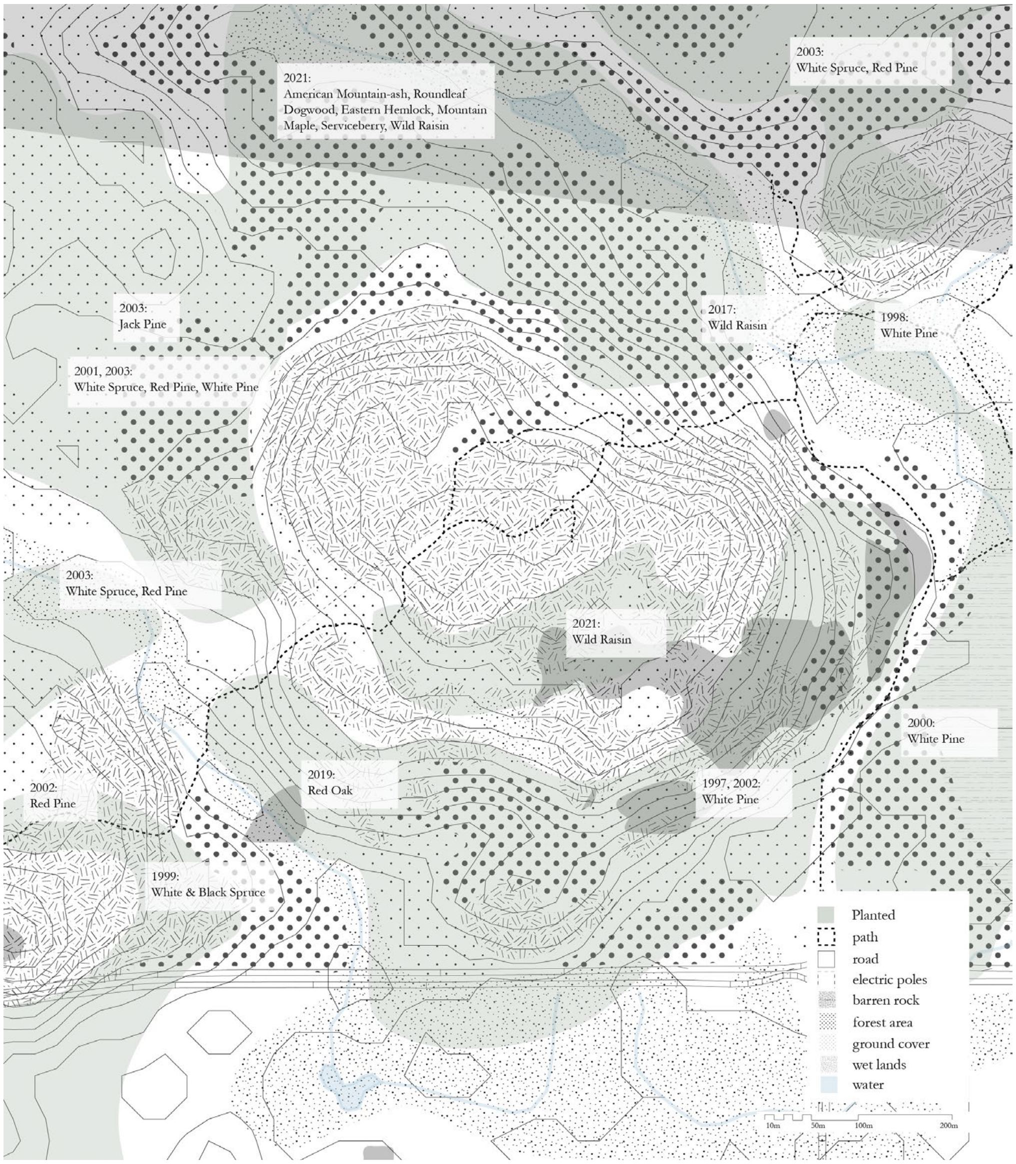


Figure 78 | **Maley Lime Treatment Sites**

The Maley Hill in particular, is a largely barren outcropping located within the rural section of Maley, receiving lime and seeding mixtures between 1991 and 2008 consisting of Canada Bluegrass, Kentucky Bluegrass, Timothy, Redtop, Creeping Red Fescue, Alsike clover, and Birdsfoot trefoil, however is still deemed as an unimproved site (Fig. 78).[153] Species of White Spruce, Jack Pine, Red Pine, and White Pine have primarily been planted within the lower regions of Maley supporting the development of its early successional forest (Fig. 79). The presence of these vegetative species indicates the likelihood of both forest and barren dwelling insects, small mammals, and birds, with the presence of larger species increasing as the forest matures. A detailed list of nearby plantings and the corresponding species supported by such vegetation can be found in Appendix C, Table 1, and Table 2.

153 "Regreening Sudbury," ArcGIS web application, accessed November 15, 2022, https://sudbury.maps.arcgis.com/apps/webappviewer/index.html?id=73fcef8187864784a3a6aad98eb9c1ba.



The rural zoning of this site offers insight into the urgency to reexamine our relationship with other species within the built environment. Where conservation efforts focus on maintaining existing ecosystems, this area of intervention is 500m beyond the conservation area, aiming to assist in the further expansion and recovery of the forest system as a whole. Located approximately 800m from the highway and beginning 100m off the pre-existing trail, the northern face of Maley hill is exposed to the harsh conditions of prevailing winds and steep inclines, requiring additional intervention to support that of the Regreening efforts. Site analysis examining Maley hills topography inclines, erosion patterns, wind conditions, and existing vegetation have been identified (Fig. 80-89).

Figure 79 | **Maley Planting Sites**

Figure 80 | **Site Analysis (1)**
[page 61]

Figure 81 | **Site Analysis (2)**
[page 61]

Figure 82 | **Site Analysis (3)**
[page 62]

Figure 83 | **Site Analysis (4)**
[page 62]

Figure 84 | **Site Analysis (5)**
[page 62]

Figure 85 | **Site Analysis (6)**
[page 62]

Figure 86 | **Site Analysis (7)**
[page 62]

Figure 87 | **Site Analysis (8)**
[page 62]

Figure 88 | **Site Analysis (9)**
[page 62]

Figure 89 | **Site Analysis (10)**
[page 62]








Given its proximity to the Maley sub-watershed branch and its access to the surrounding early successional forest, the Maley hill has the significant potential to provide for an ecologically diverse habitat capable of supporting some of the 50 at-risk species in Sudbury's Forest Management Region through design intervention (Appendix D, Table 1).[154] Specific to the Maley branch, the Junction Creek subwatershed has documented the presence of 28 of these species at-risk, 5 amphibians, 19 birds, 2 mammals, and 3 Butterflies, 20 of which are present during the breeding season (Appendix D, Table 2). As species present during the breeding period are more susceptible to environmental conditions which can greatly impact population numbers, they are key species to provide with adequate habitat conditions.[155] Of the 20 species present in Sudbury during their breeding periods, 65 percent are of various bird species (Fig. 90).

Through Sudbury's Regreening program, the monitoring of the cities ecological recovery has provided vital information about the overall health of the landscape, informing where additional efforts are to be focused. The direct tracking of many of the species absent or present during this regreening has provided the program with a measurement towards ecological development.[156] One of the key species in examining this recovery is the presence or return of various bird species within a specific site, indicating the overall health of its ecosystems.[157] Whereby the monitoring and early detection of birds or lack of can be a critical indicator of soil health, species diversity, insect population, invasive species, pollutants, environmental or climatic disruptions, among other causes.[158] As such, the intended program of the Maley Hill to provide a wildlife observation pavilion intended for multi-species use and monitoring through the process of Architectural Succession, in addition to soil retention measures and temporary habitat pavilions.

Soil Retention

Working in parallel to Sudbury's existing Regreening program, in order to decrease the severity of erosion and the accumulation of sediments within the watershed from the Maley hill, the bedrock must be regreened, extending the nearby forest structure up and onto the rocky outcroppings. Regreening treatments of crushed limestone is first applied to barren landscapes to neutralize the acidity and toxicity of the site, forming lichen communities and fertilizing and seeding the area to allow for water to be absorbed and collected at the source, in turn limiting surface runoff and decreasing pollutants from entering the streams.[159] However given the outcropping conditions of the site, an architectural intervention of soil retention measures are required in order to prevent regreening treatments from immediately becoming run off.

Figure 90 | **Species At-Risk**
[facing page]

154 The Vermilion Forest Management Company Ltd, "2020-2030 Sudbury Forest Management Plan," 13- 15.

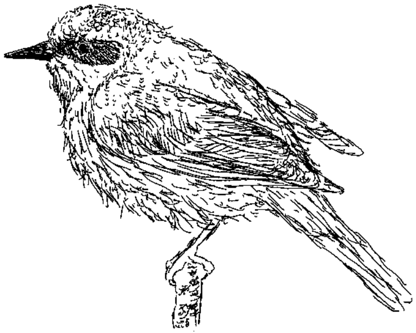
155 Paul R. Ehrlich, David S. Dobkin, and Darryl Wheye, "Breeding Season," accessed February 1, 2023, https://web.stanford.edu/group/stanfordbirds/text/essays/Breeding_Season.html.

156 "Living Landscape - A Biodiversity Action Plan for Greater Sudbury," Regreening Greater Sudbury, ISSUU, last modified November 15, 2018, https://issuu.com/sudbury/docs/biodiversity_action_plan_english_pr.

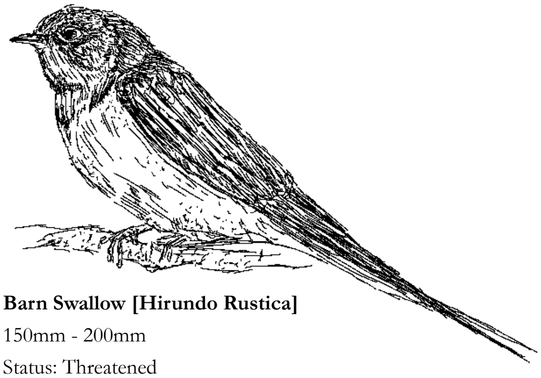
157 "Why Birds Matter," Birds Canada, accessed February 16, 2023, https://www.birdscanada.org/discover-birds/why-birds-matter.

158 "Why Birds Matter," Birds Canada, accessed February 16, 2023, https://www.birdscanada.org/discover-birds/why-birds-matter.

159 Wood Environment & Infrastructure Solutions a Division of Wood Canada Limited, "Junction Creek Subwatershed Study and Stormwater Master Plan," 277; ISSUU, "Living Landscape - A Biodiversity Action Plan for Greater Sudbury."

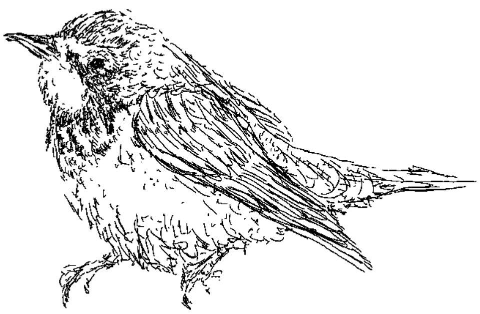


Golden-winged Warbler [Vermivora Chrysoptera]
100mm - 110mm
Status: Special Concern

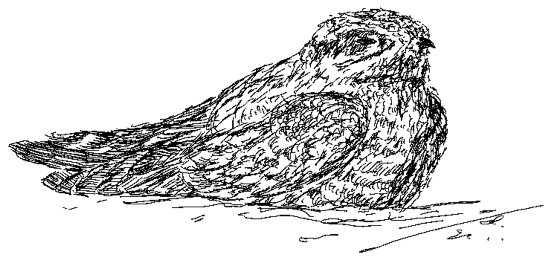


Barn Swallow [Hirundo Rustica]
150mm - 200mm
Status: Threatened

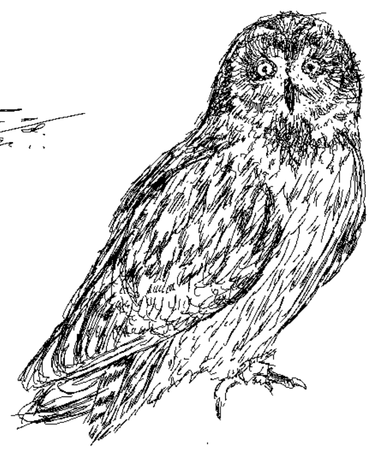
Chimney Swift [Chaetura Pelagica]
120mm - 140mm
Status: Threatened



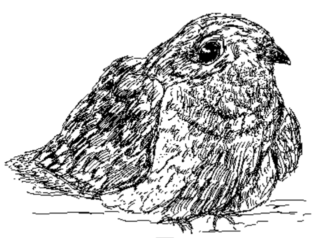
Canada Warbler [Cardellina Canadensis]
120mm - 150mm
Status: Special Concern



Common Nighthawk [Chordeiles Minor]
220mm - 240mm
Status: Special Concern



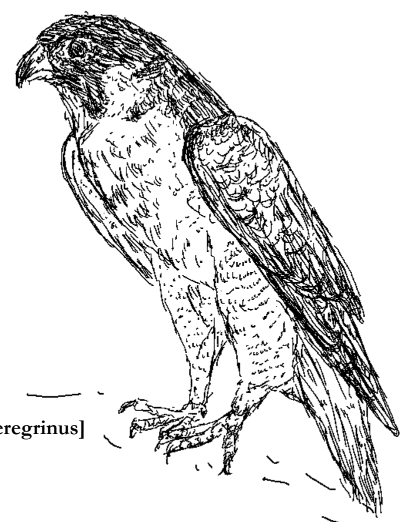
Short-eared Owl [Asio Flammeus]
340mm - 420mm
Status: Special Concern



Eastern Whip-poor-will [Antrostomus Vociferus]
220mm - 260mm
Status: Threatened

Eastern Meadowlark [Sturnella Magna]
190mm - 260mm
Status: Threatened

Bobolink [Dolichonyx Oryzivorus]
165mm - 202mm
Status: Threatened



Peregrine Falcon [Falco Peregrinus]
740mm - 1200mm
Status: Special Concern

As developed in the multi-species Chimney Swift design (chapter 3.2), the bark and sapwood of sawmilled lumber can be utilized as a material substrate to encourage multi-species habitat. As such, soil retention structures constructed out of these outer tree layers provide for an easily repeatable and adaptable modular system that is applied directly to the irregular topography (Fig. 91-94).

Positioned in overlapping horizontal orientations, the cutoff edge conditions create flat surfaces to stack each irregular piece and allow for a through dowel connection allowing for flexibility in positioning. Where the organic edge condition of bark is to be oriented towards either side providing direct contact with the additive soil substrates creating rich micro-habitat conditions where micro-organisms of bacteria, fungi, protozoa and nematodes; meso- fauna of mites and springtails; and macro-fauna of earthworms, termites, and soil insect communities can begin to form (Fig. 95).[160] These soil retention structures act as the first hosts to hundreds of species, holding the regreening treatments in place while vegetation begins to take root during its architectural succession (Fig. 96). Located within the slopes in topography where erosion naturally occurs, these soil retention structures create ecological corridors from the existing early successional forest surrounding the bottom of the hill and encourages the continued growth upwards onto the outcroppings (Fig. 97, 98).



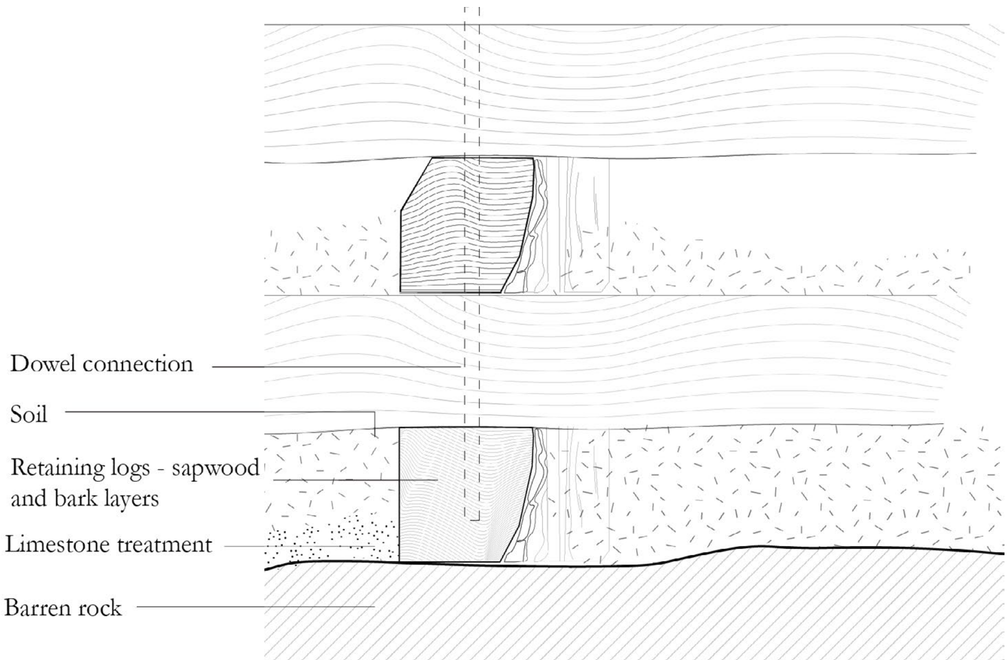

Figure 91 | **Soil Retention (1)**

Figure 92| **Soil Retention (2)**

Figure 93| **Soil Retention (3)**

Figure 94| **Soil Retention (4)**

160 ISSUU, "Living Landscape - A Biodiversity Action Plan for Greater Sudbury."



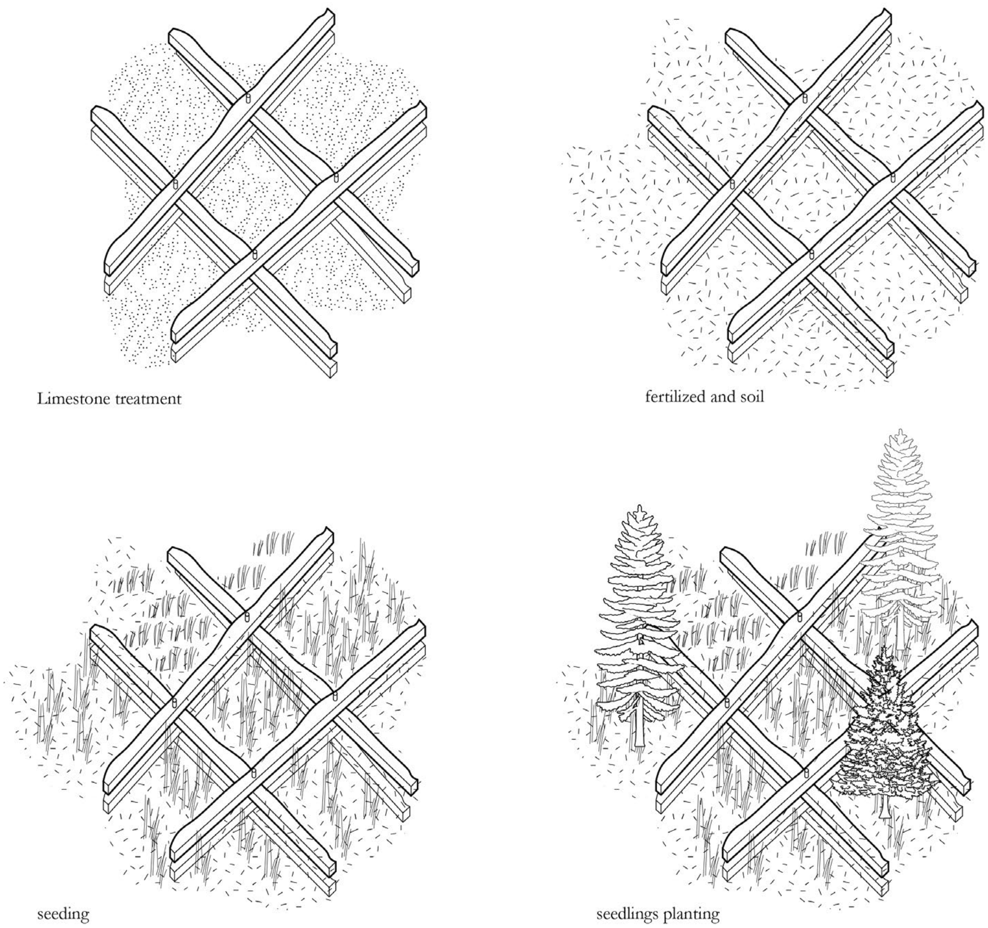
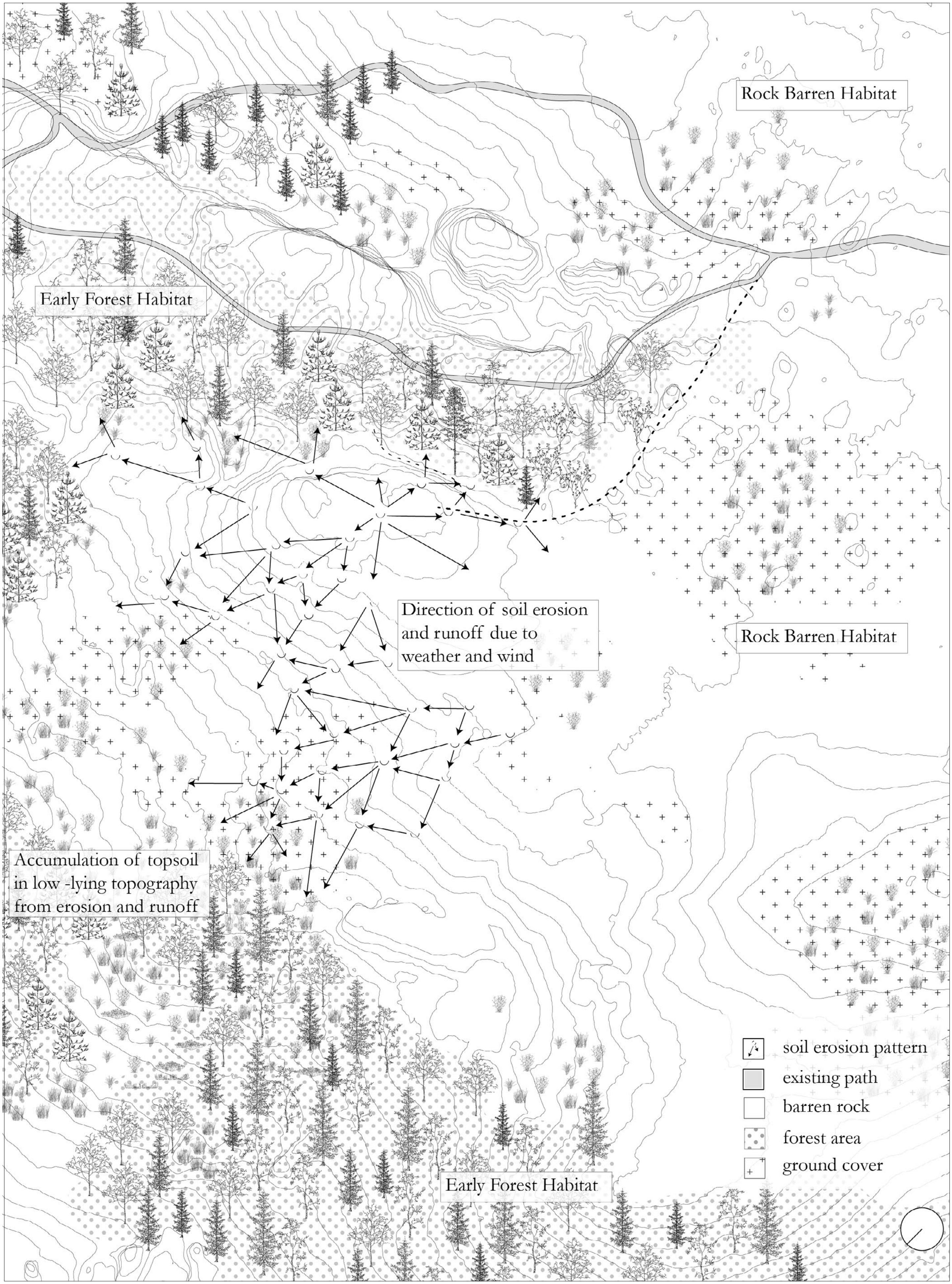


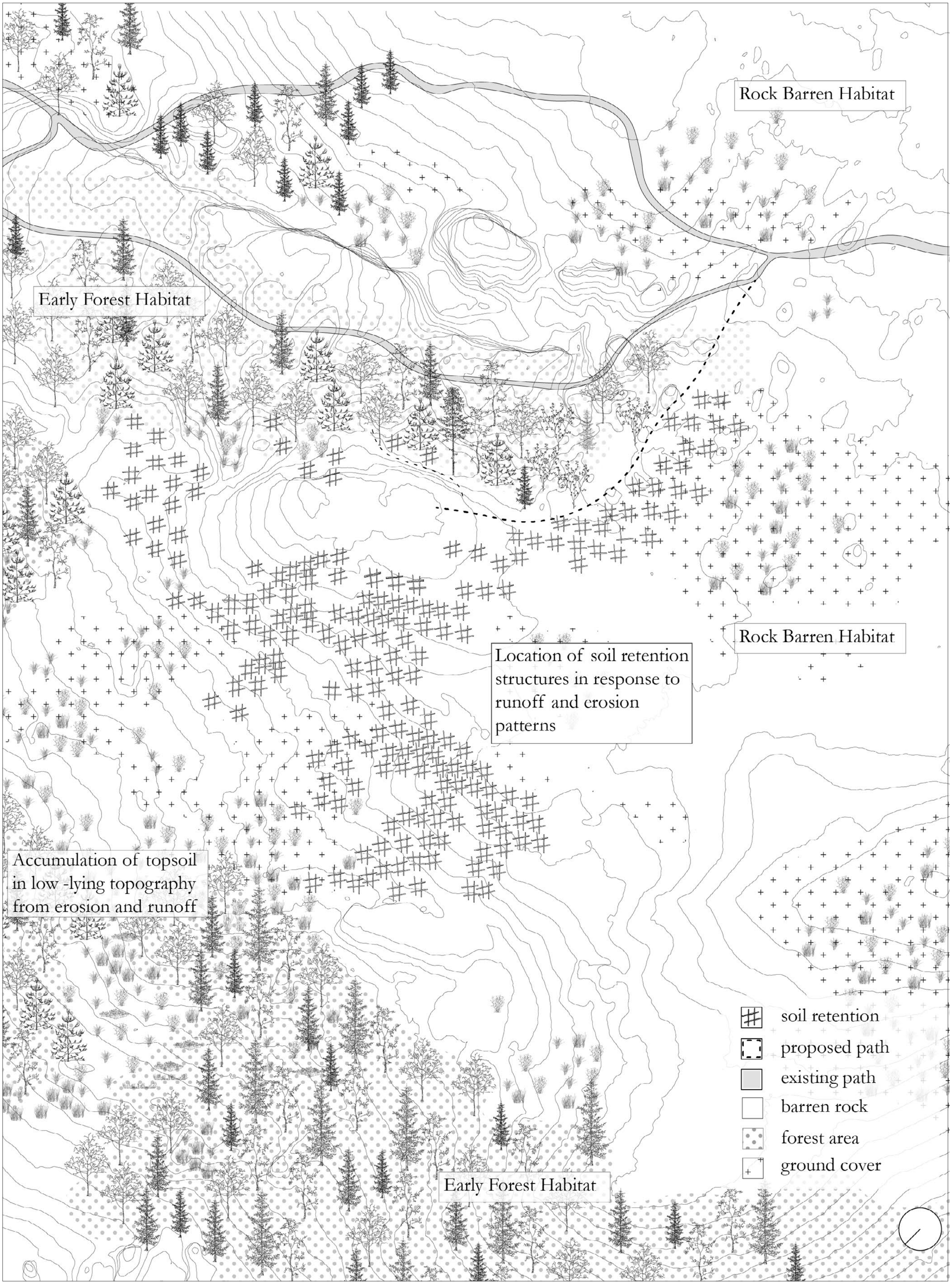
Figure 95| **Soil Retention Detail**

Figure 96 |S**oil Retention Succession**

Figure 97 |**Maley Hill Axonometric (1)** [page 67]

Figure 98 |**Maley Hill Axonometric (2)** [page 68]


Rock Barren Habitat
Early Forest Habitat
Direction of soil erosion and runoff due to weather and wind
Rock Barren Habitat
Accumulation of topsoil in low -lying topography from erosion and runoff
soil erosion pattern
existing path
barren rock
forest area
ground cover
Early Forest Habitat



Rock Barren Habitat
Early Forest Habitat
Rock Barren Habitat
Location of soil retention structures in response to runoff and erosion patterns
Accumulation of topsoil in low -lying topography from erosion and runoff
Early Forest Habitat
soil retention
proposed path
existing path
barren rock
forest area
ground cover

Habitat Typologies

To further expand the forest surrounding Maley hill, built interventions are required to temporarily provide habitat as the forest vegetation develops. In examining Maley's present and potential future species, four key habitat typologies of understory, deadwood, tree dwelling, and human infrastructure have been identified (Fig. 99). Each of these habitat typologies provides a variety of Sudbury's insect, mammal, and bird species with nesting and/or feeding grounds (See Appendix E). Whereby utilizing the proposed soil retention structures as an architectural foundation, temporary habitat pavilions constructed out of sawmill offcuts can begin to populate and connect the architectural forest corridor. As the forest matures, species will gradually transition from a dependance on each pavilion to the developing vegetation, leaving the untreaded timber as deadwood to further enrich the soil cycle.

At-risk bird species of Golden-winged Warbler, Bobolink, Eastern Meadowlark, Whip-poor-will, Canada Warbler, and Short-eared Owl, commonly nest or feed in environments with dense grasses, ground litter, and protected understory, a habitat type currently underdeveloped within the Sudbury landscape. Overlapping with habitat requirements of various forest and barren insect species (grasshopper, ant, aphid, stink bug, wood cockroach, American Painted Lady, Canadian Tiger Swallowtail long-horned beetle), and small wildlife (mice, vole, hare, fox, snake, songbirds, etc.), these understory conditions are essential in supporting a healthy ecosystem. As such, an iterative design process exploring different densities and orientations of offcut materials into habitat pavilions mimic that of dense understory conditions (Fig. 100-104).

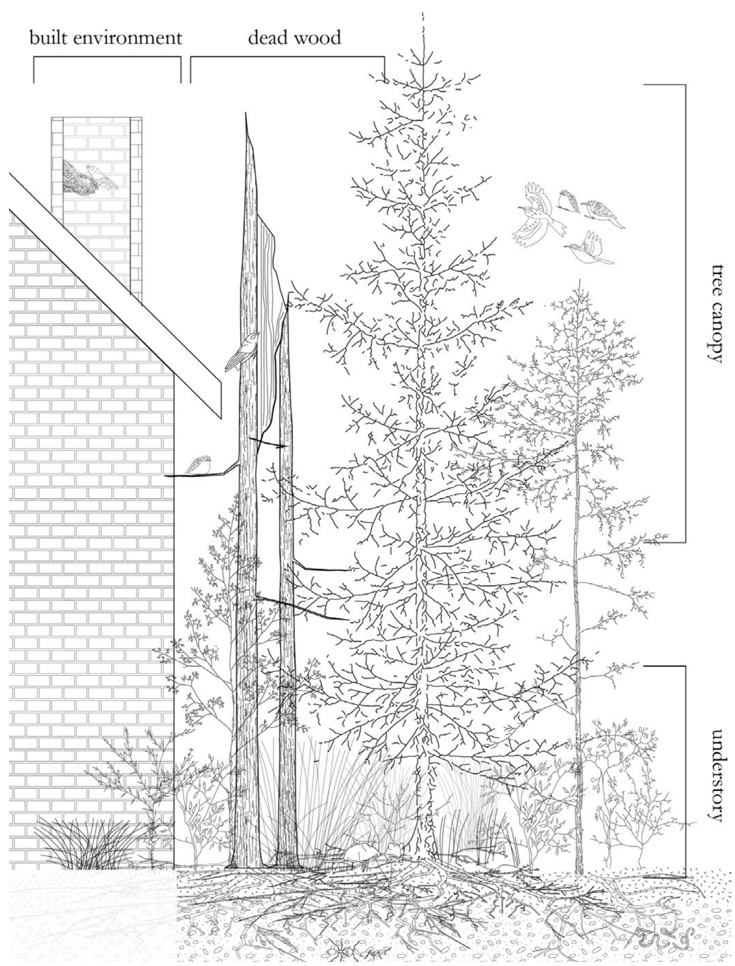


Figure 99 | **Habitat Typologies**

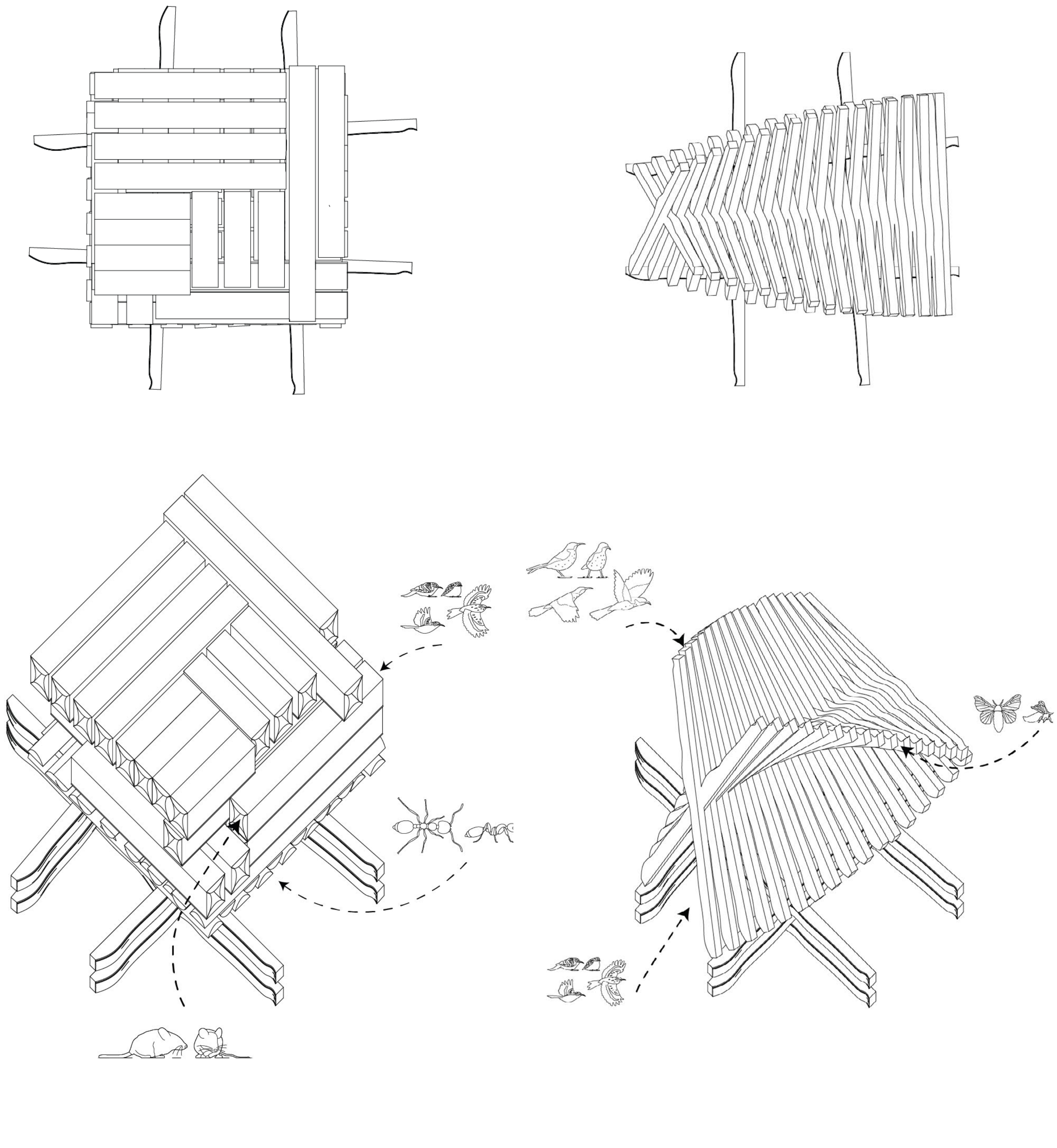
Figure 100 | **Understory Pavilion (1)**
[page 70]

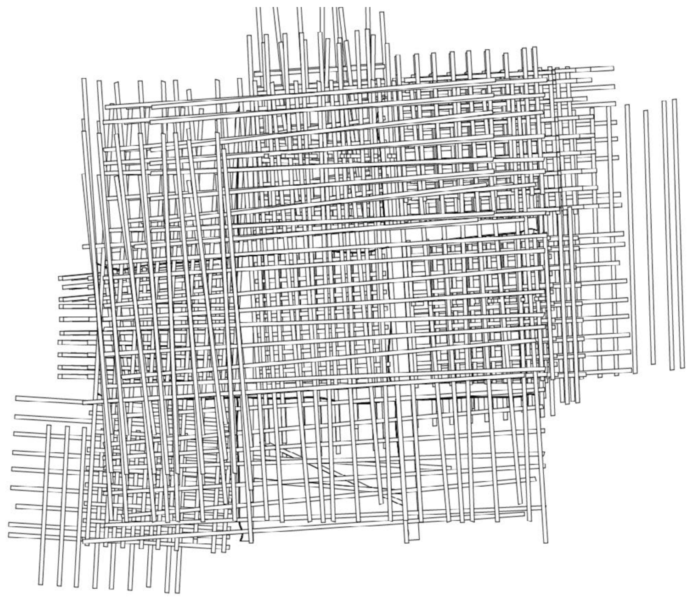
Figure 101 | **Understory Pavilion (2)**
[page 70]

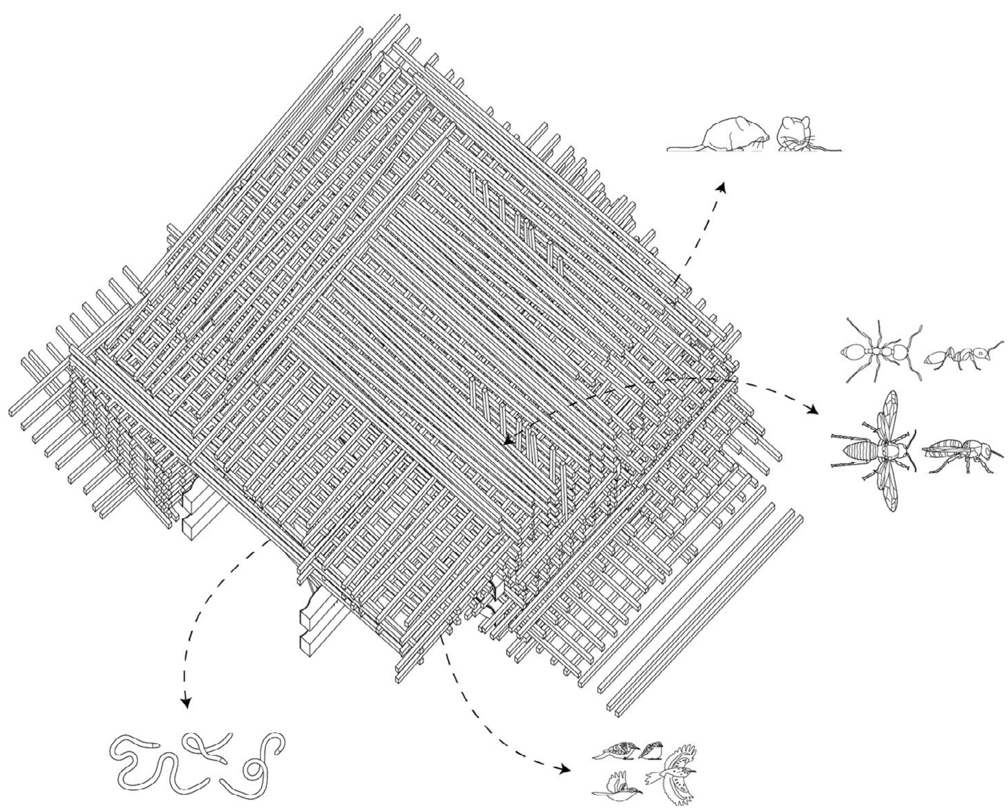
Figure 102 | **Understory Pavilion (3)**
[page 71]

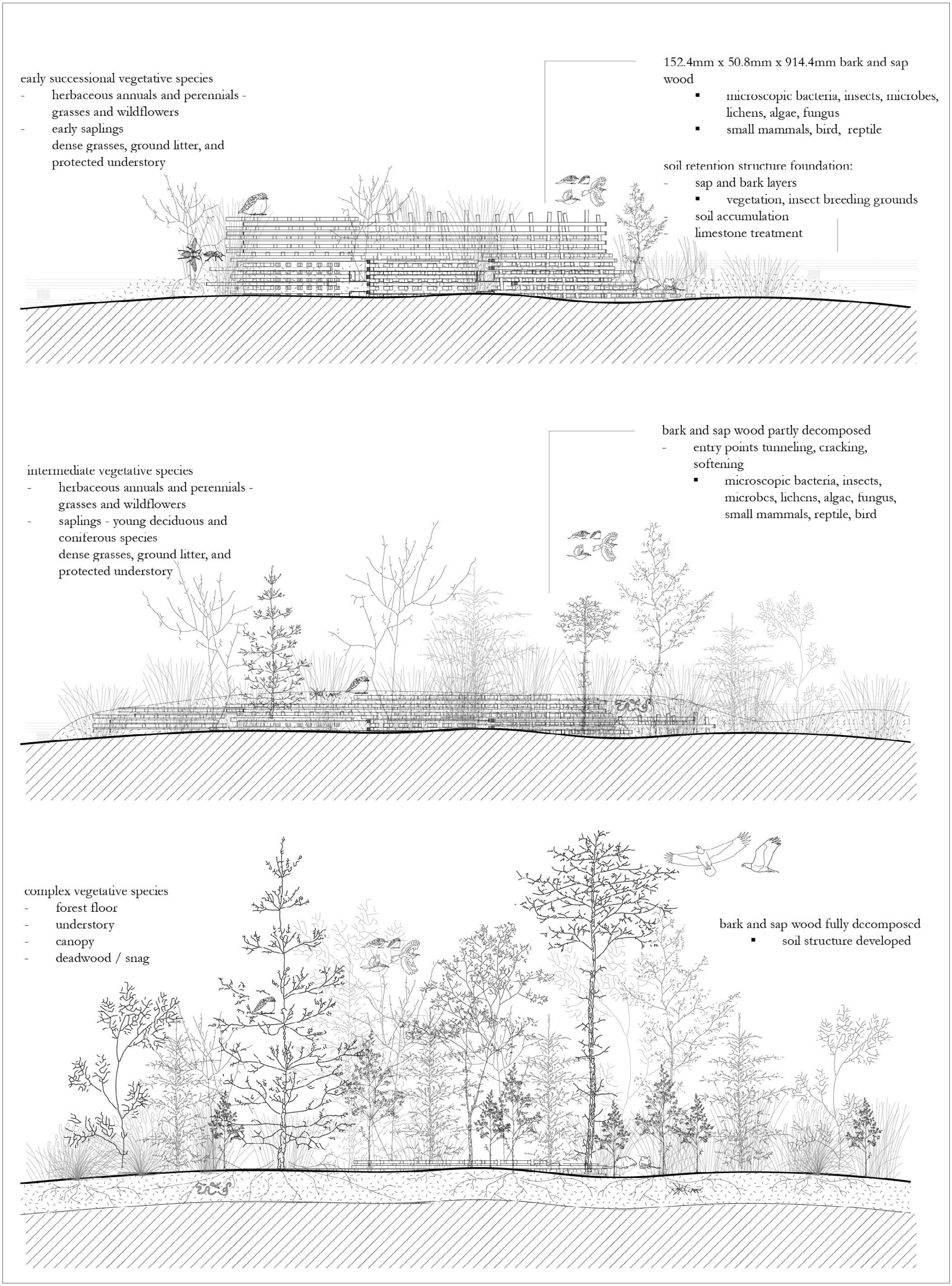
Figure 103 | **Understory Pavilion Succession**
[page 72]

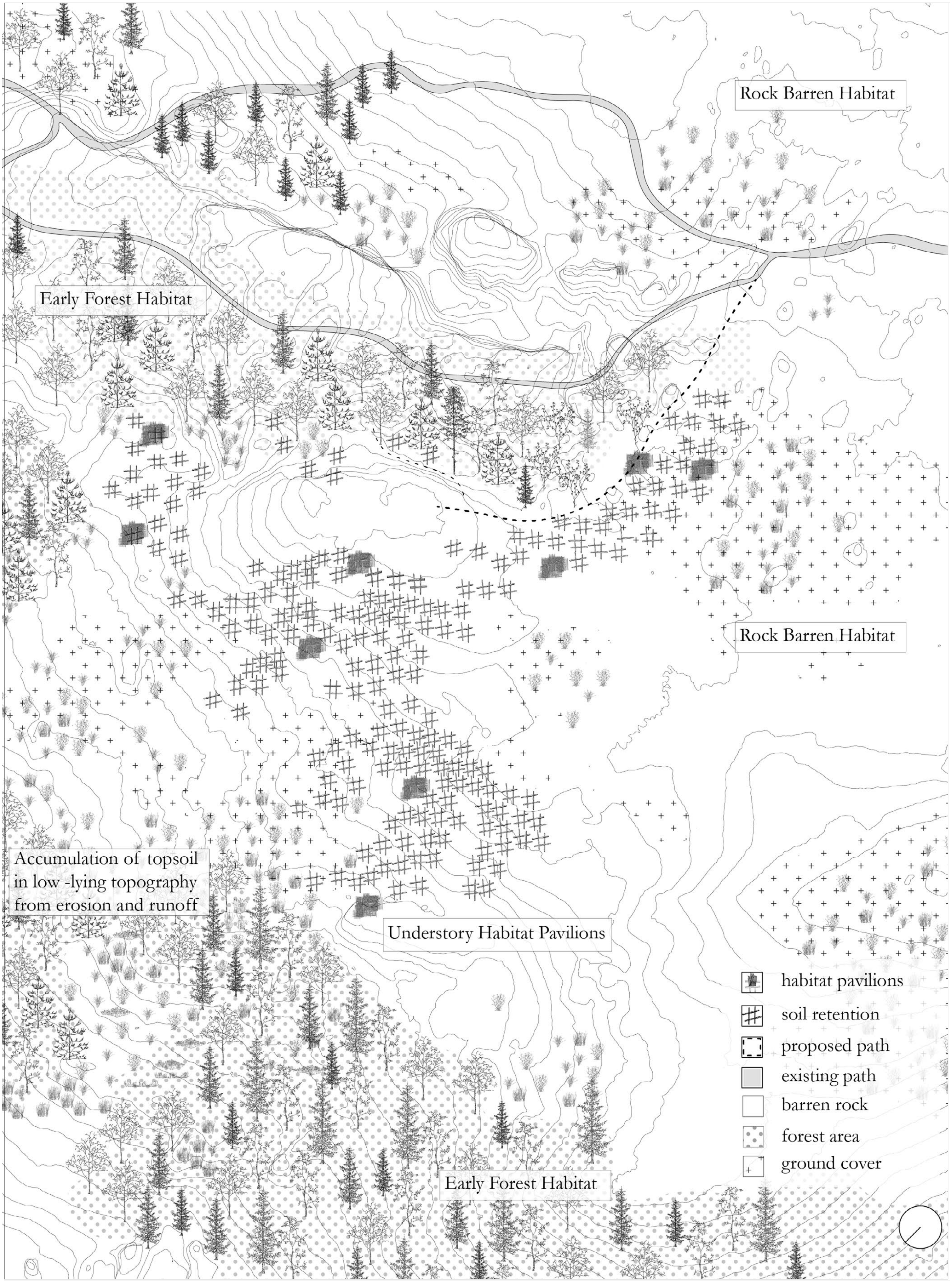
Figure 104 | **Understory Pavilion Location**
[page 73]








early successional vegetative species
- herbaceous annuals and perennials - grasses and wildflowers
- early saplings
dense grasses, ground litter, and protected understory
152.4mm x 50.8mm x 914.4mm bark and sap wood
▪ microscopic bacteria, insects, microbes, lichens, algae, fungus
▪ small mammals, bird, reptile
soil retention structure foundation:
- sap and bark layers
▪ vegetation, insect breeding grounds
- soil accumulation
- limestone treatment
intermediate vegetative species
- herbaceous annuals and perennials - grasses and wildflowers
- saplings - young deciduous and coniferous species
dense grasses, ground litter, and protected understory
bark and sap wood partly decomposed
- entry points tunneling, cracking, softening
▪ microscopic bacteria, insects, microbes, lichens, algae, fungus, small mammals, reptile, bird
complex vegetative species
- forest floor
- understory
- canopy
- deadwood / snag
bark and sap wood fully decomposed
▪ soil structure developed


Rock Barren Habitat
Early Forest Habitat
Rock Barren Habitat
Accumulation of topsoil in low -lying topography from erosion and runoff
Understory Habitat Pavilions
habitat pavilions
soil retention
proposed path
existing path
barren rock
forest area
ground cover
Early Forest Habitat

As forests structures evolve, diverse habitat types continue to develop. Mature trees begin to age allowing for deadwood snags and hollows to form, providing cavities and substrate for additional species to utilize. When standing, these cavities support species such as the at-risk Chimney Swift and Common Nighthawk. The development of fungus and lichens then begin the decomposition process accompanied by various saproxylic species, borer insects, woodpeckers, owls, songbirds, among others. Once fallen, the deadwood provides organic material for organisms like mites, collembolans, spiders, millipede, centipedes, amphibians, and small mammals and vegetation to gain access through additional entry points into the wood.[161]

Due to the Sudbury forest being within its early successional period, large vegetation capable of providing these hollow conditions are in dire need. As such, temporary pavilions following these principals have been created to mimic hollow old growth trees both in vertical and horizontal orientation (Fig. 105-109). Located amongst the soil retention structures, the deadwood pavilions are positioned where there is a lack of understory or remaining understory pavilion (Fig. 111), such that when the structure transitions from standing to fallen deadwood, necessary understory habitat will continue to be provided in those locations throughout the forest's succession (Fig. 110).

Figure 105 | **Deadwood Pavilion (1)**
[page 75]

Figure 106 | **Deadwood Pavilion (2)**
[page 75]

Figure 107 | **Deadwood Pavilion (3)**
[page 76]

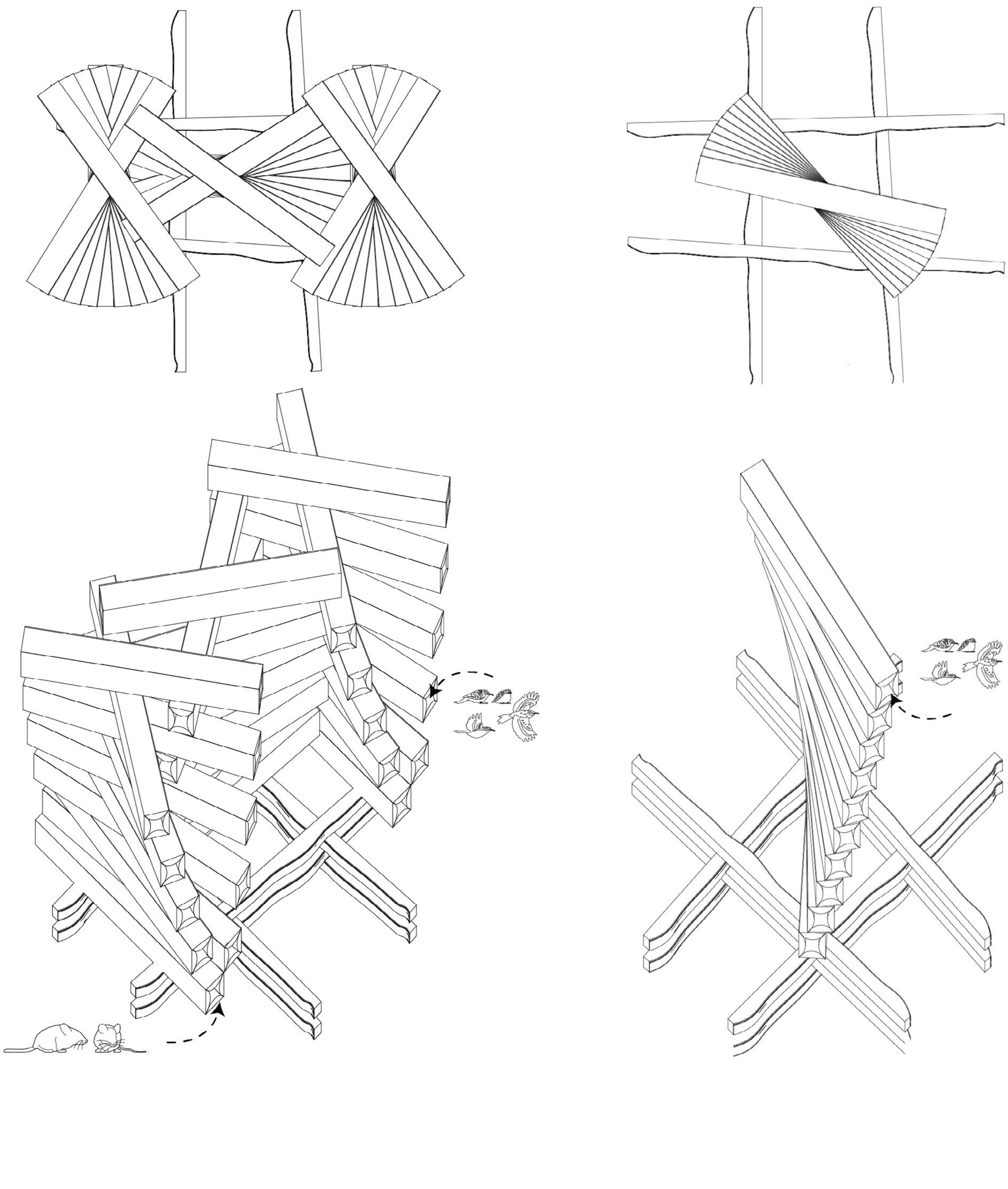
Figure 108 | **Deadwood Pavilion (4)**
[page 76]

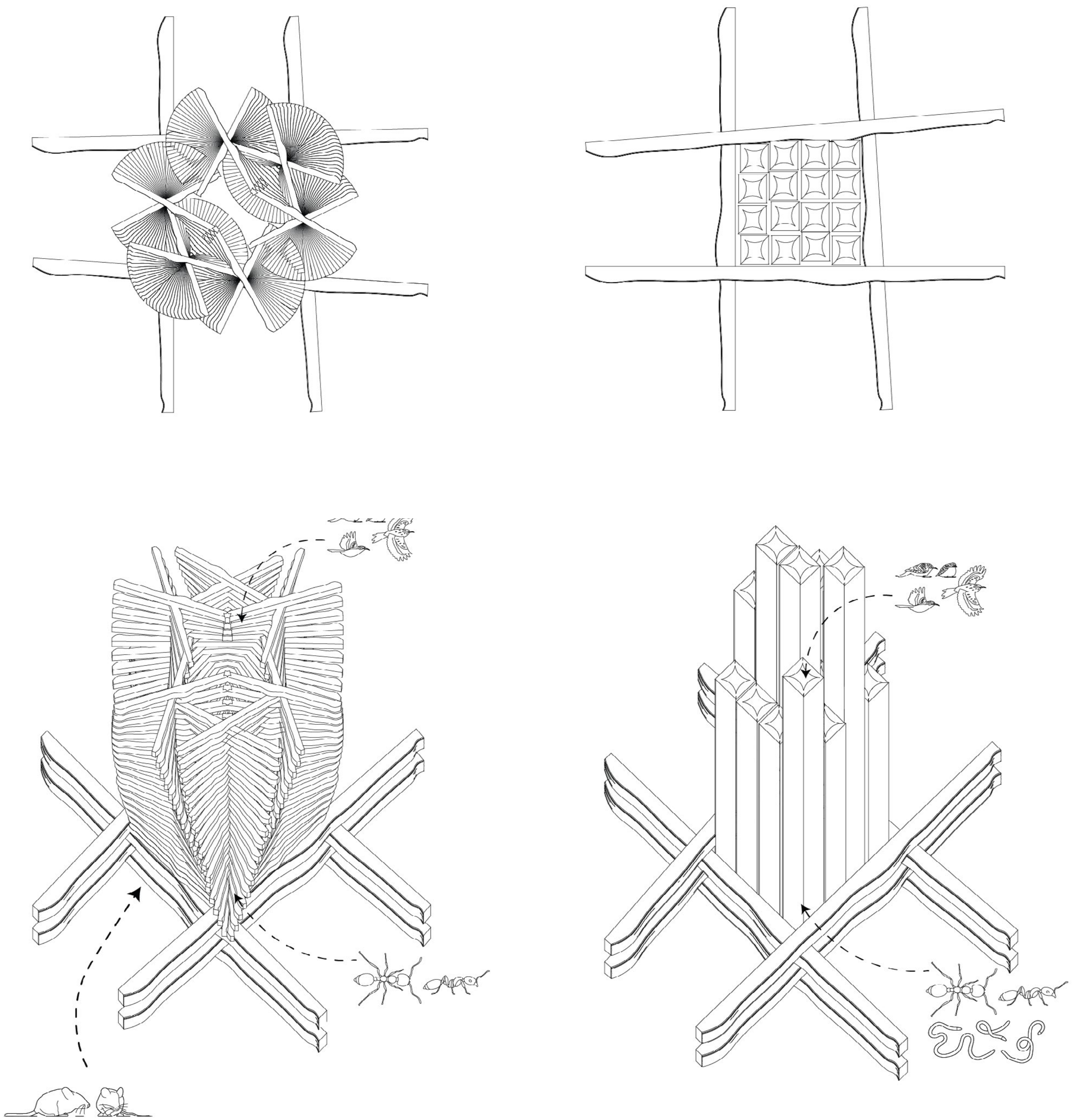
Figure 109 | **Deadwood Pavilion (5)**
[page 77]

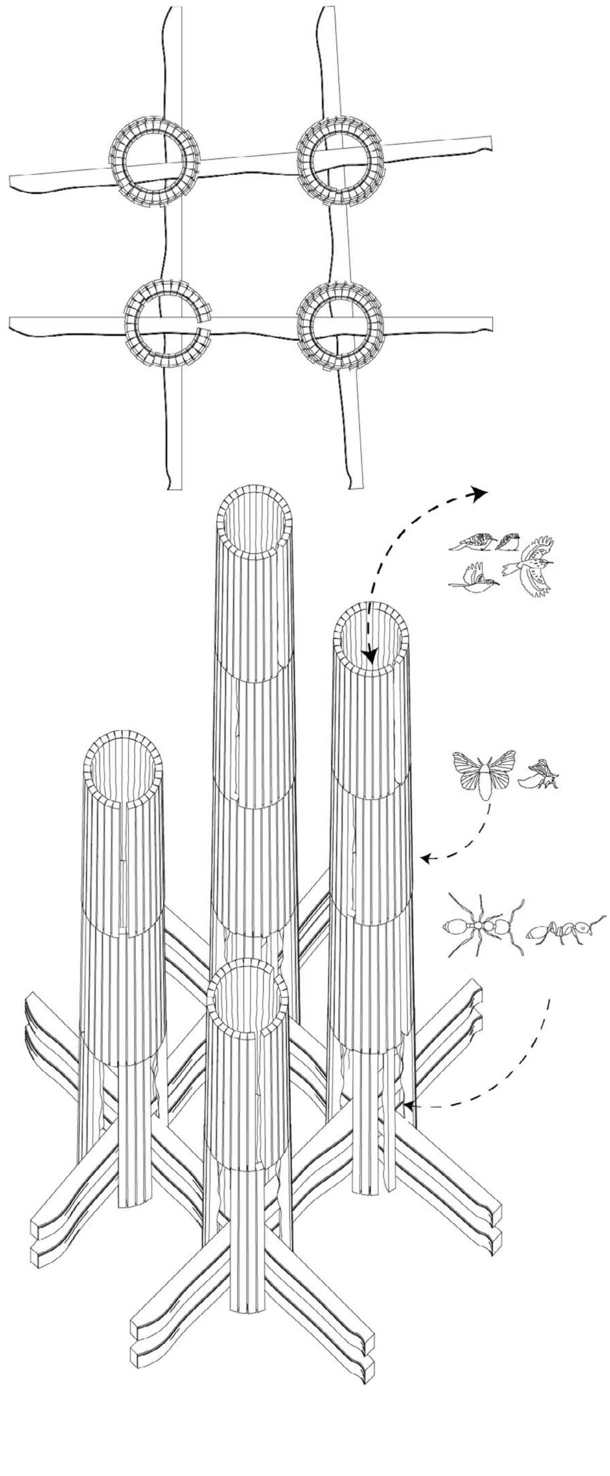
Figure 110 | **Deadwood Pavilion Succession**
[page 78]

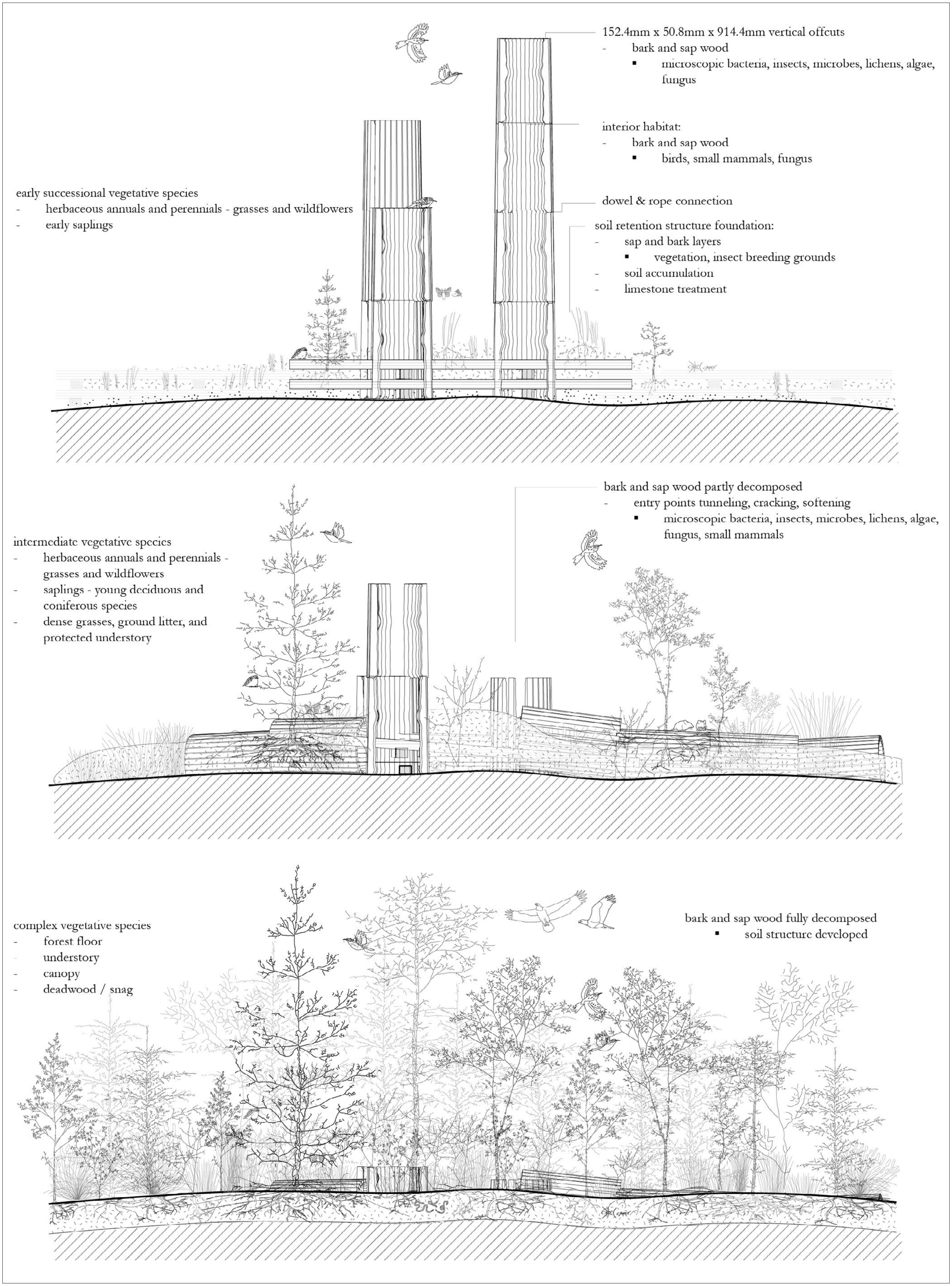
Figure 111 | **Deadwood Pavilion Location**
[page 79]

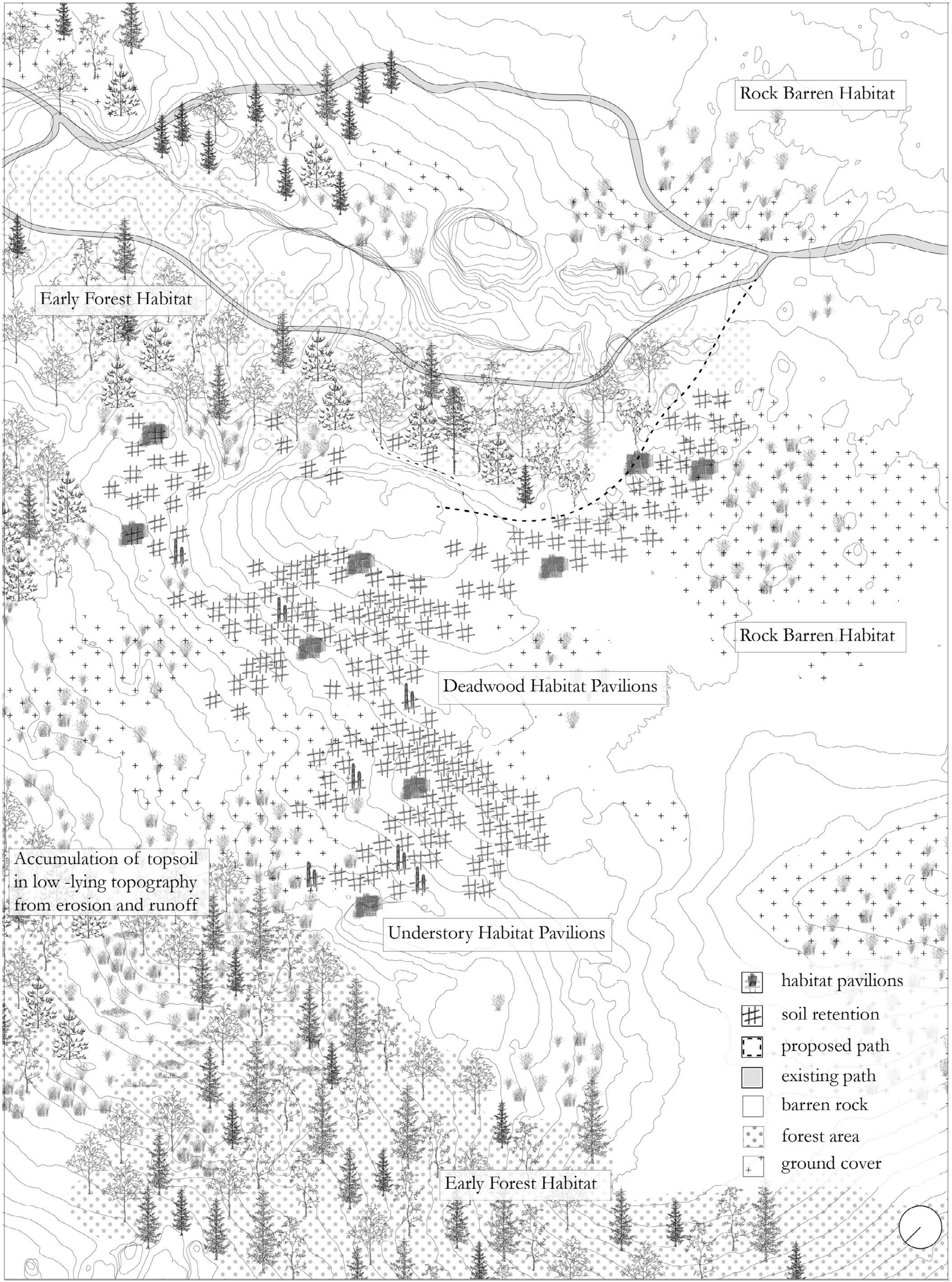
161 Chris Maser, Robert F. Tarrant, James M. Trappe, and Jerry F. Franklin, "From the forest to the sea: a story of fallen trees," *U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station*, (1988): 42, https://doi.org/10.2737/PNW-GTR-229.








152.4mm x 50.8mm x 914.4mm vertical offcuts
- bark and sap wood
▪ microscopic bacteria, insects, microbes, lichens, algae, fungus
interior habitat:
- bark and sap wood
▪ birds, small mammals, fungus
early successional vegetative species
- herbaceous annuals and perennials - grasses and wildflowers
- early saplings
dowel & rope connection
soil retention structure foundation:
- sap and bark layers
▪ vegetation, insect breeding grounds
- soil accumulation
- limestone treatment
bark and sap wood partly decomposed
- entry points tunneling, cracking, softening
▪ microscopic bacteria, insects, microbes, lichens, algae, fungus, small mammals
intermediate vegetative species
- herbaceous annuals and perennials - grasses and wildflowers
- saplings - young deciduous and coniferous species
- dense grasses, ground litter, and protected understory
complex vegetative species
- forest floor
- understory
- canopy
- deadwood / snag
bark and sap wood fully decomposed
▪ soil structure developed


Rock Barren Habitat
Early Forest Habitat
Rock Barren Habitat
Deadwood Habitat Pavilions
Accumulation of topsoil in low -lying topography from erosion and runoff
Understory Habitat Pavilions
habitat pavilions
soil retention
proposed path
existing path
barren rock
forest area
ground cover
Early Forest Habitat

Tree dwelling species of lichen, fungus, micro-organisms, insect, mammal, and bird rely on a diversity of tree vegetation to provide their habitat and feeding grounds. Early successional deciduous and coniferous woods provide habitation to species such as the at-risk Common Nighthawk and the Golden-winged Warbler, while mature trees offer the necessary changes in elevation, overall dimension, and tree canopy density for species such as the at-rick Bald Eagle and Peregrine Falcon.

A series of temporary pavilions have been designed based on early successional and mature forest structures, providing various tree canopy habitat types. The early successional pavilions are lower in elevation, focusing their density around the mid and base of the structure with multiples of horizontal surfaces and coverings (Fig. 112, 113).

The mature tree pavilions offer additional elevation, in addition to density around the base mimicking that of the understory conditions (Fig. 114, 115, 116).

As the tree pavilions go through the process of succession, much like that of the natural tree's lifecycle, they will transition from standing to fallen deadwood cavities, further enhancing the ecological development of the forest (Fig. 117). Located adjacent the the soil retention structures, the tree pavilions provide canopy to the development of surrounding vegetation plantings (Fig. 118).

112 | **Early Succession Tree Pavilion (1)**
[page 81]

113 | **Early Succession Tree Pavilion (2)**
[page 81]

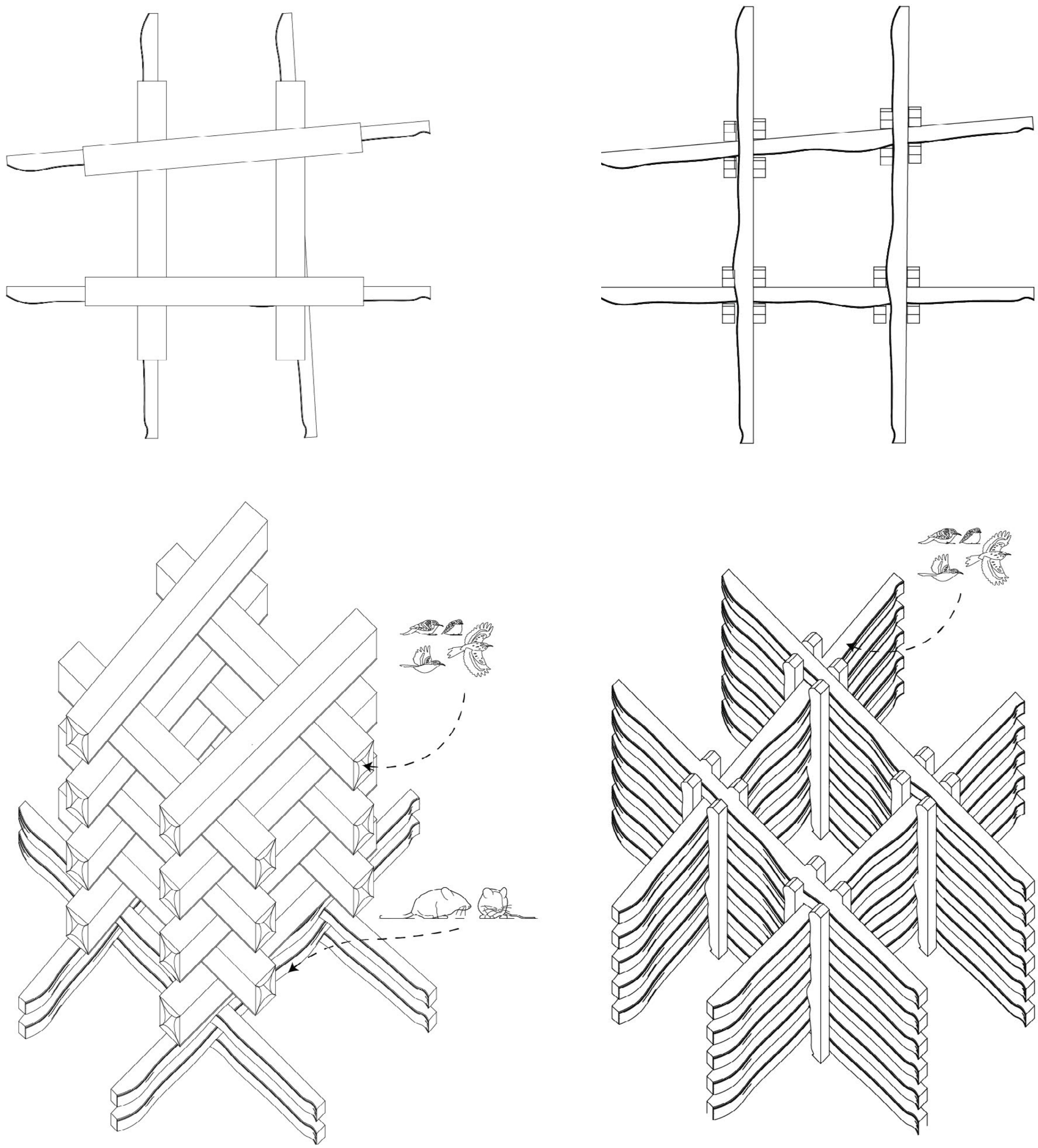
114 | **Mature Tree Pavilion (1)**
[page 82]

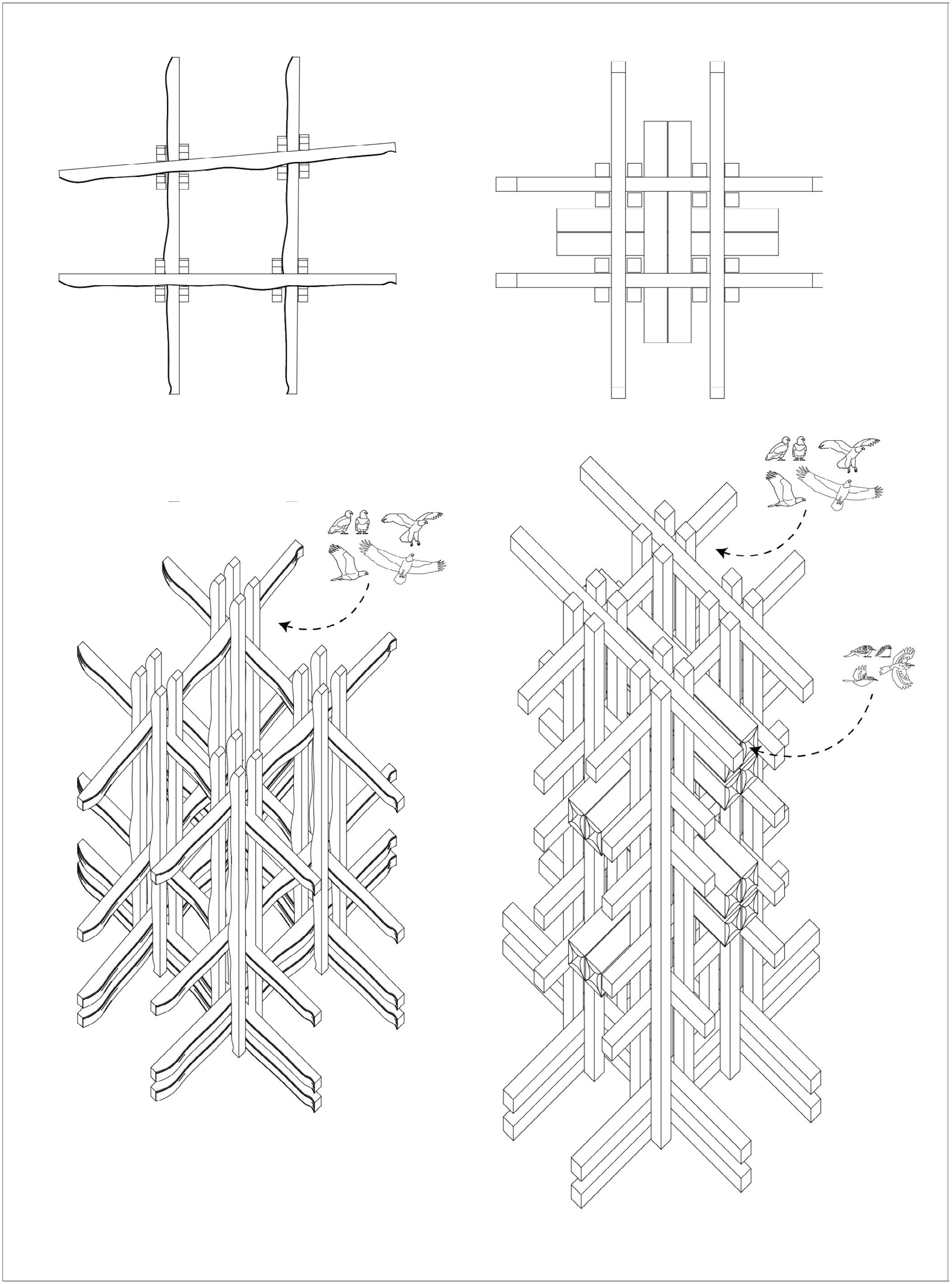
115 | **Mature Tree Pavilion (2)**
[page 82]

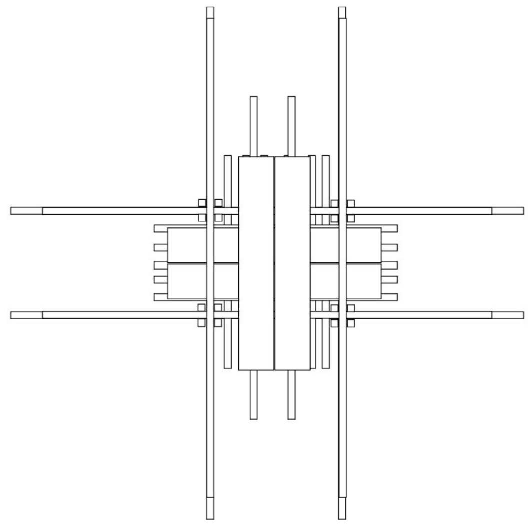
116 | **Mature Tree Pavilion (3)**
[page 83]

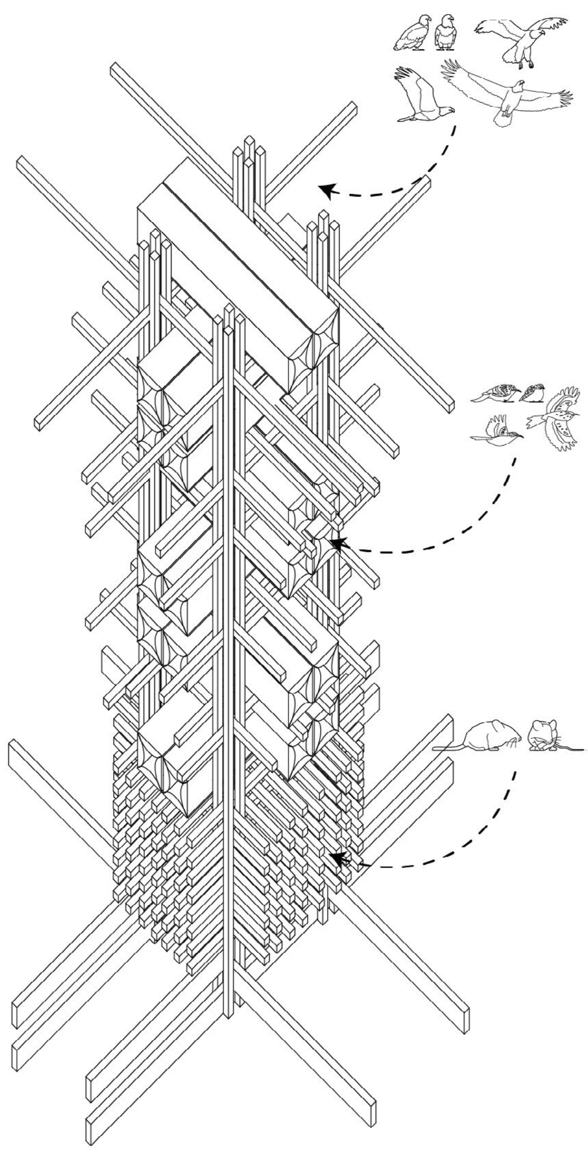
117 | **Mature Tree Pavilion Succession**
[page 84]

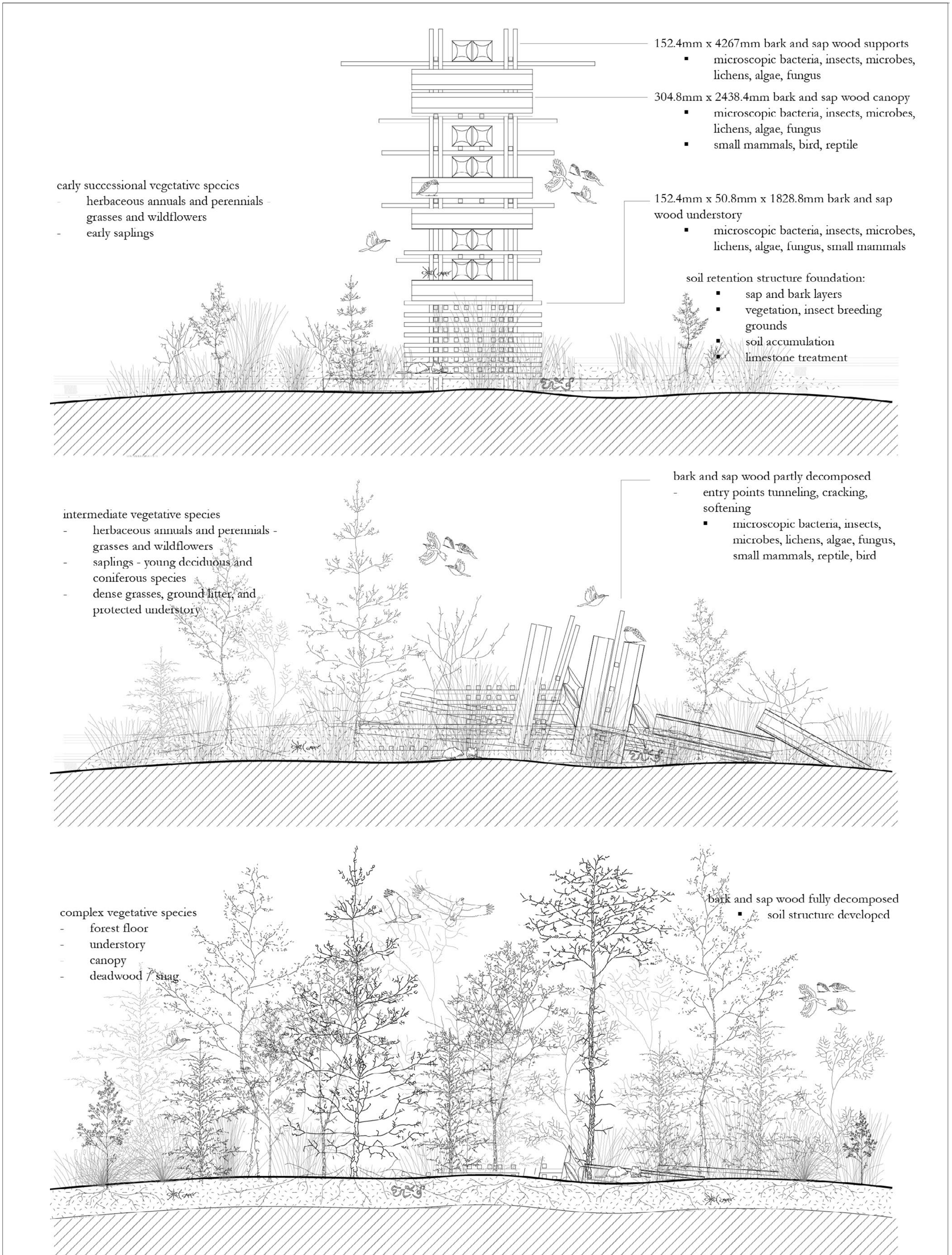
118 | **Mature Tree Pavilion Location**
[page 85]

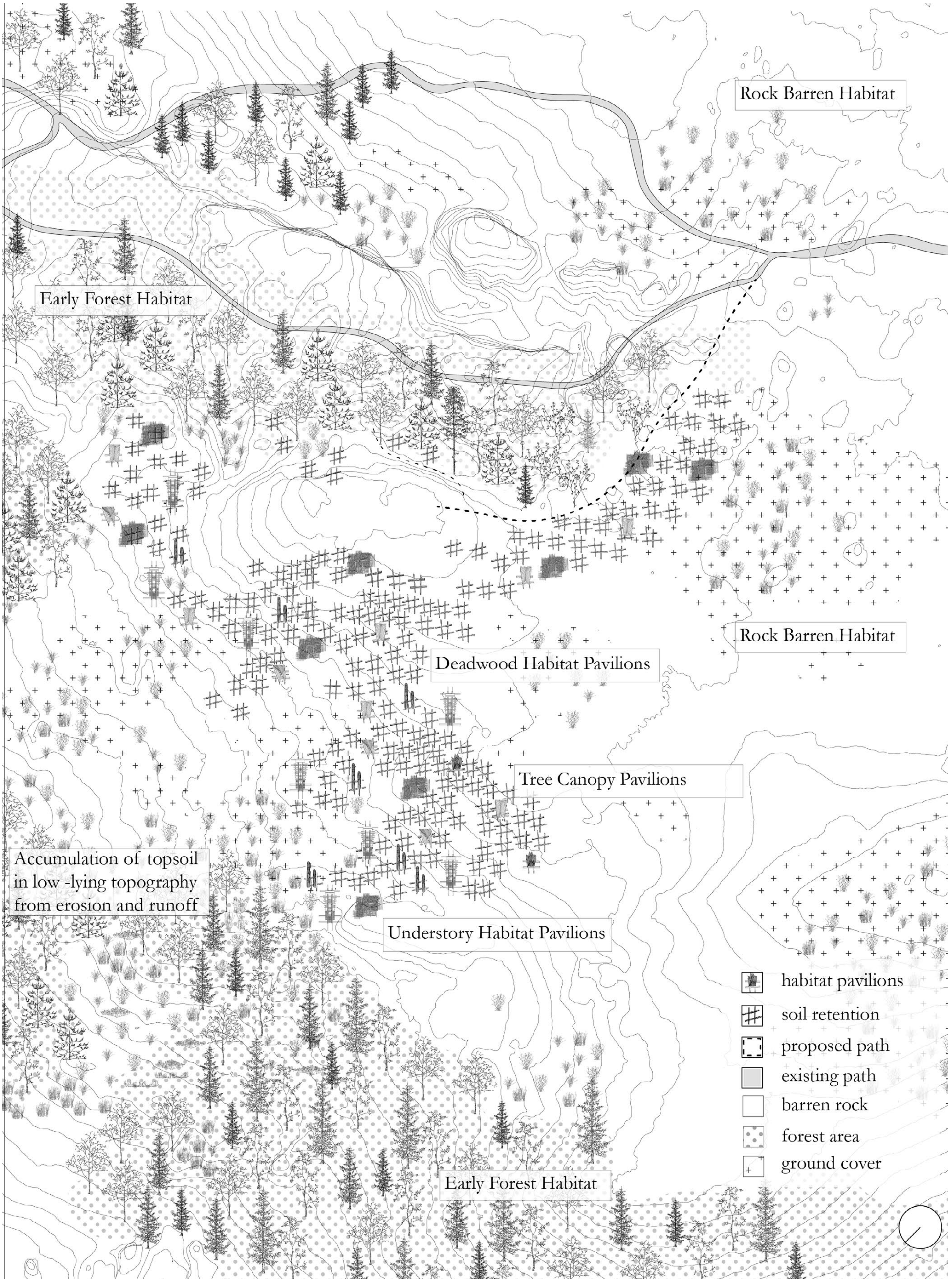









152.4mm x 4267mm bark and sap wood supports
▪ microscopic bacteria, insects, microbes, lichens, algae, fungus
304.8mm x 2438.4mm bark and sap wood canopy
▪ microscopic bacteria, insects, microbes, lichens, algae, fungus
▪ small mammals, bird, reptile
early successional vegetative species
- herbaceous annuals and perennials - grasses and wildflowers
- early saplings
152.4mm x 50.8mm x 1828.8mm bark and sap wood understory
▪ microscopic bacteria, insects, microbes, lichens, algae, fungus, small mammals
soil retention structure foundation:
▪ sap and bark layers
▪ vegetation, insect breeding grounds
▪ soil accumulation
▪ limestone treatment
bark and sap wood partly decomposed
- entry points tunneling, cracking, softening
▪ microscopic bacteria, insects, microbes, lichens, algae, fungus, small mammals, reptile, bird
intermediate vegetative species
- herbaceous annuals and perennials - grasses and wildflowers
- saplings - young deciduous and coniferous species
- dense grasses, ground litter, and protected understory
complex vegetative species
- forest floor
- understory
- canopy
- deadwood / snag
bark and sap wood fully decomposed
▪ soil structure developed


Rock Barren Habitat
Early Forest Habitat
Rock Barren Habitat
Deadwood Habitat Pavilions
Tree Canopy Pavilions
Accumulation of topsoil
in low -lying topography
from erosion and runoff
Understory Habitat Pavilions
habitat pavilions
soil retention
proposed path
existing path
barren rock
forest area
ground cover
Early Forest Habitat

Maley Hill Multi-species Pavilions

Synanthropic species rely on human infrastructure for their habitation, benefiting from conditions of the built environment such as textured and overlapping facades, extruding eaves troughs, downspouts, shingles, chimneys, soffits, overhangs, sills, among other built and otherwise unnatural conditions.[162] Species such as the Chimney Swift, as previously discussed in chapter 3.2, have become accustomed to nesting within the built environment due to humans influence, making it now the responsibility of the designers of these built environments to include them in our design approaches going forward.[163]

Maley hill, through the process of Architectural Succession will provide habitat for multiple species by use of temporary pavilions and soil retention structures. These design interventions will provide direct opportunity for the monitoring of wildlife and ecological recovery within Sudbury's landscape. As such, a series of iterative observation pavilions have been exploded in an effort to identify key opportunities for multi-species inhabitation, later informing the design of the proposed wildlife observation pavilion.

Iteration 01 explores an open-air pavilion of similar design language to that of the soil retention structures, mimicking tree-like canopies with exposed bark and sapwood columns for multi-species inhabitation (Fig. 119).

Iteration 02 investigates an enclosed domestic scaled structure with an inhabitable cladding of horizontal cavities for multi-species on the exterior façade, locating the human observation within its interior plan (Fig. 120).

Iteration 03 explores a domestic scaled structure in reference to the gabled roof in an effort to help users identify which pavilions are intended to be accessible by the human (Fig. 121).

Iteration 04 begins to determine the potential density and porosity of an inhabitable wall system within an open pavilion. Examining the overall thickness needed to allow for horizontal and vertical inhabitation throughout its cavities (Fig. 122).

Iteration 05 invites for a shared interior experience for multi-species, providing a chimney shaped ceiling where species such as birds can access from above and humans pass through and observe from below (Fig. 123).

Figure 119 | **Multi-species Pavilion (1)**
[page 87]

Figure 120 | **Multi-species Pavilion (2)**
[page 88]

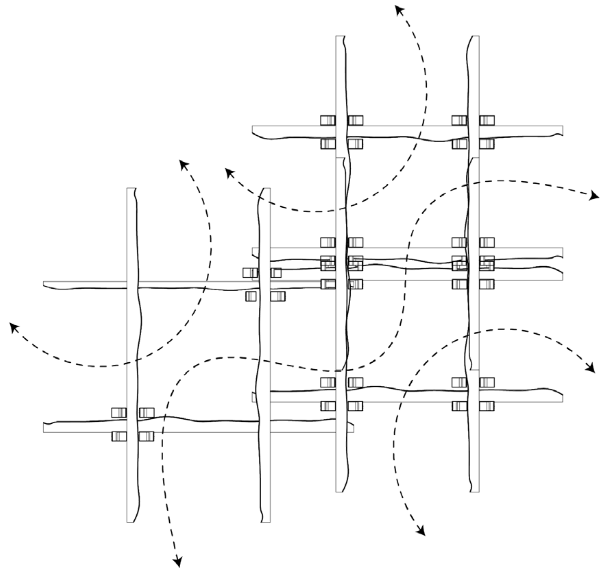
Figure 121 | **Multi-species Pavilion (3)**
[page 89]

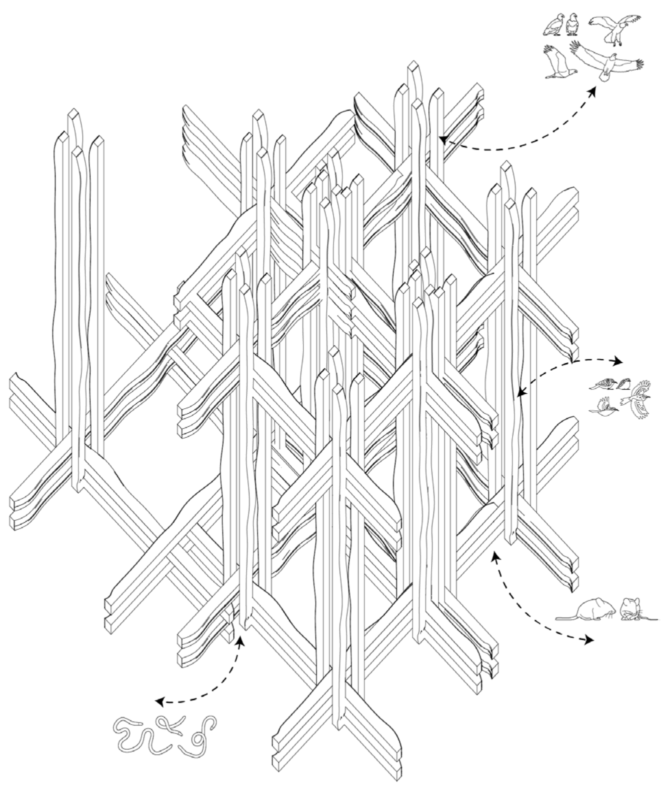
Figure 122 | **Multi-species Pavilion (4)**
[page 90]

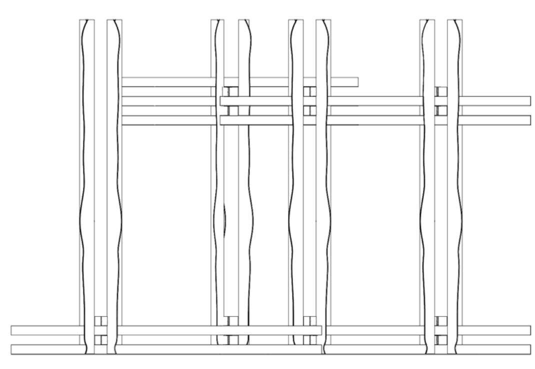
Figure 123 | **Multi-species Pavilion (5)**
[page 91]

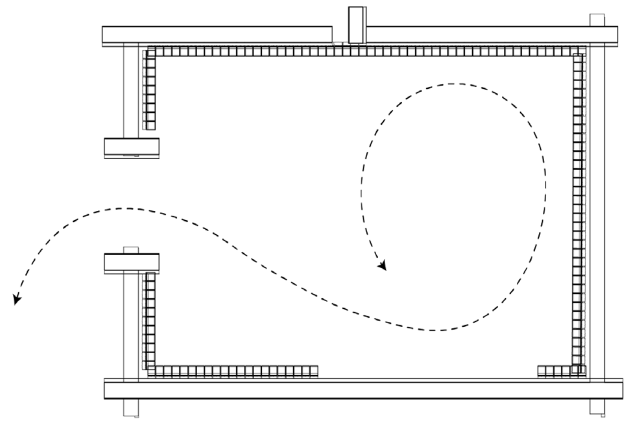
162 "Synanthrope," Wikipedia, last modified January 31, 2023, https://en.wikipedia.org/wiki/Synanthrope.

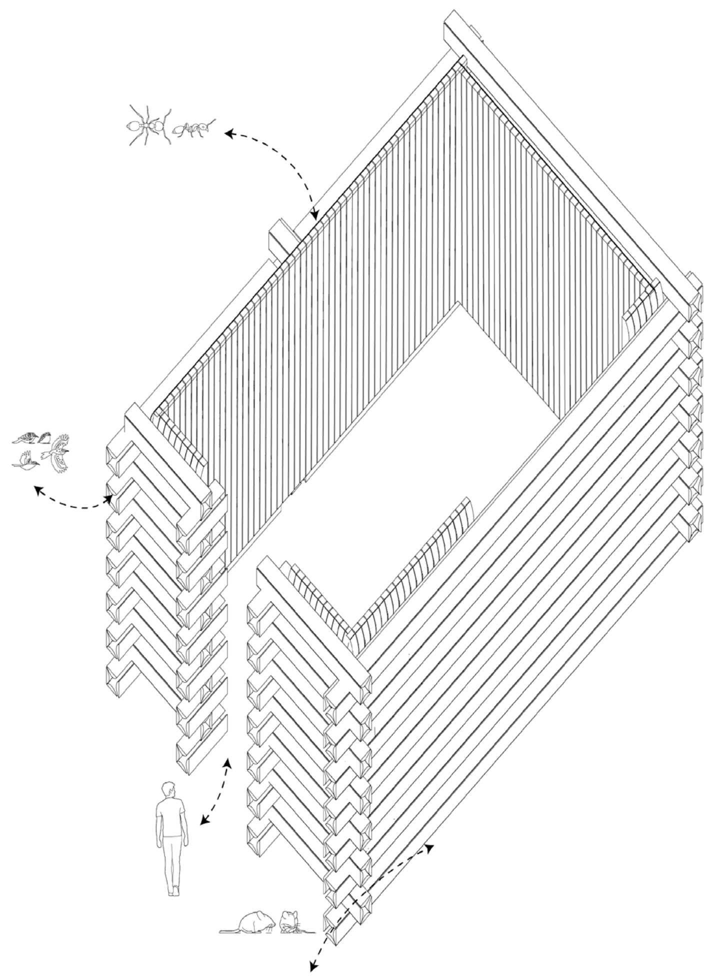
163 Courtney Le Roux and Joseph J. Nocera, "Roost sites of chimney swift (Chaetura pelagica) form large-scale spatial networks," *Ecology and Evolution* 11, (2021): 3821.

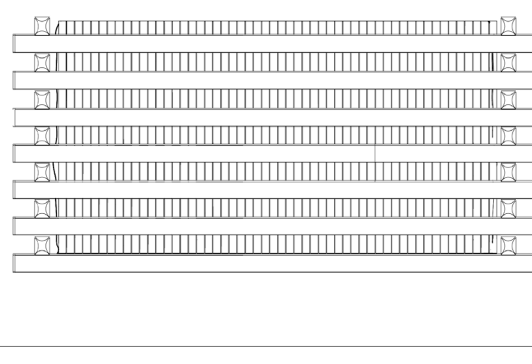


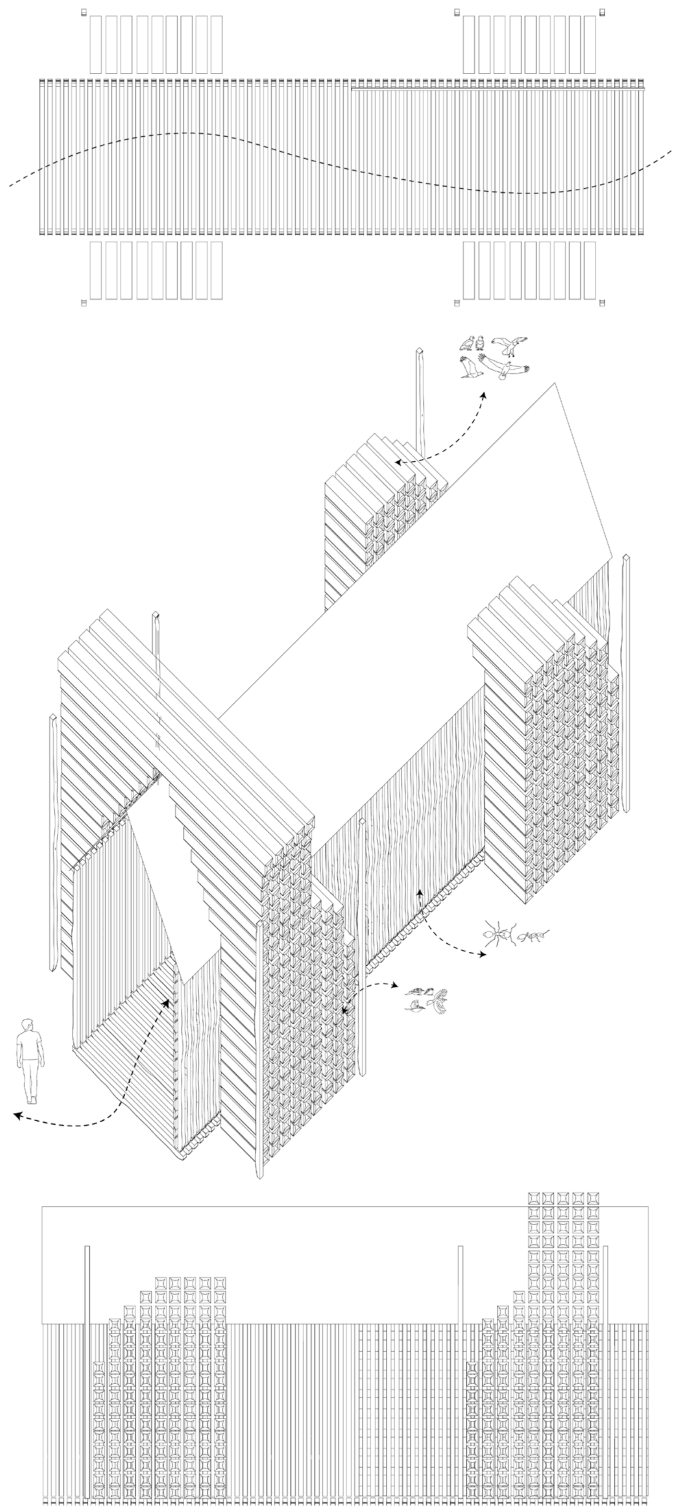


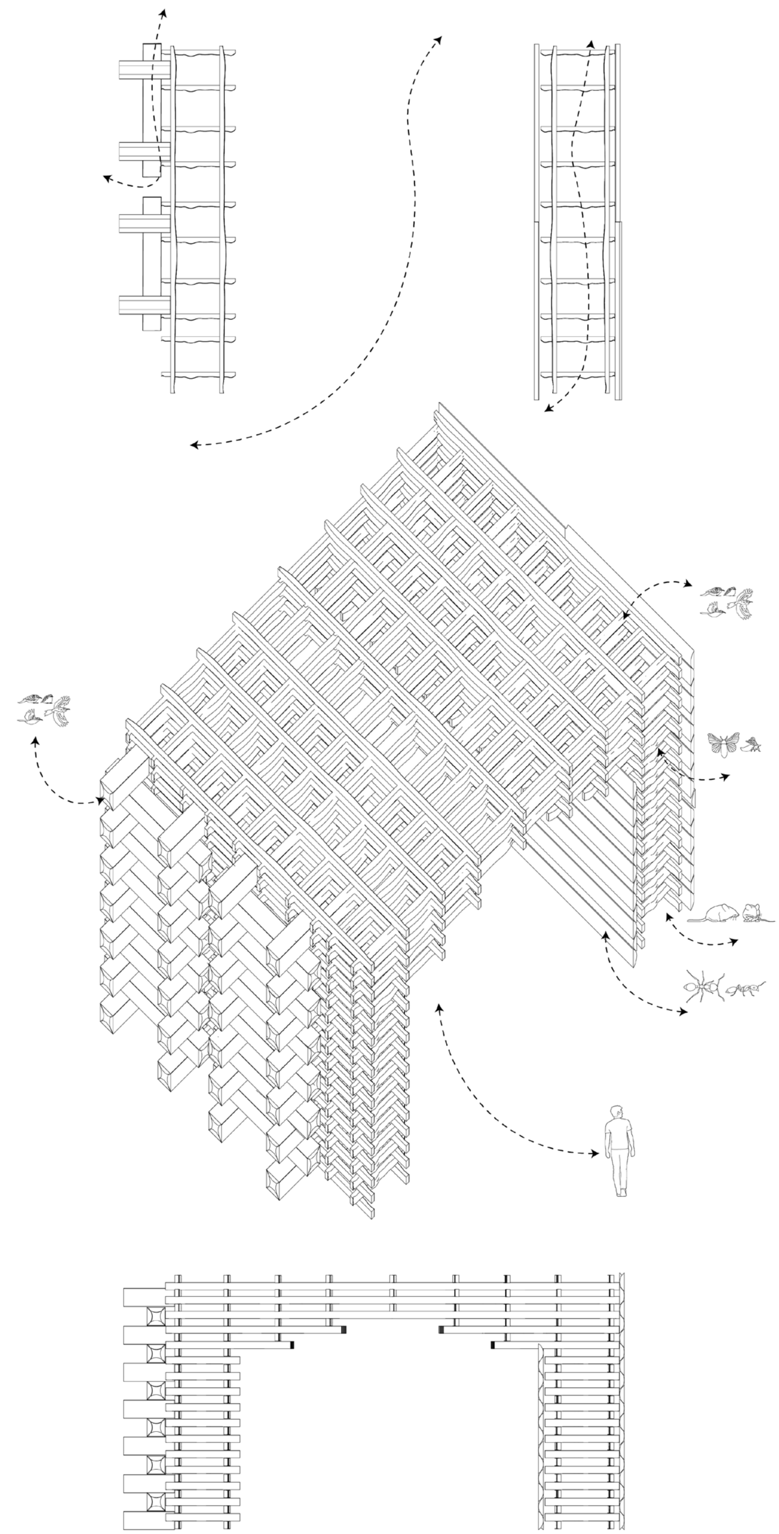


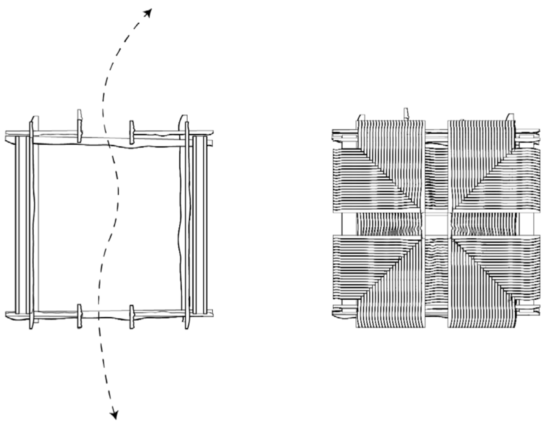


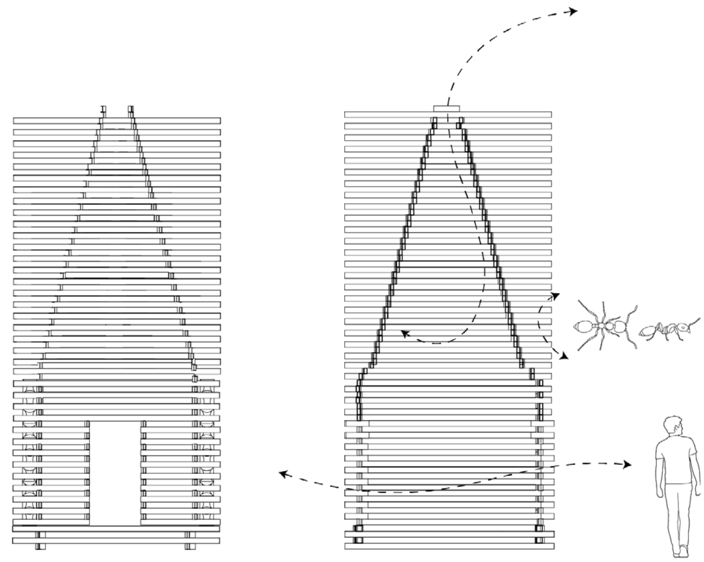


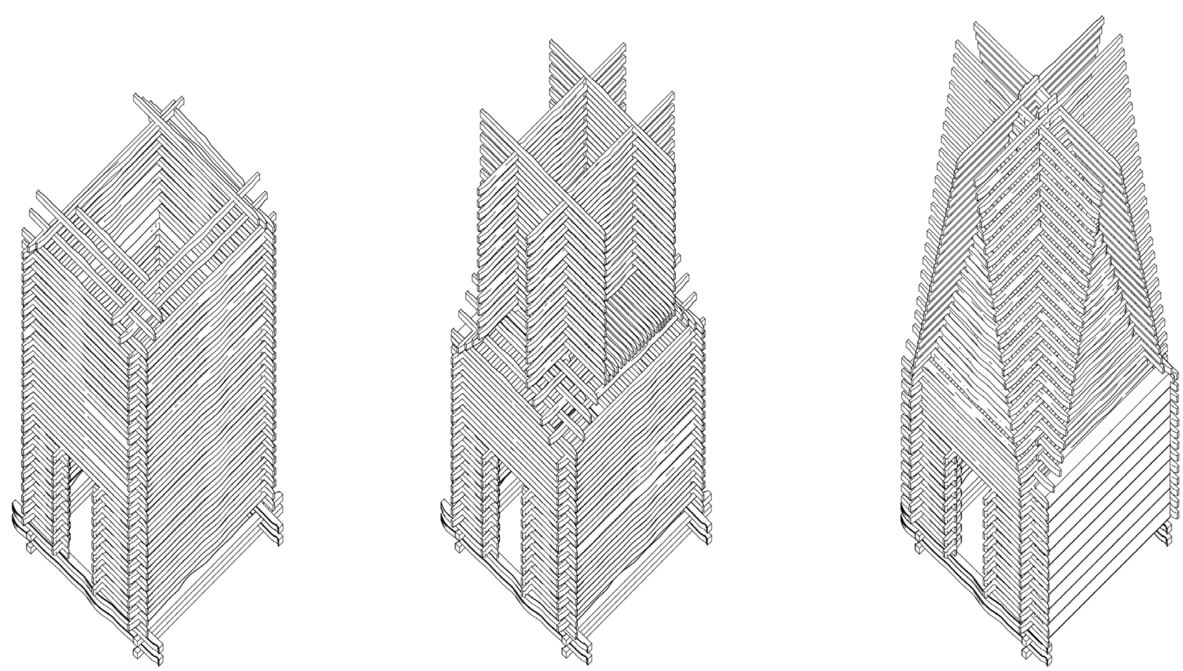












From these design explorations, the primary observation pavilion has been developed into an enclosed structure serving as a monitoring and gathering space for Maley hill visitors. The pavilion responds to the existing urban context of Sudbury, allowing for successional and multi-species design conversation to emerge. The pavilion functions in support of Sudbury's Regreening program, providing direct opportunity for the documentation of the area's ecological recovery by biologists and community naturalists in participation with the forest bird monitoring program.[164] Through the continued process of iterative designs, the relationship between its observation program, site, soil retention, pavilions, and potential use by multiple species have been explored.

Iteration 06 includes interior and exterior space, allowing for program flexibility dependent on seasonality usage. Both spaces allow for the viewer to remain minimally visible from the viewing subject through its use of soil retention like slatted structures (Fig. 124).

Iteration 07 forms a simple enclosed interior, introducing additional opportunities for multi-species inhabitation by elevating its roof members and lifting the pavilion off the exposed rock to create circulation cavities (Fig. 125).

Iteration 08 follows a similar design language of 06 and 07, introducing an elevated circulation platform for its viewers to begin observing the multiple species directly inhabiting the pavilion structure (Fig. 126).

Iteration 09 provides an enclosed woodstove heated interior, cladding its exterior façade in horizontally stacked hollows for multi-species inhabitation (Fig. 127).

Iteration 10 introduces a multiple storey light wood framed structure offering additional views onto the existing and developing forest areas. The pavilion is clad in inhabitable offcuts and its roof is elevated off the structure to provide a semi-sheltered third storey with access for several species (Fig. 128).

Key concepts explored throughout the various habitat pavilions in response to multi-species inhabitation, observation, and Architectural Succession begin to address the formal transition from exterior habitat to multi-species pavilion. The mature tree habitat pavilion, developing from the soil retention module into the free-standing structure, now transitions into an inhabitable exterior wall supporting the observation pavilion iteration 09 (Fig. 129). Whereas iteration 05's open-air chimney like structure (Fig. 130), informs the opportunity for vertical inhabitation in iteration 10 (Fig. 131).

Figure 124 | **Multi-species Pavilion (6)**
[page 93]

Figure 125 | **Multi-species Pavilion (7)**
[page 94]

Figure 126 | **Multi-species Pavilion (8)**
[page 95]

Figure 127 | **Multi-species Pavilion (9)**
[page 96]

Figure 128 | **Multi-species Pavilion (10)**
[page 97]

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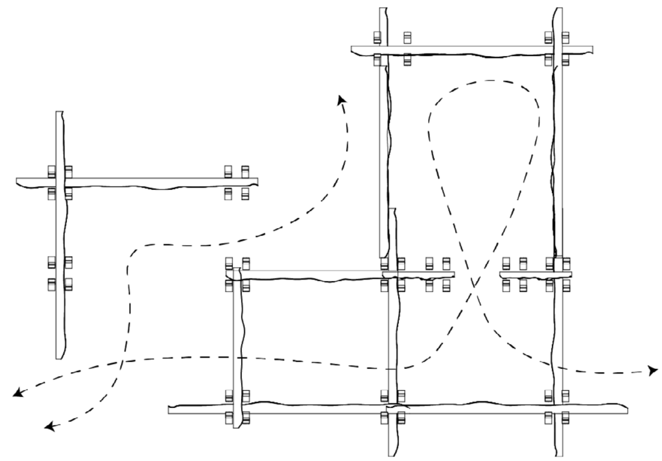
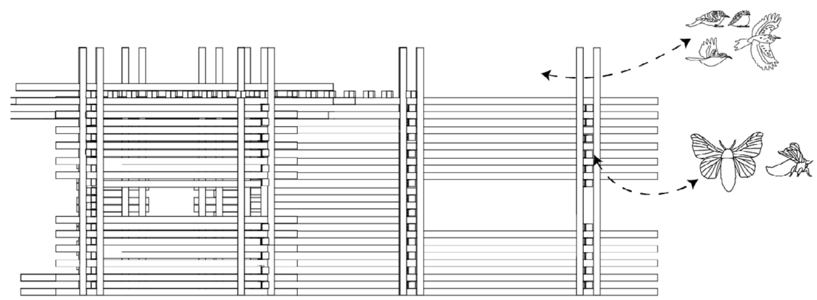
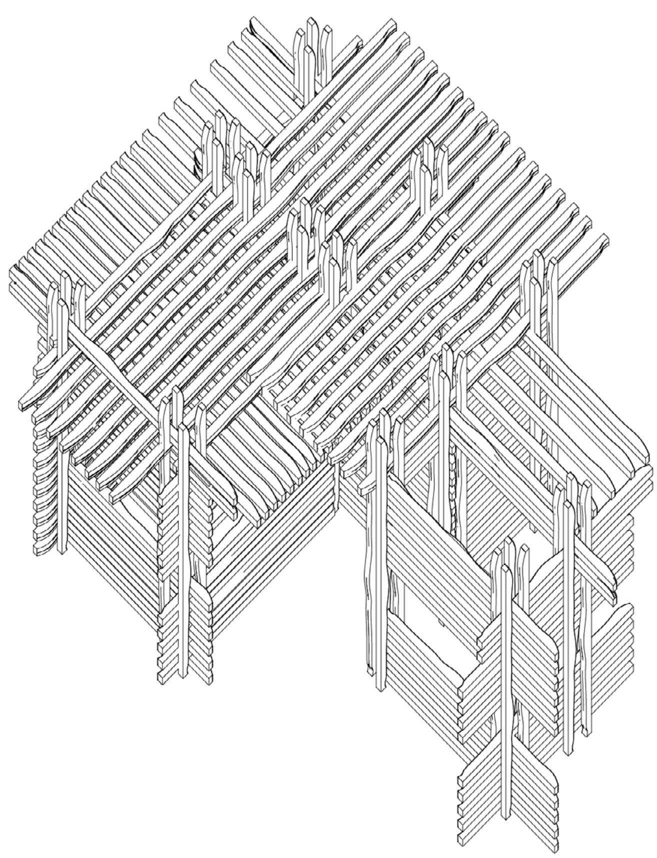
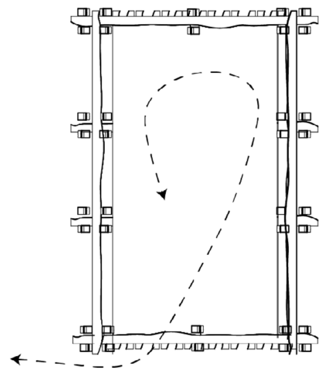
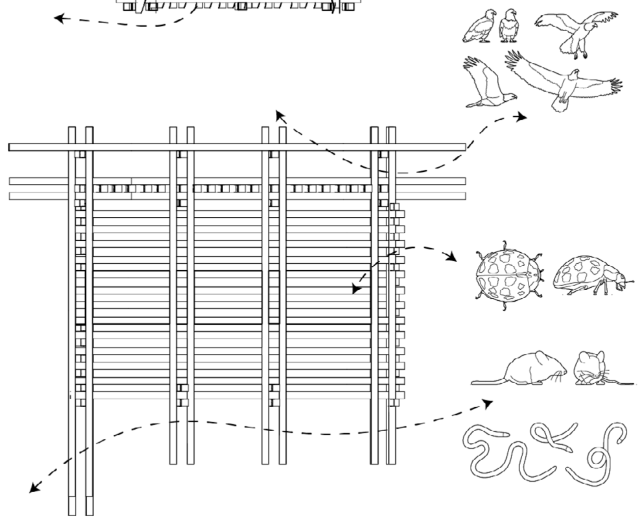
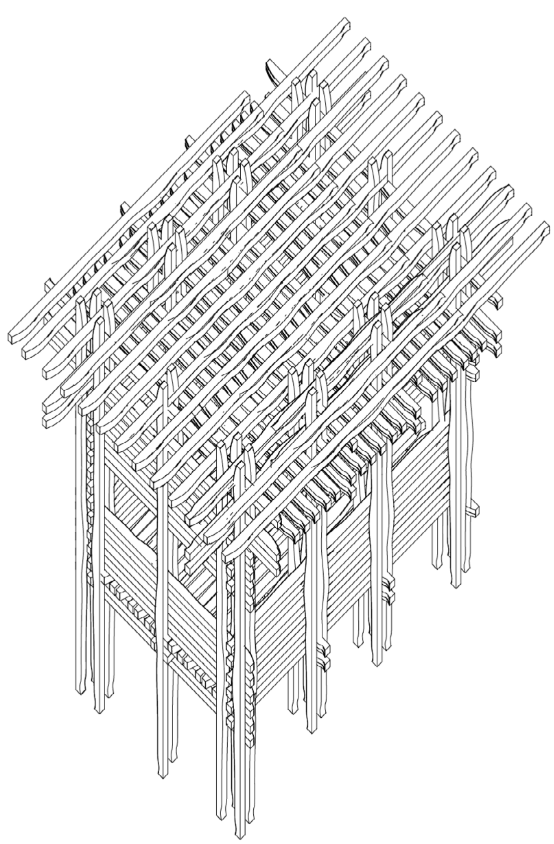


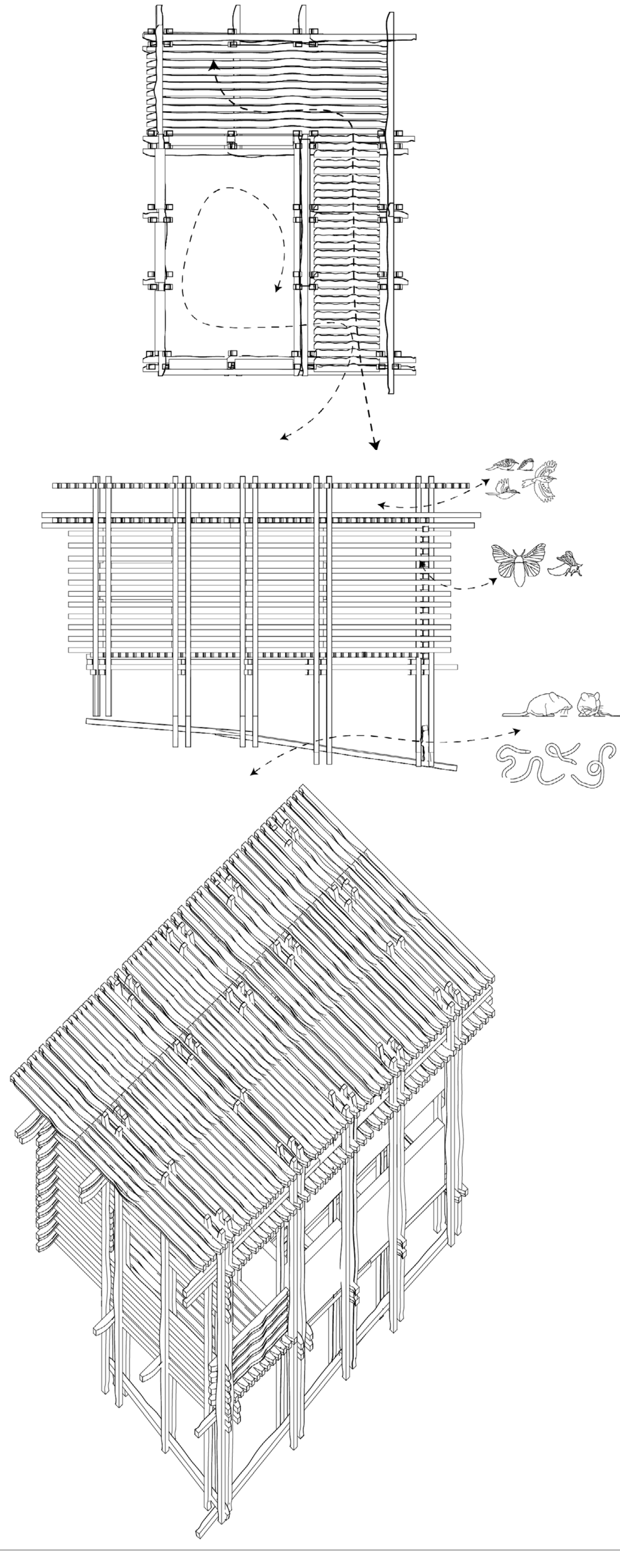


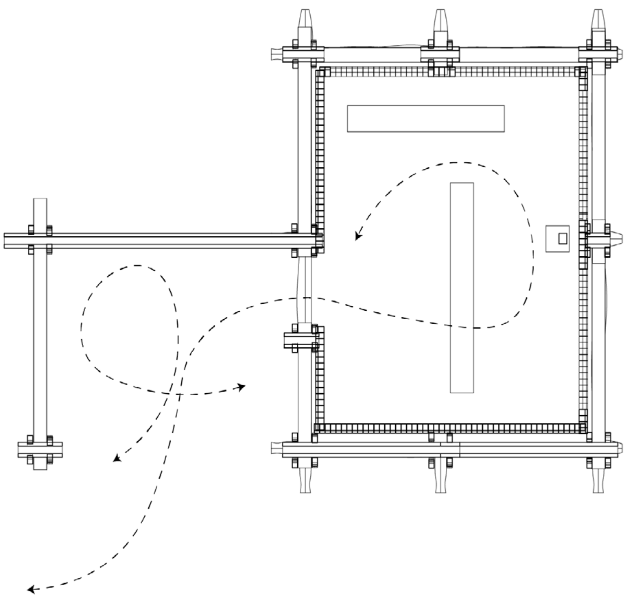


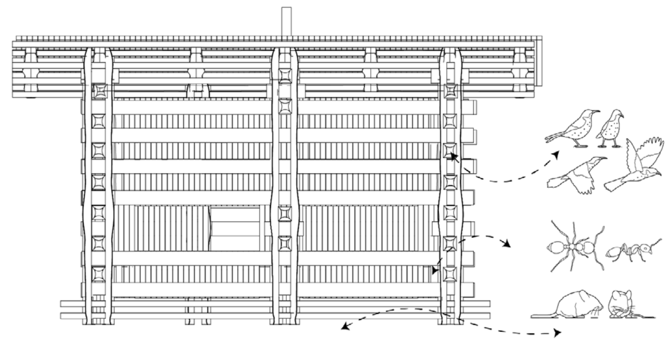


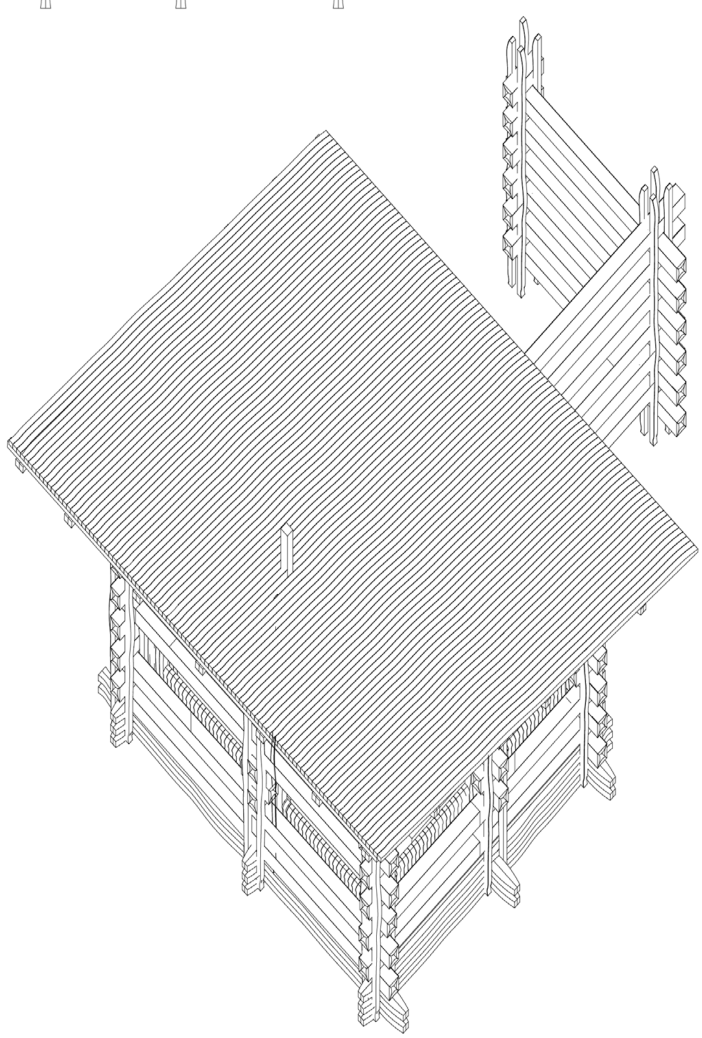


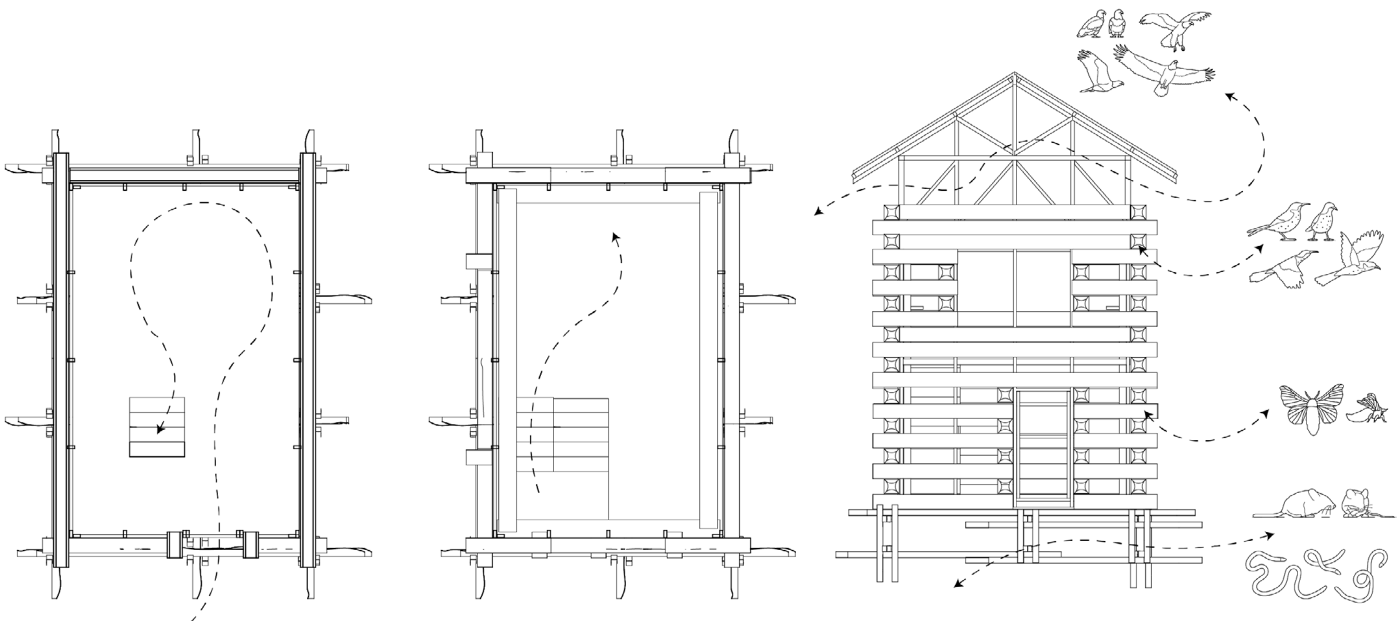












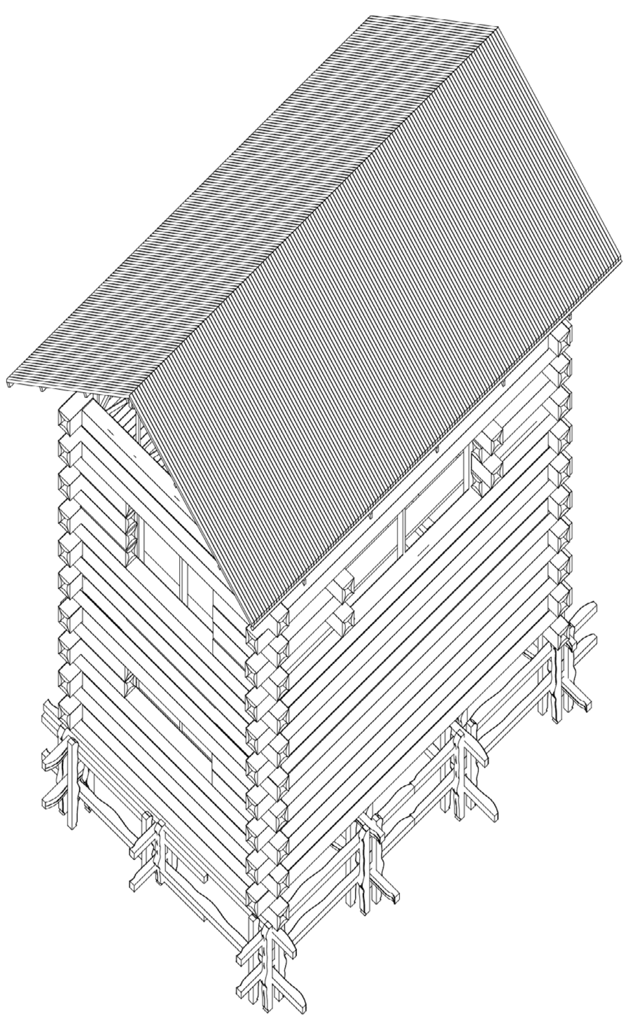


Figure 129 | **Multi-species Pavilion 9** [top]

Figure 130 | **Multi-species Pavilion 5** [middle]

Figure 131 | **Multi-species Pavilion 10** [bottom]

Maley Hill observation pavilion iteration 11 began developing the programmatic elements of the site for the anticipated human species of hikers, education groups, environmentalists. Its design incorporates the four key multi-species habitat typologies of understory, deadwood, canopy, and infrastructure dwelling species.

Approached from the south, the pavilion attracts human occupants along the existing trail toward its site on the upper most barren outcropping (Fig. 132). Exterior inhabitable partition walls are located on either side of the pavilion, directing users in towards the entrance, circulating its exterior under the roof overhang (Fig. 133). The interior provides an open floor plan for mixed use with unfixed furnishings and untreated wood surfacing, receiving diffused lighting from its northern openings (Fig. 134).

Exterior seating on the south is intended for practical use, whereas the seating on the north allows for an exterior covered and unobstructed view of the site (Fig. 135). Facing north and north-west, the interior is directed towards views of the surrounding habitat pavilions and developing forest for observation and monitoring. Provided with a woodstove, cubby space, common seating, window seating, and desk and study space, the total interior area of the pavilion is 72m2 (Fig. 136). Its exterior is clad in horizontally stacked inhabitable cladding encouraging multi-species directly within the pavilion. Given the change in topography, the pavilion rests on sill logs and an infill rock foundation gathered from the site creating additional protected habitat (Fig. 137).

Figure 132 | **Multi-species Pavilion 11 (1)**
[top]

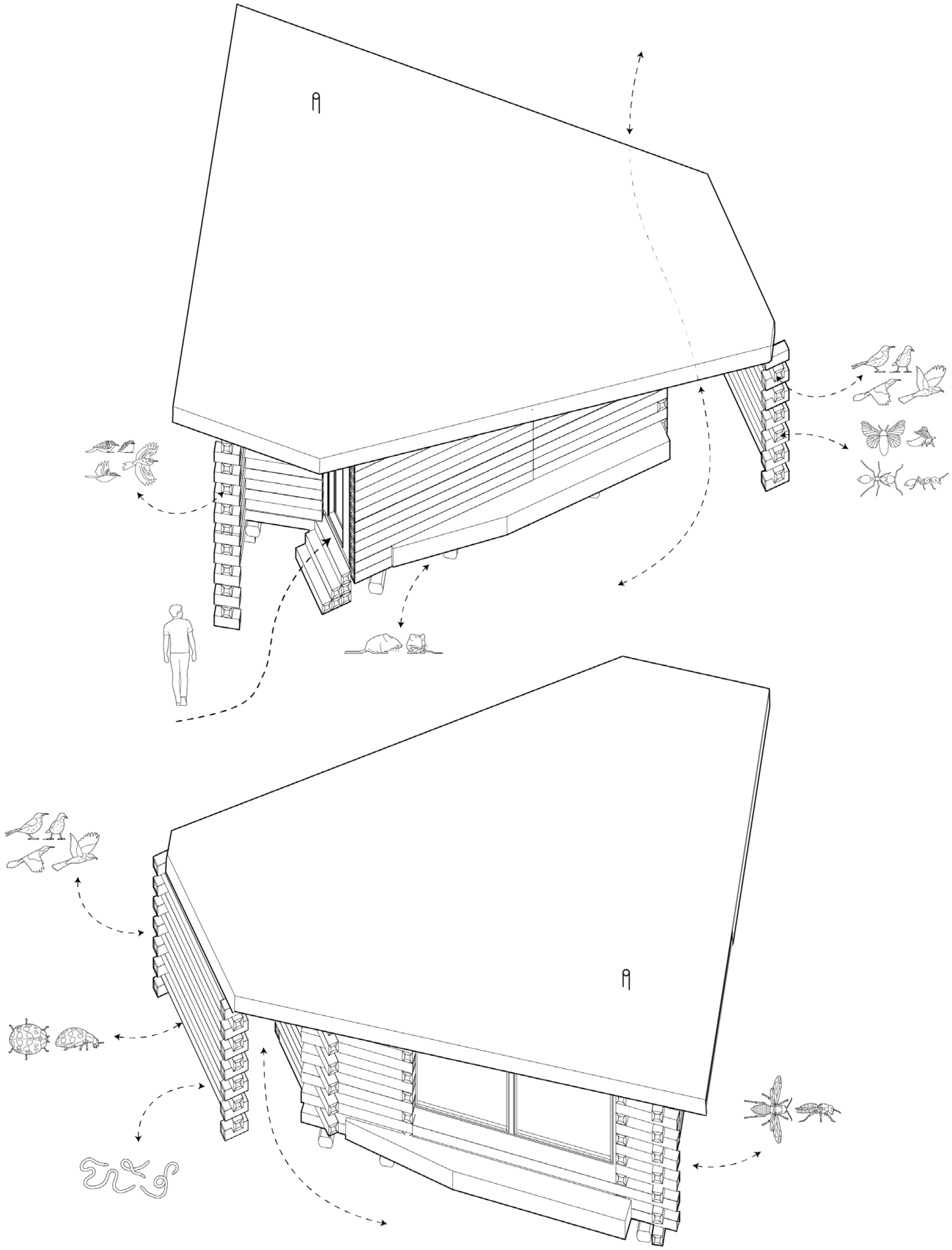
Figure 133 | **Multi-species Pavilion 11 (2)**
[middle]

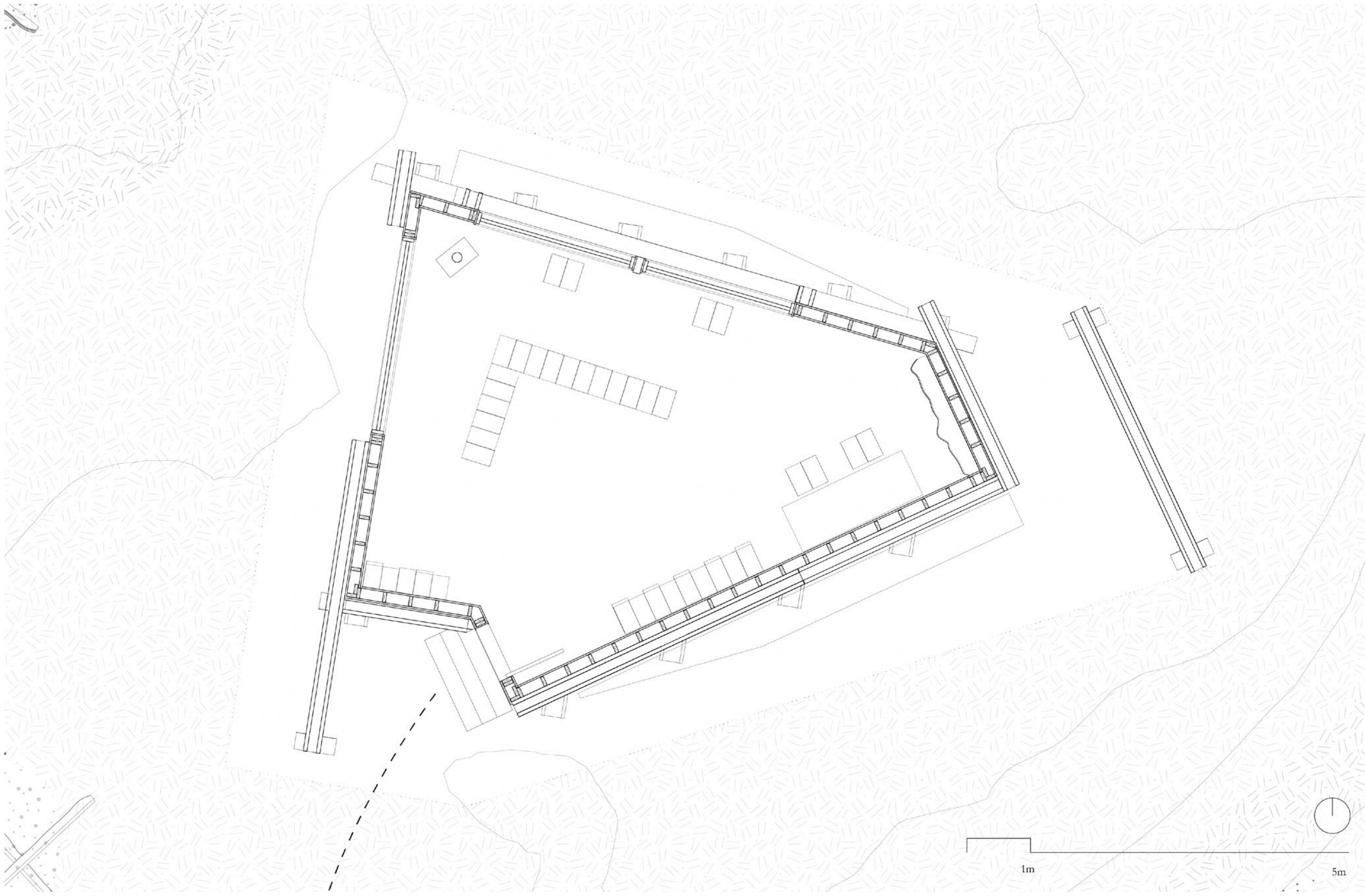
Figure 134 | **Multi-species Pavilion 11 (3)**
[bottom]

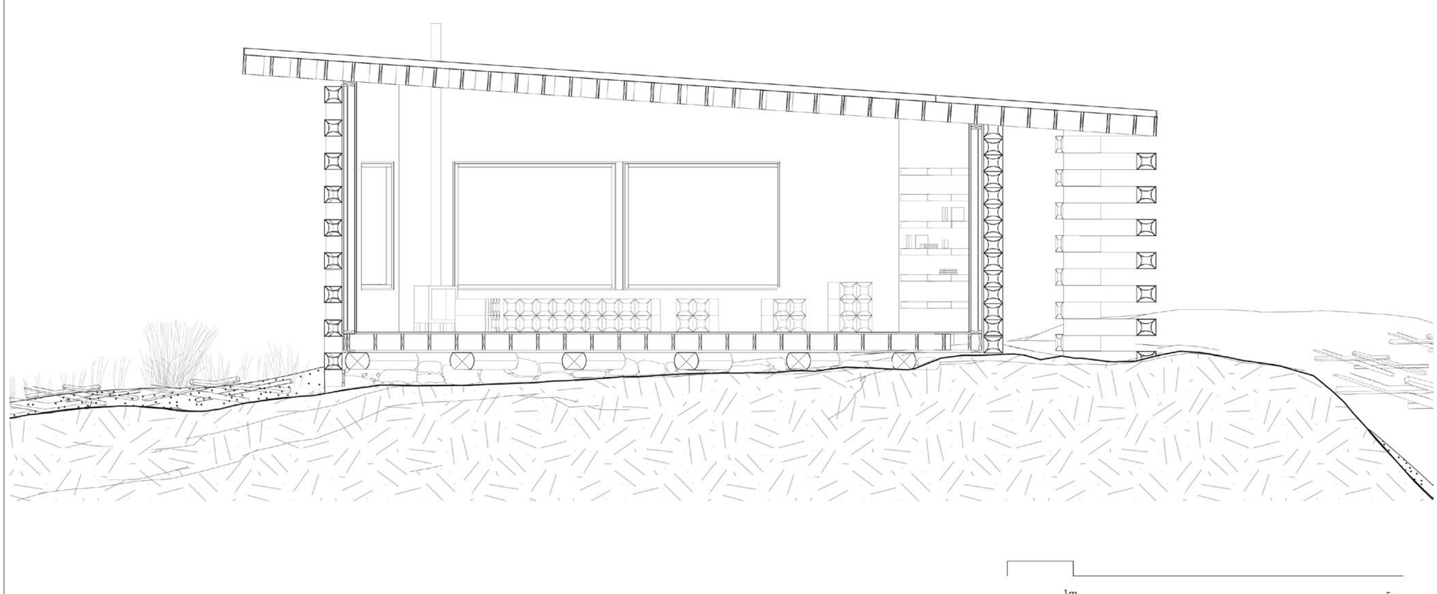
Figure 135 | **Multi-species Pavilion Axonometric**
[page 101]

Figure 136 | **Multi-species Pavilion Plan**
[page 102]

Figure 137 | **Multi-species Pavilion Section**
[page 102]




1m
5m


1m
5m

Maley Hill Observation Pavilion

While much of Sudbury's landscape consists of early successional regreened forests, the Maley hill proposal to extend existing and absent ecologies throughout its barren outcroppings does not directly address the urban areas lacking multi-species habitats.[165] With urban expansion increasing, integrating other species into our cities is a raising concern. Community efforts such as the City's Linear Infrastructure Services continue to plant trees along urban streets and city parks, and an appointed Green Space Advisory Panel has issued green spaces in need of protection and conservation alongside that of Conservation Sudbury's efforts and the Regreening program, however the rate in which habitat loss is occurring requires additional support within the built environment.[166] The multi-species pavilion explorations have identified a significant opportunity for nonhuman inhabitation within a building's exterior façade, informing architects on the possibilities of designing for multi-species by means of Architectural Succession. Where the proposed observation pavilion serves as the catalyst for the future of biodiverse built environments.

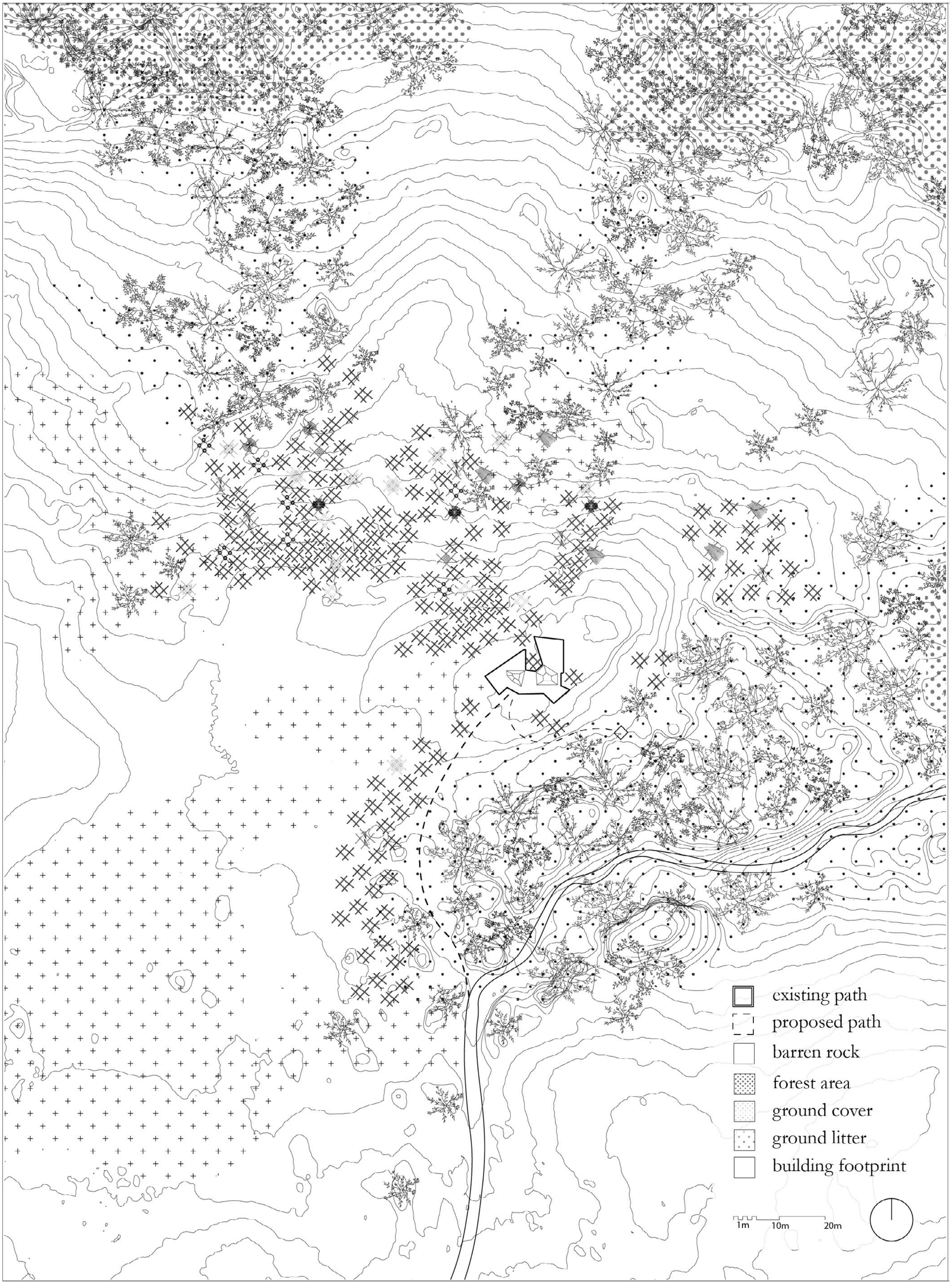
The Maley Hill Observation Pavilion's aims to attract and support other species within the pavilion itself, while engaging the human users as stewards of the site. The site can be accessed along a proposed 200m path branching north off the 4km Maley Conservation Area trail, passing through the early successional forest up towards the Maley hill (Fig. 138).

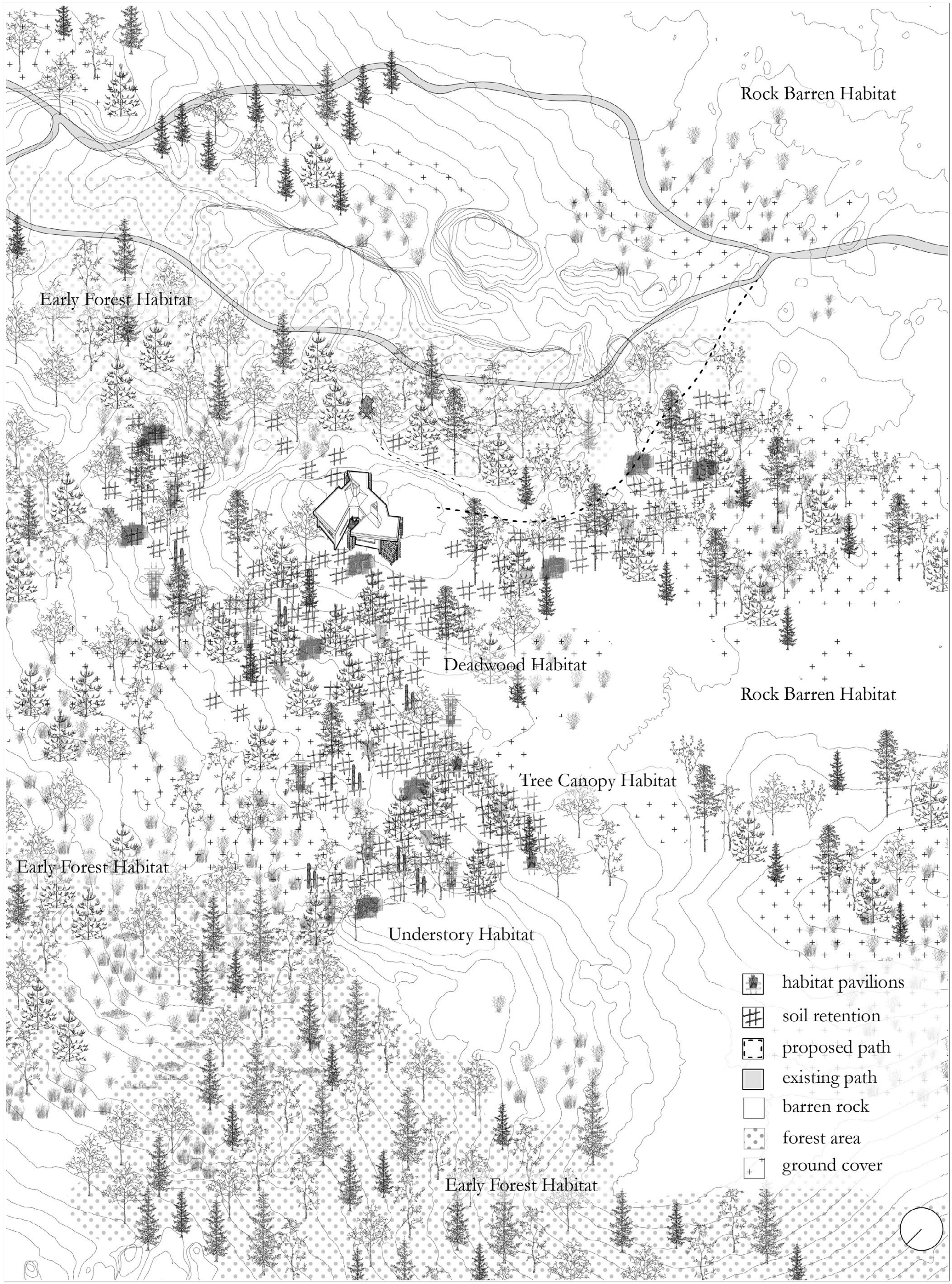
The soil retention structures located along Maley hill respond to erosion patterns and gradual changes in topography where soil accumulation is likely to occur, developing early successional habitat corridors. These corridors extend toward that of the existing forest, intersecting at the proposed observation pavilion site. The pavilion serves as a destination for visitors to interact with the site, while simultaneously functioning as a habitat corridor. This corridor connects the existing forest, habitat pavilions, and soil retention structures (Fig 139).

Figure 138 | **Observation Pavilion Site Plan**
[page 104]

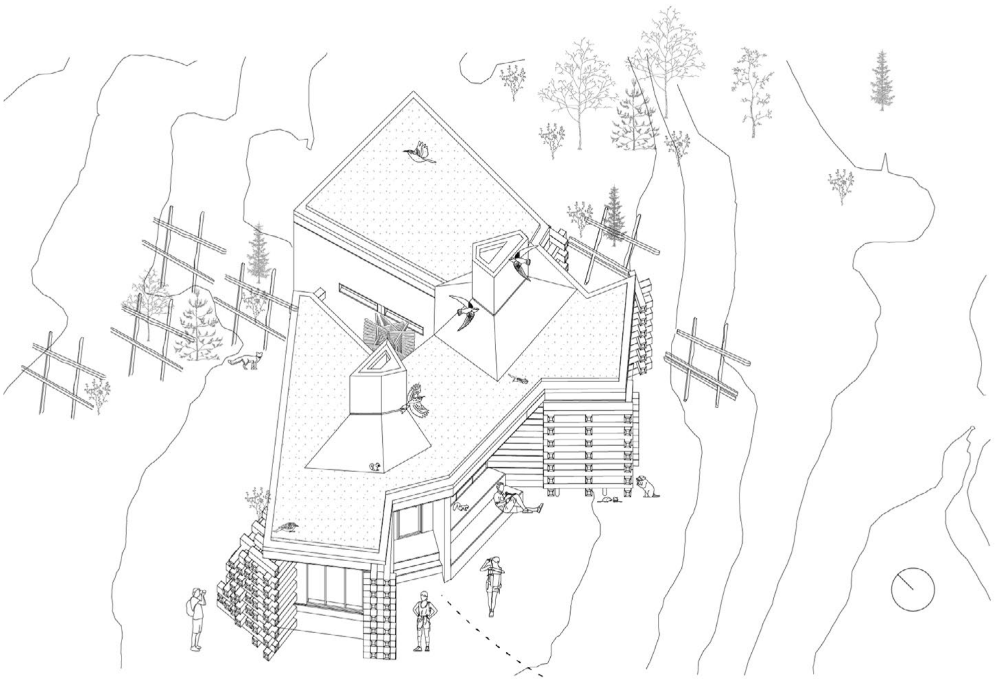
Figure 139 | **Observation Pavilion Site Axonometric**
[page 105]

165 ISSUU, "Living Landscape - A Biodiversity Action Plan for Greater Sudbury."
166 ISSUU, "Living Landscape - A Biodiversity Action Plan for Greater Sudbury."


existing path
proposed path
barren rock
forest area
ground cover
ground litter
building footprint
1m
10m
20m


Rock Barren Habitat
Early Forest Habitat
Deadwood Habitat
Rock Barren Habitat
Tree Canopy Habitat
Early Forest Habitat
Understory Habitat
Early Forest Habitat
habitat pavilions
soil retention
proposed path
existing path
barren rock
forest area
ground cover

Informed by the Chimney Swift tower project and the habitat pavilion iterations, the observation pavilion's roof serves as an opportunity for expanded greenspace in supporting and attracting various species. Extending upward from the intersection of roof planes, 2 exterior inhabitable chimney-like structures allow for views from the interior space below, integrating the fourth habitat typology of built condition into its design (Fig. 140, 141).



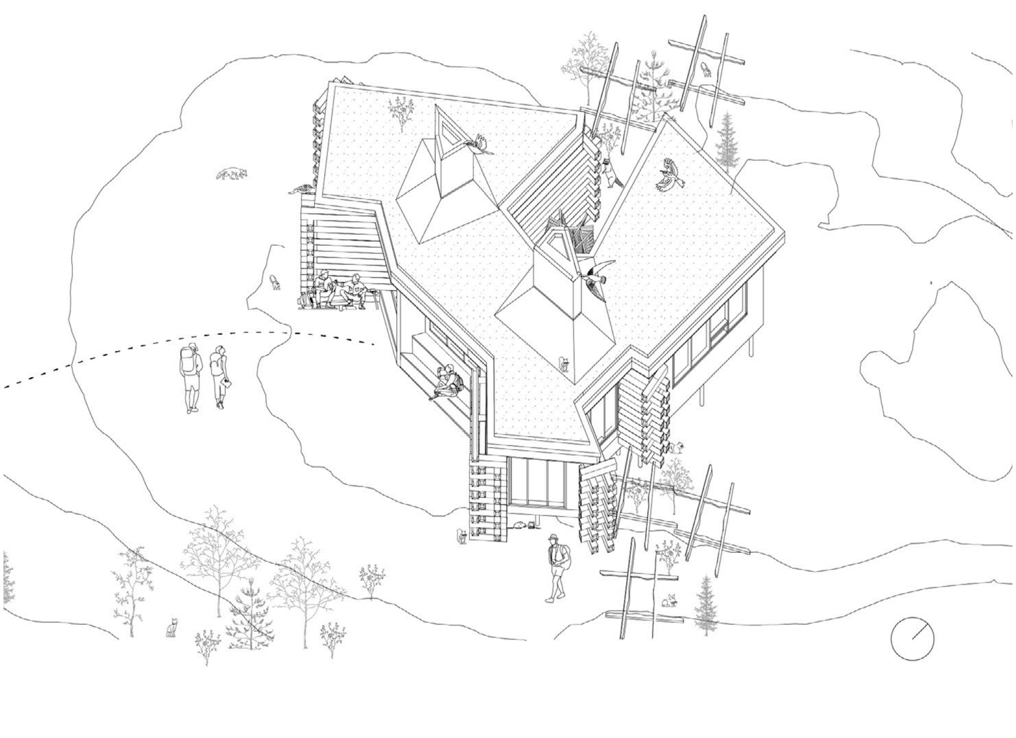


Figure 140 | **Observation Pavilion Axonometric (1)**

Figure 141 | **Observation Pavilion Axonometric (2)**

In response to the anticipated forested regions to its north-west and the existing early-stage forest to the south-east, the observation pavilion's tree-root-like footprint responds directly to the site's successional conditions. The building form extends toward each habitat zone to allow for optimal ecological monitoring and observation, while simultaneously providing habitat in toward the pavilions negative space. Upon entry, the various users of hiker, educational groups, environmentalists, among others are provided with the various view-oriented spaces for resting, destination viewing, documentation, and teaching gathering (Fig. 142). Provided with a small woodstove for heating and an outdoor composting toilet located 20m off the proposed trail, the pavilion is capable of supporting longer durations of human occupancy.

Varying in form and size, each window opening responds directly to the sensitivity and proximity of each associated habitat, framing views of the surrounding soil retention structures, habitat pavilions, existing forest, inhabitable façade, and barren landscape. The integration of skylights to the roofs inhabitable chimney-like structures allows for vertical observation into the habitat of infrastructure dwelling species such as the Chimney Swift (Fig. 143). Informed by the research creation Swift tower, the chimney's interior is finished in horizontally grooved sapwood providing surfaces for the attachment of nests and small species to seek shelter. The use of cedar shakes as a cladding material enacts the bark crevices large numbers of insects and small mammals rely on for resting, hunting, breeding, and hatching grounds. The pavilions green roof attracts species towards the rooftop, encouraging the inhabitation of the wood as it weathers and decays.

Exposing areas where single-species designs fail to accommodate multiple species, specifically a buildings envelope, the pavilion invites for a larger conversation on the relevance and potential of biodiverse built environments. A building's façade, rooftop, and ground condition reimagined for inhabitation by other species proves essential in expanding habitat within urbanized areas. In particular, the further development of multi-species inhabitable cladding responding to site-specific ecologies. Referencing the multi-species analysis of a tree in chapter 3.1, the use of sawmill offcuts when explored as façade system further connect each habitat corridor. The bark and sapwood attract multiple species within its material substrate, and when inverted create an inhabitable horizontal cavity condition (Fig. 144). These horizontal cavities stack to clad the pavilions façade in varying depths and densities in response to their adjacent habitat types. Variations in the cladding alignment allow for the support of vegetation by functioning as soil retention structures, in turn attracting additional species toward the pavilion. The buildings form directly responds to its inhabitable façade, providing visitors with opportunities for viewing directly within the facades habitat (Fig. 145).

The pavilion rests upon and is anchored to the bedrock, creating additional habitat beneath the structure. Insulative cavities within the light wood framed walls, roof, and floor systems are filled with sawdust insulation to allow for a fully biodegradable building structure, functioning as additional multi-species habitat throughout the pavilions succession. Following this process of Architectural Succession, the observation pavilion is anticipated to become obsolete with the expansion of the surrounding forest, no longer requiring human intervention to support its development (Fig. 146). As such, its decomposition coincides with that of the soil retention and habitat pavilion ecological corridor.

Figure 142 | **Observation Pavilion Floor Plan**
[page 109]

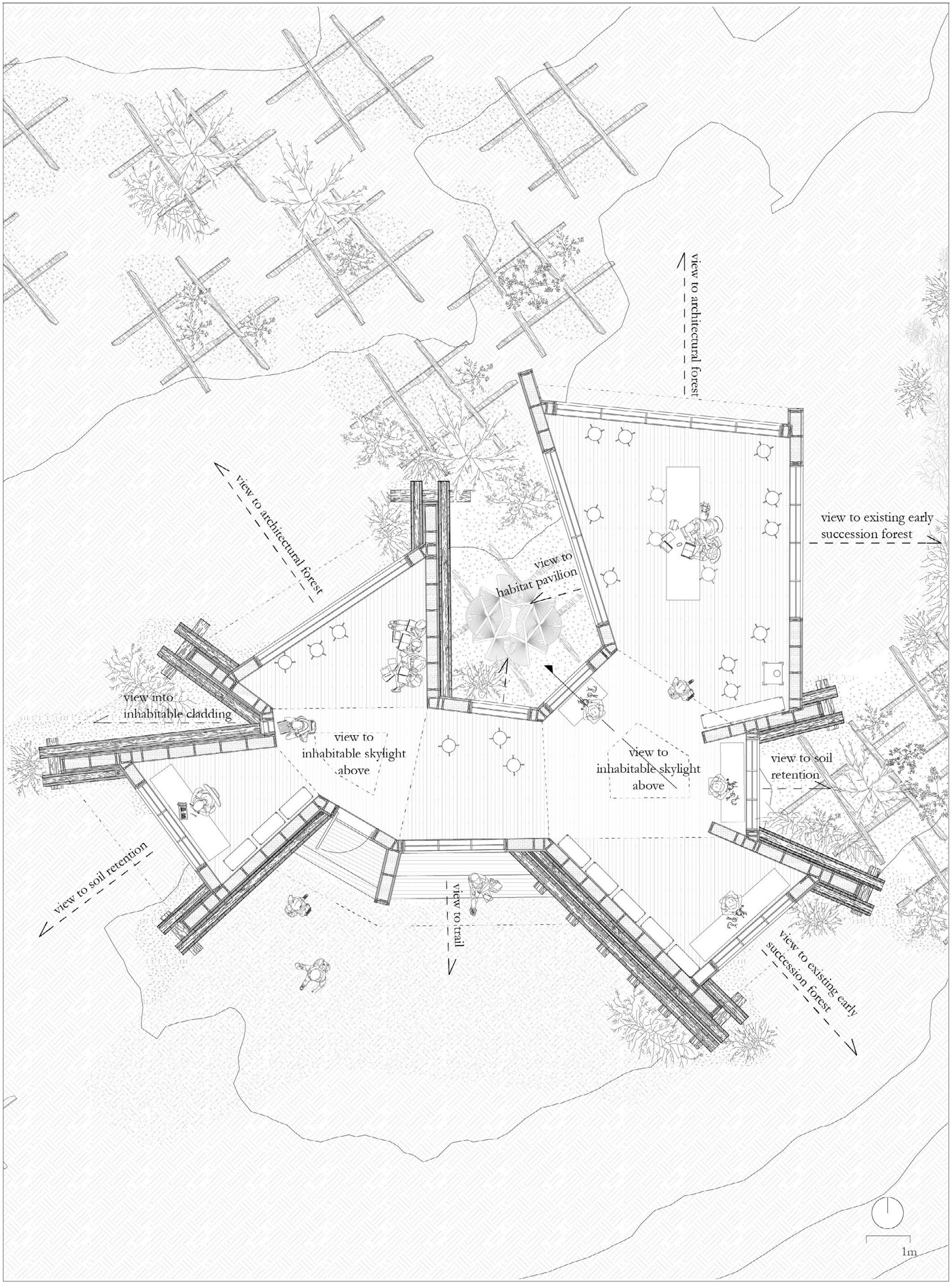
Figure 143 | **Observation Pavilion Section**
[page 110]

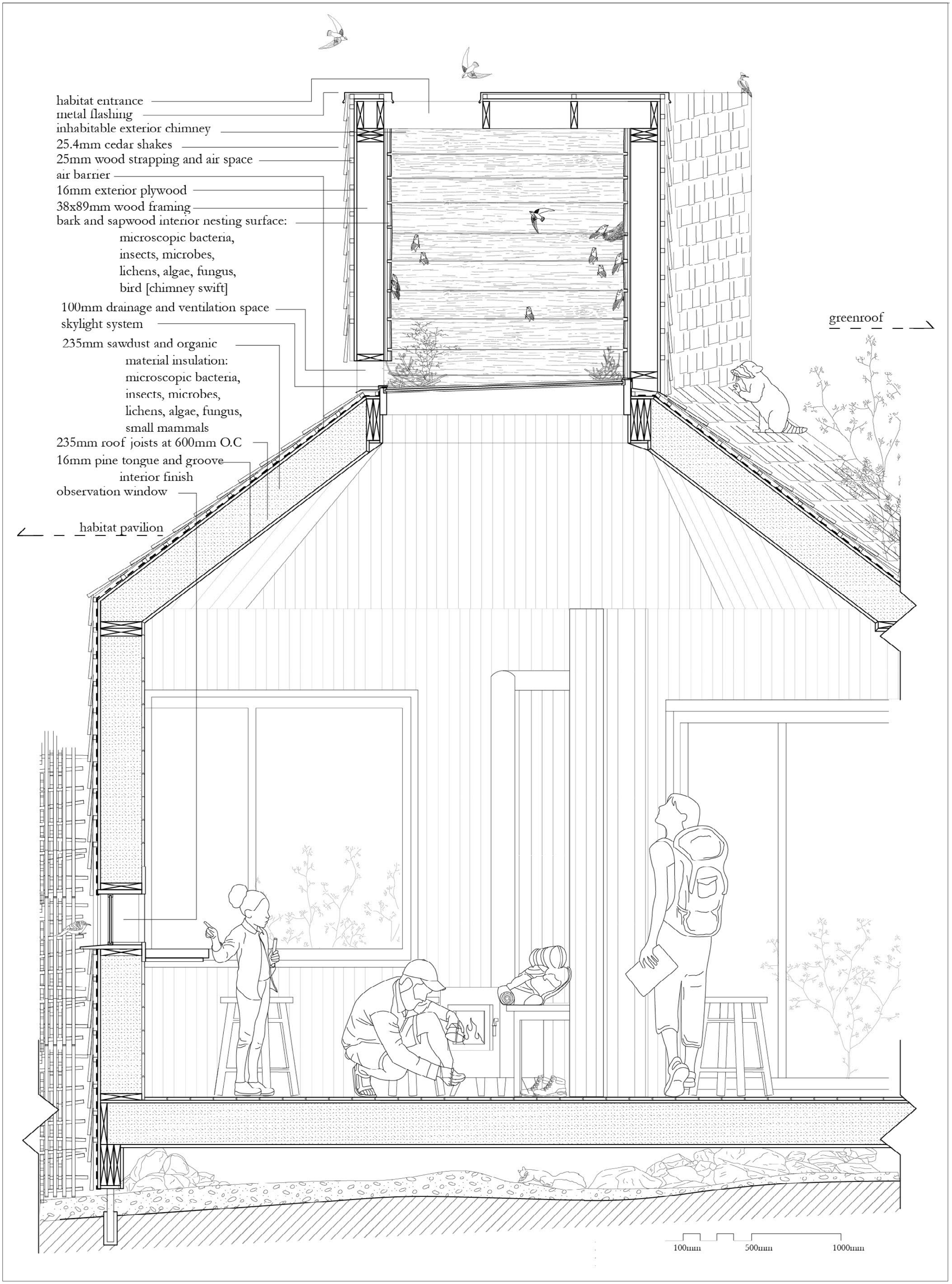
Figure 143 | **Observation Pavilion Wall Section Detail**
[page 111]

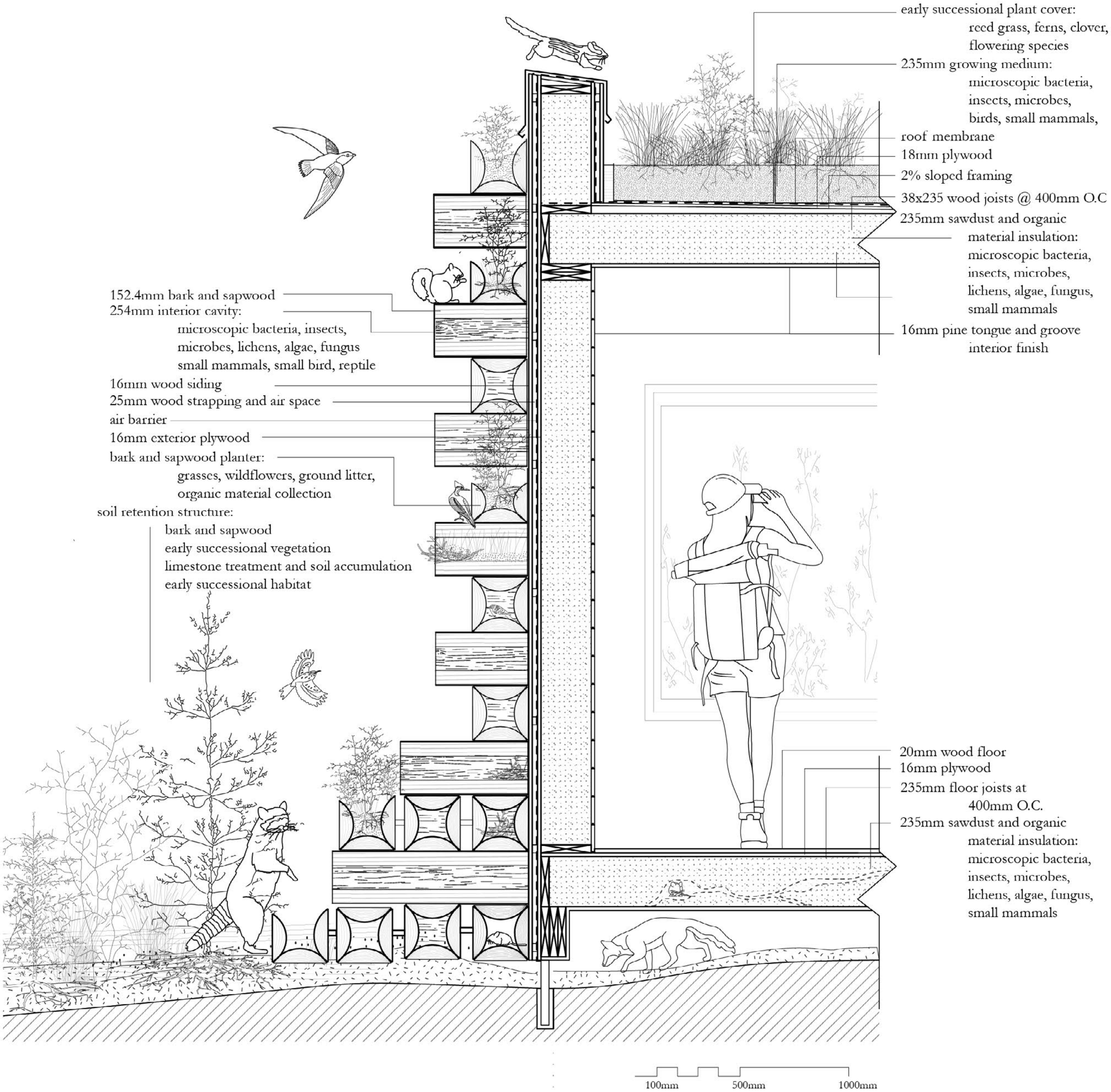
Figure 144 | **Observation Pavilion Floor Plan Detail**
[page 112]

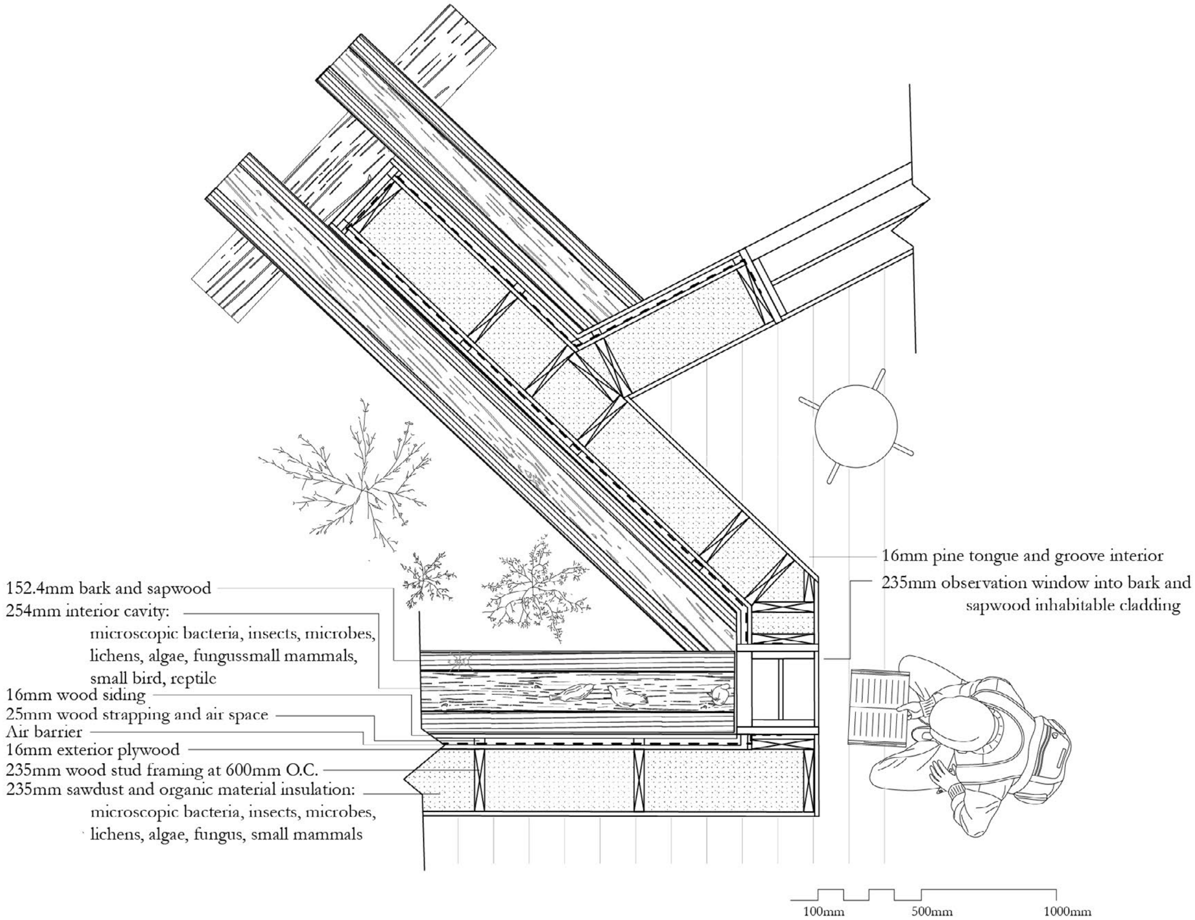
Figure 145 | **Observation Pavilion Floor Plan Detail**
[page 112]

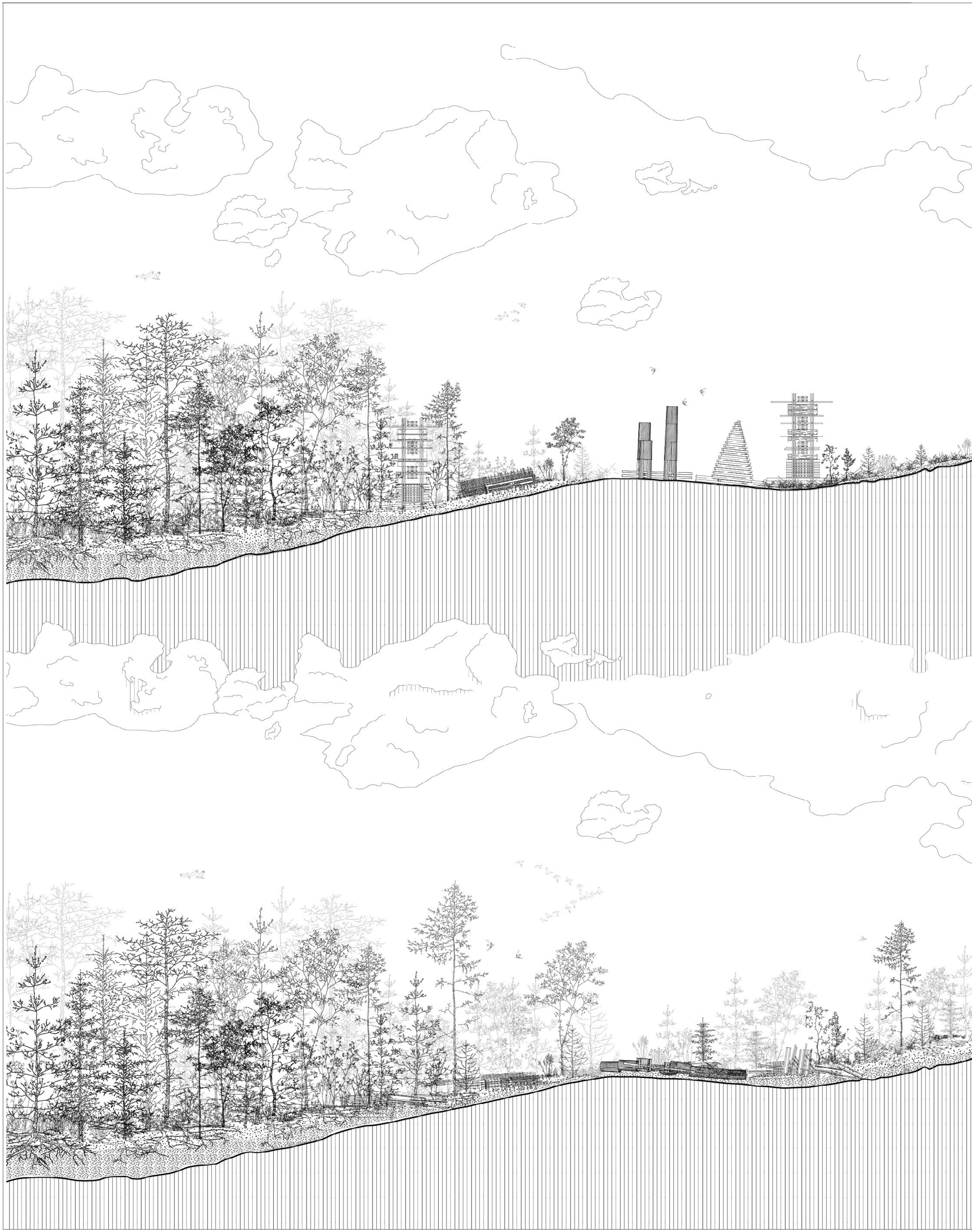
Figure 146 | **Observation Pavilion Site Section Architectural Succession**
[page 113, 114]

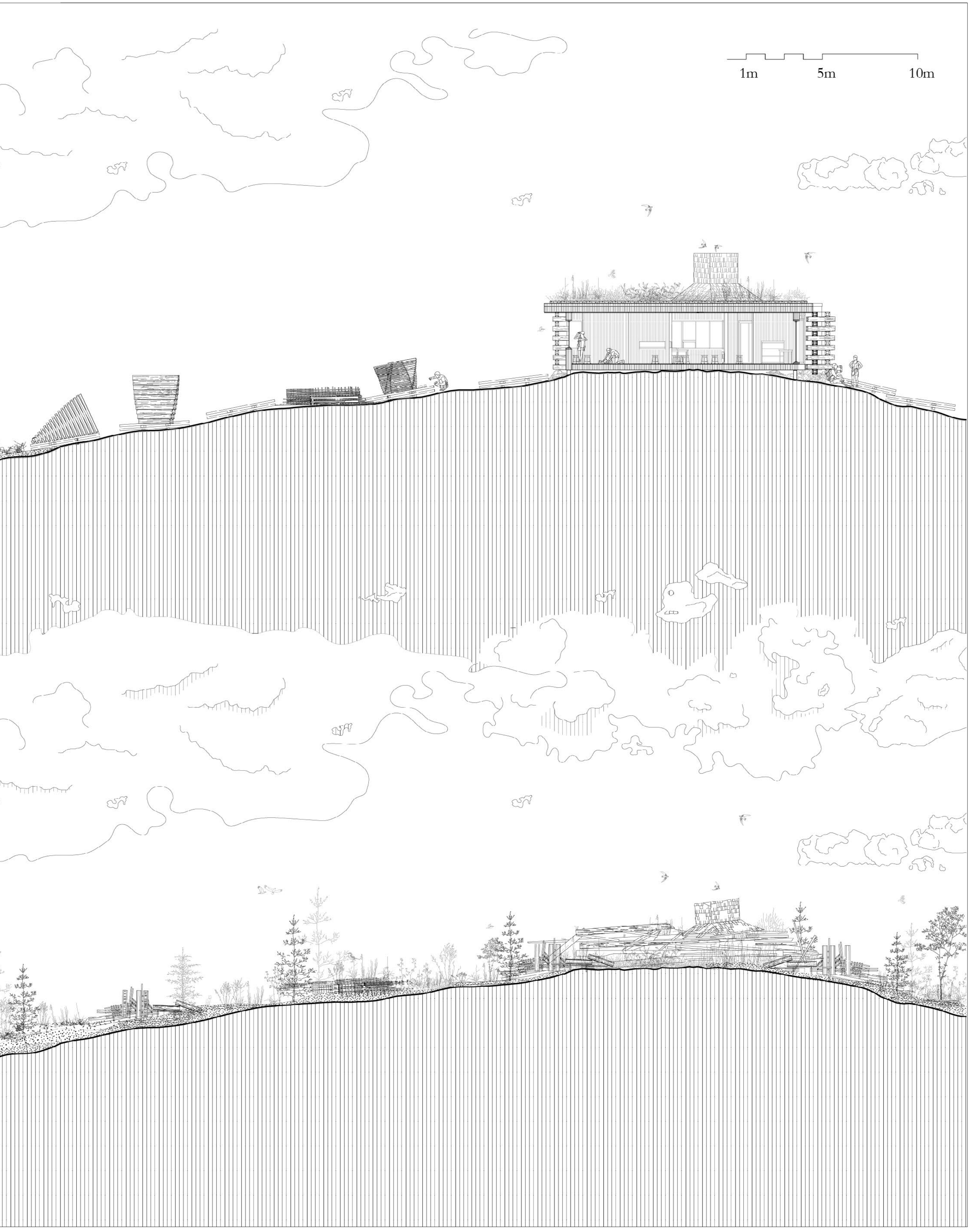

view to architectural forest
view to architectural forest
view to existing early succession forest
view to habitat pavilion
view into inhabitable cladding
view to inhabitable skylight above
view to inhabitable skylight above
view to soil retention
view to soil retention
view to trail
view to existing early succession forest
1m


habitat entrance
metal flashing
inhabitable exterior chimney
25.4mm cedar shakes
25mm wood strapping and air space
air barrier
16mm exterior plywood
38x89mm wood framing
bark and sapwood interior nesting surface:
microscopic bacteria,
insects, microbes,
lichens, algae, fungus,
bird [chimney swift]
100mm drainage and ventilation space
skylight system
235mm sawdust and organic
material insulation:
microscopic bacteria,
insects, microbes,
lichens, algae, fungus,
small mammals
235mm roof joists at 600mm O.C
16mm pine tongue and groove
interior finish
observation window
habitat pavilion
greenroof
100mm
500mm
1000mm


early successional plant cover:
reed grass, ferns, clover,
flowering species
235mm growing medium:
microscopic bacteria,
insects, microbes,
birds, small mammals,
roof membrane
18mm plywood
2% sloped framing
38x235 wood joists @ 400mm O.C
235mm sawdust and organic
material insulation:
microscopic bacteria,
insects, microbes,
lichens, algae, fungus,
small mammals
16mm pine tongue and groove
interior finish
152.4mm bark and sapwood
254mm interior cavity:
microscopic bacteria, insects,
microbes, lichens, algae, fungus
small mammals, small bird, reptile
16mm wood siding
25mm wood strapping and air space
air barrier
16mm exterior plywood
bark and sapwood planter:
grasses, wildflowers, ground litter,
organic material collection
soil retention structure:
bark and sapwood
early successional vegetation
limestone treatment and soil accumulation
early successional habitat
20mm wood floor
16mm plywood
235mm floor joists at
400mm O.C.
235mm sawdust and organic
material insulation:
microscopic bacteria,
insects, microbes,
lichens, algae, fungus,
small mammals
100mm
500mm
1000mm


16mm pine tongue and groove interior
235mm observation window into bark and sapwood inhabitable cladding
152.4mm bark and sapwood
254mm interior cavity:
microscopic bacteria, insects, microbes, lichens, algae, fungussmall mammals, small bird, reptile
16mm wood siding
25mm wood strapping and air space
Air barrier
16mm exterior plywood
235mm wood stud framing at 600mm O.C.
235mm sawdust and organic material insulation:
microscopic bacteria, insects, microbes, lichens, algae, fungus, small mammals
100mm
500mm
1000mm




1m
5m
10m

Branching off the Maley Conservation trail, visitors are guided through the existing early-stage forest toward Maley hill by a path marked by soil retention structures. The path ends where visitors are then greeted by the observation pavilion. The pavilion's entrance is framed between two inhabitable walls and provided with exterior seating under the roofs overhang overlooking the existing forest (Fig. 147).

Figure 147 | **Observation Pavilion (1)**

Approaching the observation pavilion from a multi-species perspective, the ecological corridor provided by the surrounding soil retention and habitat pavilions are extended upward throughout the pavilion by use of its building envelope. The rooftops' green space and inhabitable chimneys attract both flying and climbing species, which visitors can observe from both the pavilions exterior and interior (Fig. 148).

Figure 148 | **Observation Pavilion (2)**

The inhabitable cladding exposes multi-species rich sapwood to its exterior, encouraging the breaking down wood cells and fibers by organisms and weathering. While smaller species gain access through boring entry points into the sapwood, larger organisms like insects, amphibians, small mammals, and birds occupy its internal cavities. Plant roots may begin to colonize the decaying wood from the accumulation of organic materials within each cladding cavity, further splitting and compressing openings in the wood as it grows (Fig. 149).

Figure 149 | **Observation Pavilion (3)**

These bark and sapwood cavities minimize the perceived separation between other species and human habitats, inviting multi-species interaction and cohabitation of the pavilion. Windows are used as tools for framing views directly into the various habitat typologies encompassing the pavilion, encouraging curiosity and stewardship of the forest's development by the human occupant (Fig. 150).

Figure 150 | **Observation Pavilion (4)**

Furnished with unfixed seating, visitors are encouraged to inhabit the pavilion's interior however they seem fit (Fig. 151). Allowing for flexibility in group sizes and use, each unenclosed nodal space offers adequate space for the various user groups of hikers, environmentalists, researchers, architects and designers, educational tour groups associated with the cities Regreening program, among others.

Figure 151 | **Observation Pavilion (5)**

Anticipated activities of resting, viewing, documenting, teaching, gathering, and eating are accompanied by a woodstove and flexible table area (Fig. 152). The woodstove extends the use of the space throughout the day, allowing for observation of select species from dusk till dawn, as well as into the winter months.

Figure 152 | **Observation Pavilion (6)**

Using the pavilion to expanded habitat both horizontally and vertically, visitors are invited to engage in different forms of discussion and activity surrounding the various habitat typologies of the pavilion. Anchored by the interior sloped ceilings, the pavilion is divided into two larger circulation spaces which emphasize the inhabitable chimneys above (Fig. 153).

Figure 153 | **Observation Pavilion (7)**

A more intimate study space overlooks the existing early successional forest to the south-east. Suitable for resting, viewing, and documentation, the large window frames both conditions directly adjacent to the pavilion as well as further within the forested region (Fig. 154).

Figure 154 | **Observation Pavilion (8)**

Looking north-west, a large window frames the existing barren outcropping overlooking the early successional forest below Maley hill. This study space directly observes the extension of ecological corridors using soil retention structures and habitat pavilions (Fig. 155).

Figure 155 | **Observation Pavilion (9)**

The larger gathering space facing north and north-east frames the extension of habitat corridor between the upper existing forest and lower lying regions of Maley hill (Fig. 156). A closer proximity to habitat pavilions provides an opportunity for observation of their inhabitation.

Figure 156 | **Observation Pavilion (10)**

Succession

Contending a greater attention toward the paradigm shift from single-species to multi-species built environments, the observation pavilion atop Maley hill articulates the relevance of addressing biodiversity loss within the scope of architectural discipline by ensuring each of Sudbury's critical habitat typologies are incorporated within its design. Exposing areas where single-species designs fail to accommodate for multiple species, specifically a buildings envelope, the observation pavilion invites a larger conversation on the potential of supporting the greater ecology directly within the built environment.

Providing temporary habitat to at-risk species, the soil retention structures, habitat pavilions, and observation pavilion all intentionally contribute to the ecological recovery of Sudbury's industrialized landscape with their decomposition. The monitored Architectural Succession of these biodiverse built environments enables visitors with the knowledge and vocabulary to further support multiple species within habitats of their own.

Coinciding with the ecological succession of a tree, the Architectural Succession of these built interventions allow for the gradual transition of species reliance from pavilion to developing forest. Observing in close proximity the succession of a soil retention structure, the anticipated timeframe of this transition can be closely monitored (Fig. 157).

Figure 157 | **Observation Pavilion Architectural Succession (1)**

The need for ecological monitoring and human intervention is anticipated to reduce alongside the forest's development, and along with it, the pavilion will one day become obsolete to the human user. This obsolescence will occur gradually, transitioning the observation pavilion from an enclosed structure (Fig. 158), to openair pavilion, and eventually resulting in its decomposition.

Figure 158 | **Observation Pavilion Architectural Succession (2)**

As root structures develop and no longer require soil retention members, the pavilions naturally decay, further contributing to the built ecosystem. The pavilions inhabitable façade functions much like the protective external layer of a plant (the bark), providing nutrient source and habitat for external species, while maintaining interior conditions. Once penetrated, the building assembly (the cambium layer) becomes the host to hundreds of species of microscopic bacteria, insects, lichens, algae, fungus, birds, and small mammals (Fig. 159).

Figure 159 | **Observation Pavilion Architectural Succession (3)**

The accumulation of the pavilion's fallen wood forms a physical-chemical link between successional stages of the forest structure, providing a dynamically increasing spectrum of nutrient source for various species. The consuming and breaking down of this assembly begins the decomposition process, inviting its human occupants to remove and recycle all windowpanes and non-biodegradable materials, transitioning its program from enclosed to open air structure (Fig. 160).

Figure 160 | **Observation Pavilion Architectural Succession (4)**

These large entry points in the assembly invite environmental factors to penetrate the structure, furthering its decay. The nutrient source provided by its decomposition mimic that of the decomposing tree, serving as a substrate for its rooftop vegetation to take deeper root within the structure, further splitting and compressing with growth (Fig. 161).

Figure 161 | **Observation Pavilion Architectural Succession (5)**

Where typical architectural methods design for a single species, the Maley hill observation pavilion supports multiple species through the process of Architectural Succession, serving as the catalyst for the future of multi-species built environments. As a fallen tree does not decay simply due to ground contact but because it has been utilized as a resource by a variety of species, its decomposition fosters life, where the tree is once again growing (Fig. 162).

Figure 162 | **Observation Pavilion Architectural Succession (6)**

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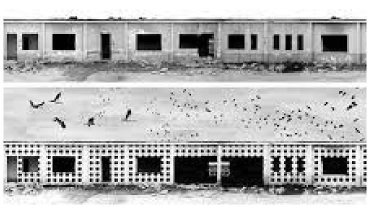
Appendix A - Case Studies

Art / Activism: Animal Estates

Architect and artist Fritz Haeg designs projects where the architectural occupant is wildlife instead of human. His on-going Animal Estates project displays events and exhibitions centered around the animals humans share cities with; providing dwellings for species that have become displaced by human measures. The Animal estates focuses on reintroducing animals back into cities, strip malls, harages, parks, roadways, yards, parking lots, skyscrapers, and neighborhoods. Experimenting with varying levels of visibility to the general public (human).

Built or unbuilt: Built
Human Interaction / Intervention: Art activism / social awareness at the benefit of non-human
Inhabitants: Beaver, bat, bee, bird, bobcat, duck, eagle, opossum, owl, salamander, squirrel, and turtle
Dimensions: Varying scales based on natural habitat dimensions
Location: Built Environment: Sculpture Court of the Whitney Museum
Adjacencies: High traffic area: corner of Madison Avenue and East 75th Street in Manhattan.
Materials: Varying natural and unnatural materials (ie: untreated wood birds nest attached by metal fasteners)



Art / Activism: DAAR - Return to Nature

DAAR - Return to Nature project proposes the re-inhabitation of an abandoned Palestinian military base by migratory birds to prevent Israeli takeover. This project proposal focuses on utilizing the evacuated summit and its buildings as a temporary migration habitat for an estimated 520 bird species in the Jordan Valley-Jericho and Jerusalem Mountains routes, rendering the building less desirable for human inhabitation.

Built or unbuilt: Unbuilt / imagined project
Human Interaction / Intervention: Art activism / Social awareness at the benefit of human
Inhabitants: Storks, Pelicans and raptors such as Lesser Kestrel, Honey Buzzard, Lesser Spotted Eagle, and Egyptian Vulture
Dimensions: Military Base
Location: Built Environment: Palestine
Adjacencies: Military Base of Oush Grab
Materials: Existing building

Figure 163 | **Fritz Haeg**

Figure 164 | **DAAR - Return to Nature**

Artificial Habitat: Chimney Swift Tower

Typical artificial Chimney Swift towers have been designed to support this at-risk species by mimicking these residential and industrial chimney conditions that the Chimney Swifts have become accustomed to. Accounting for the Chimney Swift's wingspan, 12-14" interior diameters are preferable, and a height of 8-11' is recommended to provide protection from direct sunlight. The top opening should be no more than half of the tower's interior diameter and be located on the north to further protect the interior. Artificial towers have been designed to include bottom ventilation to prevent the structures overheating with a grid of holes no larger than 3/8". The interior surface shall be of rough texture to allow for the swifts to be able to cling to the vertical surface.

Built or unbuilt: Built; DIY.
Human Interaction / Intervention: Artificial habitat to species at risk
Inhabitants: Chimney Swift
Dimensions: Varies: D: 305mm, W: 406mm, H:2400mm and upwards
Location: Roof tops, open space, greenspace, urban, rural
Adjacencies: Roof tops, surrounding buildings
Materials: Brick, wood, concrete, metal

Artificial Habitat: Prosthetic Lizard Homes

Prosthetic Lizard Homes by undergraduate Product Design students Renee Davies, Cris de Groot and Martin Boult at Unitec New Zealand designed this project for the Waitakere City Council building's green roof. In an effort to identify significant insect diversity that can support lizard habitation, this design was established to examine how green roofs can provide habitat for the relocation of endangered lizard species while maintaining an aesthetic for the green roof.

Built or unbuilt: Built
Human Interaction / Intervention: Artificial habitat to species at risk
Inhabitants: Reptiles such as Ornate skink (Oligosoma ornata)
Dimensions: D: 600mm, W: 600mm, H: 300mm
Location: Built/Natural Environment: rooftop garden (Waitakere City New Zealand)
Adjacencies: isolated from human environment
Materials: Raw concrete

Figure 165 | **Typical Artificial Chimney Swift Tower**

Figure 166 | **Prosthetic Lizard Home**

Artificial Habitat: Insect Hotels

Insect Hotels provide habitat for a variety of different insect species, either serving as free standing structures or integrated into the facade of buildings. Both applications consist of small holes and/or openings for insects to take shelter within.

Built or unbuilt: pre-Built or home assembly
Human Interaction / Intervention: Insect habitat
Inhabitants: Varying insect Species: beetles, ladybirds, butterflies, spiders, bees, wasps, and more
Dimensions: Holes 2mm – 8mm
Location: Varying
Adjacencies: Varying
Materials: Wood or logs, Bark, Reeds, Bamboo, Rocks, Sticks, Pinecones, Moss, etc.

Artificial Habitat: Insect Hotel Pavilion

The Insect Hotel pavilion by architects Maiju Suomi and Elina Koivisto in Finland is designed to provide habitat for pollinators in an urban environment. The structure consists of low-rise structures/walls made from varying forms of clay such as rammed earth, fired and unfired bricks, as well as wood. The perforations in each brick provide habitat for insects and pollinators to take habitation.

Built or unbuilt: Built - Temporary
Human Interaction / Intervention: Insect and pollinator habitat / social awareness
Inhabitants: Insect / pollinator
Dimensions: D: 450mm, W: 125mm, H: 425mm on average per brick
Location: Urban Environment
Adjacencies: Urban: between the Museum of Finnish Architecture and Helsinki Design Museum
Materials: Varying forms of clay brick

Figure 167 | **Insect Hotel**

Figure 168 | **Insect Hotel Pavilion**

Artificial Habitat: Bat Roost Boxes

Bat Roosting habitats come in a variety of materials and applications; bat roosting boxes can consist of wooden boxes attached to the facade of buildings, as well as integrated boxes which can be set into the facade of a building. Both applications consist of an interior with grooves to provide grip for the bats to cling on to. These bat boxes provide habitat for small clusters of bats and serve as a commercial solution to accommodating bats in new or existing buildings.

Built or unbuilt: Built, Prefab or DIY
Human Interaction / Intervention: Artificial habitat to species at risk
Inhabitants: Bat
Dimensions: D: 125mm, W: 200mm, H: 470mm
Location: Located on or in a building facade
Adjacencies: Directly adjacent to building, small in scale
Materials: Concrete and/or wood

Artificial Habitat: Deller's Bat House

Jeremy Deller's Bat house was selected as the winning entry in a WWT London Wetlands Centre nature reserve competition looking to provide artificial habitat to a Bat species. Designed in response to the gradual decline in human infrastructure capable of supporting bat habitation, such as grooved facades and overhangs, this design proposes a timber structure with plywood layering for bat roosting year-round.

Built or unbuilt: Built
Human Interaction / Intervention: Artificial habitat to species at risk
Inhabitants: Bat
Dimensions: D: 2400mm, W: 3000mm, H: 4200mm
Location: Greenspace; WWT London Wetlands Centre nature reserve
Adjacencies: Located in area open to human interaction
Materials: Hempcrete, plywood, timber

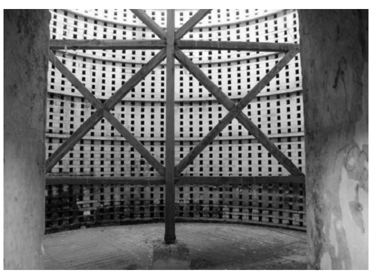
Figure 169 | **Bat Roost Boxes**

Figure 170 | **Deller's Bat House**

Artificial Habitat: Dovecote Tower

Modern dovecote designed by architect Oscar Niemeyer. Intended to serve as a public art installation / sculpture and support the housing of pigeon populations in the courtyard of the federal Court of Justice in Brasília Brazil.

Built or unbuilt: Built
Human Interaction / Intervention: Artificial habitat / public art
Inhabitants: Pigeon
Dimensions: H: 7000mm
Location: Public courtyard, Federal Court of Justice
Adjacencies: Public buildings, high foot traffic
Materials: Concrete, timber



Traditional Use: Pigeon Tower

16th and 17th century architecture around the world included the construction of Pigeon towers known as dovecotes, pigeonniers, doocots, colombiers, among others. These 10-12 meter high towers were typically built from mud-brick and stone with timber framing, although each design and material varies. Constructed as an inner and outer drum, these pigeon towers housed and harvested upwards of 14,000 pigeons in addition to collecting the droppings for fertilizer. Narrow openings prevented larger birds from entering the towers and in certain geographical areas, smoothed surfaces at the base prevented snakes and other species from climbing the tower.

Built or unbuilt: Built
Human Interaction / Intervention: Farming purposes
Inhabitants: Pigeon
Dimensions: H: 10,000mm
Location: 16th and 17th century, notably central Iran is known for its pigeon towers
Adjacencies: Varies
Materials: Varies: Mud-brick, stone, timber framing

Figure 171 | **Dovecote Tower**

Figure 172 | **Pigeon Tower**

Traditional Use: Ottoman Bird Houses

16th century traditional Turkish Ottoman architecture included birdhouses mimicking the building's architectural typology directly into and on the facades of mosques, inns, bridges, libraries, schools, and fountains. Ranging from simple one story bird houses to multi story complexes, supporting sparrows, swallows, and pigeons nesting, while limiting bird droppings from staining the walls of surrounding buildings. Thought to support religious beliefs, bringing forth good deeds to those who built these birdhouses.

Built or unbuilt: Built
Human Interaction / Intervention: Provide bird habitat while maintaining architectural style
Inhabitants: Bird; sparrows, swallows, and pigeons
Dimensions: Approximately D: 400mm, W: 1800mm, H: 1200mm
Location: Inserted or attached to the facades of mosques, inns, bridges, libraries, schools, and fountains
Adjacencies: Surrounding buildings, public
Materials: Concrete, stone

Traditional Use: House Barn

Housebarns were constructed to utilize the body heat of animals to warm human living areas by providing living space for livestock and human dwelling under the same roof, sometimes separated by walls or lofts, and prevented livestock from being stolen or injured during the night. This method of housebarn / semi-detached house barn has been used into the 19th century and onwards.

Built or unbuilt: Built
Human Interaction / Intervention: Heating of dwelling, protect livestock
Inhabitants: Livestock and human
Dimensions: Varies
Location: Varies
Adjacencies: Human living space
Materials: Varies; wood construction

Figure 173 | **Ottoman Bird Houses**

Figure 174 | **House Barn**

Human Infrestructure: Wildlife Corridors

Wildlife corridors allow for animals to cross over or under human infrastructure safely. The large wildlife overpass bridge crossing on Highway 69 south of Sudbury Ontario measures 30 m wide and is surrounded by 10 kilometers of animal fencing, 27 one-way gates, and two ungulate guards. By limiting the fragmentation of natural ecosystems through corridors that help direct wildlife safely around human infrastructure, biodiversity can help be sustained. Other wildlife corridors may exist in forms of box culverts, elliptical metal culverts, open span bridges, and creek bridge pathways.

Built or unbuilt: Built
Human Interaction / Intervention: Wildlife crossing at the benefit of human and wildlife
Inhabitants: Wildlife
Dimensions: W: 30,000mm
Location: Highway 69 south of Sudbury Ontario
Adjacencies: Highway
Materials: Concrete bridge, green surface

Human Infrestructure: Living Seawall

The Living Seawall project by Volvo and the Sydney Institute of Marine Science and Reef Design Lab have created an artificial 3D printed seawall structure to mimic the root structure of native mangrove trees to provide habitat for marine life. Intended to aid in the attraction and support of existing biodiversity of the sea which clean and filter sea waters, 50 3D printed tiles have been installed on the Sydney Harbour's existing seawall. The tiles will be monitored over the next 20 years to observe the filtering and feeding organisms it attracts and supports.

Built or unbuilt: Built
Human Interaction / Intervention: Aid and attract filter-feeding organisms
Inhabitants: Marine life
Dimensions: W: 304.8mm, H: 304.8mm x50 installed
Location: Sydney Harbour
Adjacencies: Installed along an existing seawall structure
Materials: 3d Printed. Plastic

Figure 175 | **Wildlife Corridors**

Figure 176 | **Living Seawall**

Human Infrestructure: Oyster-tecture

Commissioned by the Museum of Modern Art in 2009 for the Rising Currents exhibition, the Oyster-tecture proposal by SCAPE aims to construct an underwater living reef to attract and support millions of oyster and blue mussels. The project aims to filter the seawater at the New York Harbour through the biotic filtration processes of oysters, mussels, and eelgrass. A woven web of fuzzy rope forms a three-dimensional reef condition intended to house the mussels. The cleaner water quality produced by this process is intended to enable surrounding neighborhoods to create new channels inland from the Gowanus Canal, generating a water regional park.

Built or unbuilt: Proposal
Human Interaction / Intervention: Aid and attract oysters to filter water for human use
Inhabitants: Oyster
Dimensions: N/A
Location: Brooklyn, NY Harbour
Adjacencies: Harbour
Materials: A woven web of fuzzy rope

Human Infrestructure: Portal 1: Haynes Inlet

The Haynes Inlet Portal is an installation intended to protest the proposed route of the Pacific Connector Pipeline across the Pacific Northwest of North America. Located on an ecologically healthy site, this pavilion invites for human non-human interaction with benches on the interior for human occupation and loose thatch (Juncus effuses) and tule Schoenoplectus acutus) on its exterior to attract wildlife. Its circular form references time as cyclical weather, tides, water levels and planetary movement.

Built or unbuilt: Built
Human Interaction / Intervention: Protest pipeline. Cohabitation.
Inhabitants: Human and non-human.
Dimensions: L: 3657mm, H: 2438mm
Location: Pacific Connector Pipeline
Adjacencies: Wetland
Materials: Dimensional lumber. Thatch

Figure 177 | **Oyster-tecture**

Figure 178 | **Portal 1: Haynes Inlet**

Appendix B - Chimney Swift Food Source

SPECIES	HABITAT	FOOD SOURCE
Mosquito	Forests, marshes, tall grasses. Larvae and pupae live in the water with little or no flow.	Primary food source of flower nectar. Mosquitoes transfer pollen from flower to flower as they feed on nectar, fertilizing plants and allowing them to form seeds and reproduce.
Midges	Fresh water close to marine. Larvae can be found in benthic regions among the debris and aquatic vegetation. They also dwell in soft sediment and on the surface of rocks	Primary food source of flower nectar.
Flies	Live in close proximity to suitable food sources and breeding grounds. Often found in and around building.	Primary food source of organic decaying material. This includes, fruit, vegetables, meat, animal, plant secretions and human feces. Both male and female flies suck nectar from flowers.
Spittlebugs	Live in close proximity to open, grassy areas.	Primarily feed on grasses, goldenrods, or other nonwoody plants
Aphids	Live on plants, especially on new plant growth and buds.	Feeding exclusively on plant sap.
Winged Ants	Live in close proximity to moisture, light, and wood. These ants might be found lingering around a pool, swarming after a fresh rain, or even flying around in humidity. Actively searching out moisture.	Feeding on cellulose, nectar, seeds, other insects, and food debris sometimes found around and inside homes.
Bees and Wasps	Nesting underground or in shrubs, trees, or bushes, and corner spot where the nest will be protected from the elements.	Feeding on nectar, fruit, small insects, and plants.
Mayflies	Live in close proximity to streams, but some can also be found in still waters.	Primary food source of detritus and algae.
Moths	Live in lowland forest, wetlands, grasslands, and built environments with dark corners under shelter.	Food source of the larvae is lichen found on bare ground. Mature moth food source of natural fibres such as cotton, velvet, silk, wool, fur, leather and linen.
Spiders	Live in protected areas they can attach their nest.	Primary food source of insects.
Stoneflies	Live in close proximity to aquatic habitats.	Feeding on plants, decaying organic matter, and other insects.
Termites	Living in large colonies underground and within decaying organic matter.	Feeding on the cellulose found in wood.

Appendix C - Maley Hill Species Planting

Table 1: Seed Mixtures

SPECIES	**SUPPORTED SPECIES**
Canada Bluegrass	Leaf beetles, the Bluegrass Billbug , larvae of the Green June Beetle and Japanese Beetle, stink bugs, tarvae of moths,, skippers, butterflies,. Grasshopper, Straight-lanced Meadow Katydid. Various song birds. Foliage is a source of food for the Ruffed Grouse, Wild Turkey, Cottontail Rabbit, Elk, and voles.
Kentucky Bluegrass	An important winter forage grass for elk, deer. Rabbits, turkey, songbirds and rodents. Supports insects of white grubs, billbugs and sod webworm.
Timothy	High in fibre and low in protein which is a combination critical to the health of rabbits and other small animal. Used as feed for cattle and horses.
Redtop	Suports white-tail deer, small mammals, upland gamebirds.
Creeping Red Fescue	Habitat for crickets, beetles, grasshoppers, millipedes, and worms.
Alsike Clover	Its foliage supports deer, rabbits, groundhogs. Leaves, flowerheads and seeds support squirrel, sparrow, mourning dove, canada goose, ruffed grouse, wild turkey, and black bear. Supports insects of bees, grasshoppers, moths, beetle, butterfly.
Fall Rye	High-preference forages for deer.
Canada Wild Rye	High-preference forages for rabbit and deer. Habitat for various grassland birds.
Little Blue Stem	High-preference forages for deer. Supporting many different types of grasshoppers, beetles, spittlebugs, leafhoppers, and other herbivorous insects nesting and feeding on its vegetation.
Slender Wheatgrass	High-preference forages for deer, upland birds, songbirds and small rodents.
Birdsfoot Trefoil	Supporting canada goose, deer, and various songbirds and small rodents. Its leaves support insects of butterfly caterpillar, and larva of moth.

Table 2: Plantings

SPECIES	HABITAT	SUPPORTED SPECIES
Spruce, White	Prefers well-drained soils but occurs on a variety of land forms and soil types.	Supports deer, red squirrels, porcupines and grouse. A primary food source for red squirrels, chickadees, nuthatches and crossbills. Snowshoe hares, mice and voles eat the seedlings and spruce grouse feed on the needles. Black bears particularly like to eat the inner bark. Supports insects of bagworm, balsam twig aphid, bark beetles, Cooley spruce gall adelgid, eastern spruce gall adelgid, gypsy moth, spruce bud scale, spruce spider mite, and white pine weevil
Pine, Jack	Prefers sandy or shallow soil, and even on permafrost and rock.	Winter support for hares, deer, spruce grouse, and porcupines. Porcupines eat the bark. Burrowing animals of small mammals, snakes, salamanders and insects live in the understory. Shade-tolerant species such as black spruce, white spruce, and balsam fir often form the understory. Supports insects of white pine weevil, jack pine sawfly. The jack pine budworm attack jack pine.
Pine, White	Prefers dry sandy soils and rocky ridges to sphagnum bogs, growing best on moist, sandy loam. Often sinker roots growing down from them.	Bark and foliage are consumed by beaver, snowshoe hares, rabbits, porcupines, red and gray squirrels, mice, and white-tailed deer. Songbirds and small mammals feed on the seeds. White snowshoe hares and various deer graze on the needles. Bark, roots, and seedlings are food for small rodents. The high canopies and robust branches provide residence for peregrine falcon and bald eagles in addition to cavity-nesting wildlife.
Pine, Red	Prefers full sun. Can tolerate poor, rocky, and sandy soil.	Seeds are eaten by songbirds, squirrels, chipmunks, mice and various small rodents. Occasionally browsed by larger mammalian herbivores, including white-tailed deer and moose. Bats utilize red pine as cover while hunting for insects. Supports insects of moth species and butterflies.
White Birch	Forest edges, lakeshores, and roadsides. A wide variety of soils.	Support goldfinch, finches, chickadees, fox sparrows, tree sparrows, and redpolls, purple finch. Pine siskins eat the seeds. White tail deer consume the twigs and foliage, beavers and porcupines chew on the bark and wood. Seedlings of river birch trees are part of a wild rabbit's diet. The ruby-throated hummingbird, squirrels and yellow-bellied sapsucker ingest the sap from the tree. Birch borers feed on the insides of the birch tree. Ruffed grouse eat the catkins, buds, and seeds.

Appendix D - Sudbury's Species At-Risk

Table 1: Sudbury's Forest Management Region 50 Species At-Risk

SPECIES OF SPECIAL CONCERN	**SPECIES UNDER THREAT**	**SPECIES ENDANGERED**
Monarch Butterfly	Shortjaw Cisco	Butternut
West Virginia White	Blanding's Turtle	Spotted Turtle
Yellow-banded Bumble Bee	Eastern Foxsnake	Wood Turtle
Northern Brook Lamprey	Eastern Hognose Snake	Loggerhead Shrike
River Redhorse	Eastern Massasauga Rattlesnake	Golden Eagle
Eastern Musk Turtle	American White Pelican	Eastern Cougar
Eastern Ribbonsnake	Bank Swallow	Eastern Small-footed Myotis
Northern Map Turtle	Barn Swallow	Little Brown Myotis
Snapping Turtle	Bobolink	Northern Myotis
Bald Eagle	Chimney Swift	Tri-coloured Bat
Black Tern	Eastern Meadowlark	Gypsy Cuckoo Bumble Bee
Canada Warbler	Eastern Whip-poor-will	Riverine Clubtail
Common Nighthawk	Least Bittern	Transverse Lady Beetle
Evening Grosbeak	Algonquin Wolf	Shortnose Cisco
Golden-winged Warbler		Lake Sturgeon
Olive-sided Flycatcher		
Peregrine Falcon		
Red-headed Woodpecker		
Rusty Blackbird		
Short-eared Owl		
Yellow Rail		

Table 2: Maley Branch 20 Species At-Risk During Breeding Season

SPECIES AT-RISK	STATUS	CAUSE OF THREAT	FOOD SOURCE	HABITAT
Northern Myotis	Endangered	Due to the spread of a fungus that causes White-Nose Syndrome (WNS)	Primarily feeding on moths, flies and beetles.	Roosting under loose bark and in the cavities of trees.
Lake Sturgeon	Threatened	Due to harvesting, dams, habitat loss, and poor water quality.	Primarily feeding on insect larvae, crayfish, worms and mollusks.	Aquatic habitat.
Barn Swallow	Threatened	Due to the declining populations of insect prey, increasing frequency of severe temperature fluctuations, loss of nesting sites.	Feeding on flying insects of flies, grasshoppers, dragonflies, beetles, bees, wasps, moths and other insects.	Open areas, waterbodies, pastures with livestock, and woodland edges.
Blanding's Turtle	Threatened	Due to loss or fragmenting of habitat, motor vehicles, and raccoons and foxes that prey on eggs.	Feeding on fish, frogs, frog eggs, and carrion.	Requires aquatic habitat.
Bobolink	Threatened	Due to the loss of habitat.	Feeding on the seeds of weedy plants and insect larvae, adult insects, spiders, and arachnids.	Nesting in tallgrass prairie and other open meadows.
Chimney Swift	Threatened	Due to the loss of habitat and decline in food source of arial insects due to a loss of habitat.	Feeding on insects caught in flight including moths, spiders, ants, flies, beetles, etc.	Nesting on cave walls, hollow trees or tree cavities in old growth forests, primarily relying on human-made structures such as chimneys.
Eastern Whip-poor-will	Threatened	Due to habitat loss and degradation as a result of changes when open fields and thickets become closed forest in the north, and intensive agriculture in the south.	Feeding on insects such as moths, beetles, and fireflies.	Nesting in areas with a mix of open and forested areas, mixed forest are important for foraging.
Eastern Meadowlark	Threatened	Due to threats of habitat loss and degradation.	Feeding on insects, seeds and berries.	Nesting in tall grasslands, and small trees, shrubs or fence posts.
Bald Eagle	Special Concern	Due to habitat loss and unintentional DDT poisoning. (insecticide Dichlorodiphenyltrichloroethane)	Feeding on fish, waterfowl, turtles, rabbits, snakes, and other small animals and carrion.	Nesting in forested areas close to lakes, rivers, marshes and coastal habitats. nest in trees except in regions where only cliff faces or ground sites are available.

Black Tern	Special Concern	Due to draining and altering of wetlands, water pollution and human disturbance at nesting colonies.	Feeding primarily on fish, insects, crayfish, and small mollusks.	Building floating nests in loose colonies in shallow marshes, especially in cattails.
Canada Warbler	Special Concern	Due to habitat loss and degradation.	Feeding on insects, including beetles, mosquitoes, flies, moths, and smooth caterpillars such as cankerworms; also spiders.	Nesting in dense shrub and understory vegetation help conceal Canada Warbler nests that are usually located on or near the ground on mossy logs or roots, along stream banks or on hummocks.
Common Nighthawk	Special Concern	The causes of decline are not well known; reduce the numbers of aerial insects on which this species forages, which can be attributed to agricultural and other pesticides, and changes in precipitation, temperature and hydrological regimes.	Feeding on flying insects, including beetles, moths, grasshoppers, and many others. Will feed heavily on swarms of winged ants or termites.	Nesting in open and partially open habitats, including forest openings and post-fire habitats, prairies, bogs, and rocky or sandy natural habitats, as well as disturbed areas.
Eastern Wolf	Special Concern	Due to loss of habitat, hunting and trapping.	Feeding on moose, caribou, elk, and deer, but their primary source is white-tailed deer.	Mixed and coniferous forests.
Golden-winged Warbler	Special Concern	Due to the loss of habitat in eastern North America.	Feeding on caterpillars, moths, other winged insects, and spiders.	Nesting in mosaics of shrubby, open areas (for nesting) and mature forest habitats (which offer cover for fledglings from like predators like hawks) are important landscape features.
Milksnake	Special Concern	Due to urbanization, road construction and conversion of natural areas to agricultural uses are further threats to milksnake populations in Ontario.	Feeding on crickets and other insects, slugs, and earthworms and small mammals.	Nesting in rocky outcrops, rocky hillsides and forests.

Monarch	Special Concern	Due to the use of pesticides — including toxic neonicotinoids and herbicides, which are killing off the milkweed plants they need to survive — as well as urban development and climate change.	Feeding on milkweed.	Prairies, meadows, grasslands.
Olive-sided Flycatcher	Special Concern	Due to the loss of wintering habitat in northern South America.	Feeding on small wasps, winged ants, beetles, caterpillars, midges, and flies, with smaller numbers of true bugs, grasshoppers, and others. Also eats spiders, and occasionally a few berries.	Nesting on the edges of coniferous or mixed forests with tall trees or snags for perching, alongside open areas, or in burned forest with standing trees and snags.
Peregrine Falcon	Special Concern	Due to habitat loss and destruction, disturbance and persecution by people, and environmental contaminants.	Feeding primarily on various birds. Pigeons are often favored prey around cities, and ducks and shorebirds often taken along coast; known to take prey as larger birds of loon, geese, large gulls.	Nesting on tall, steep cliff ledges close to large bodies of water, and have adapted well to city life nesting on tall buildings.
Short-eared Owl	Special Concern	Due to habitat loss and degradation on its wintering grounds are most likely the major threat, while continuing habitat loss and degradation on its breeding grounds in southern Canada and pesticide use are secondary threats.	Feeding mostly at dawn or dusk on small mammals and sometimes birds.	Nesting in grasslands, marshes and tundra where it nests on the ground and hunts for small mammals, especially voles.
Snapping Turtle	Special Concern	Due to road mortality, hunting and poaching.	Feeding on plants, insects, spiders, worms, fish, frogs, small turtles, snakes, birds, crayfish, small mammals, and carrion.	Aquatic habitat.

Appendix E - Key Habitat Typoloies

	UNDERSTORY	DEADWOOD	TREE CANOPY	BUILT ENVIRONMENT
HABITAT	Dense grass, ground litter, understory vegetation.	Snags, deadwood, fallen deadwood, decomposing organic matter.	Mature tree canopy and heights. Young canopy, mid elevations. Horizontal and vertical shelter.	Built conditions: under edges, horizontal surfaces, vertical surfaces, interior conditions.
SPECIES AT-RISK	Bobolink, Eastern Meadowlark, Eastern Whip-poor-will, Canada Warbler, Short-eared Owl, Golden-winged Warbler.	Chimney Swift, Common Nighthawk.	Common Nighthawk, Olive-sided Flycatcher, Bald Eagle, Peregrine Falcon	Chimney Swift, Barn Swallow, Peregrine Falcon
ADDITIONAL SPECIES	Red-legged Grasshopper, Aphids, Stink Bug, mice, small rodents, Foam Lichen, Haircap Moss, ants, Wood Cockroach, mink, reindeer lichen, Salamander, Long-horned Beetle, Tufted Hairgrass, Lowbush Blueberry, American Painted Lady, Canadian Tiger Swallowtail, Snowshoe Hare, Black Bear, Red Fox, Smooth Green Snake, Ruffed Grouse, Yellow-rumped Warbler, Winter Wren.	Nodding Pohlia Moss, Bronze Birch Borer, Hairy Woodpecker, British Soldiers, Wood Cockroach, owl, burrowing mammals.	Forest Tent Caterpillar, Hairy Woodpecker, Chestnut-sided Warbler (early successional deciduous woods), Old Man's Beard Lichen, American Porcupine, Red Squirrel, Black-throated Green Warbler	Pigeons, European starlings, and house sparrows, songbirds, squirrel, small rodents, various insects