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**Student Research Report**

# The Importance of Biodiversity at UBC: Recommendations for Climate Action Plan 2030

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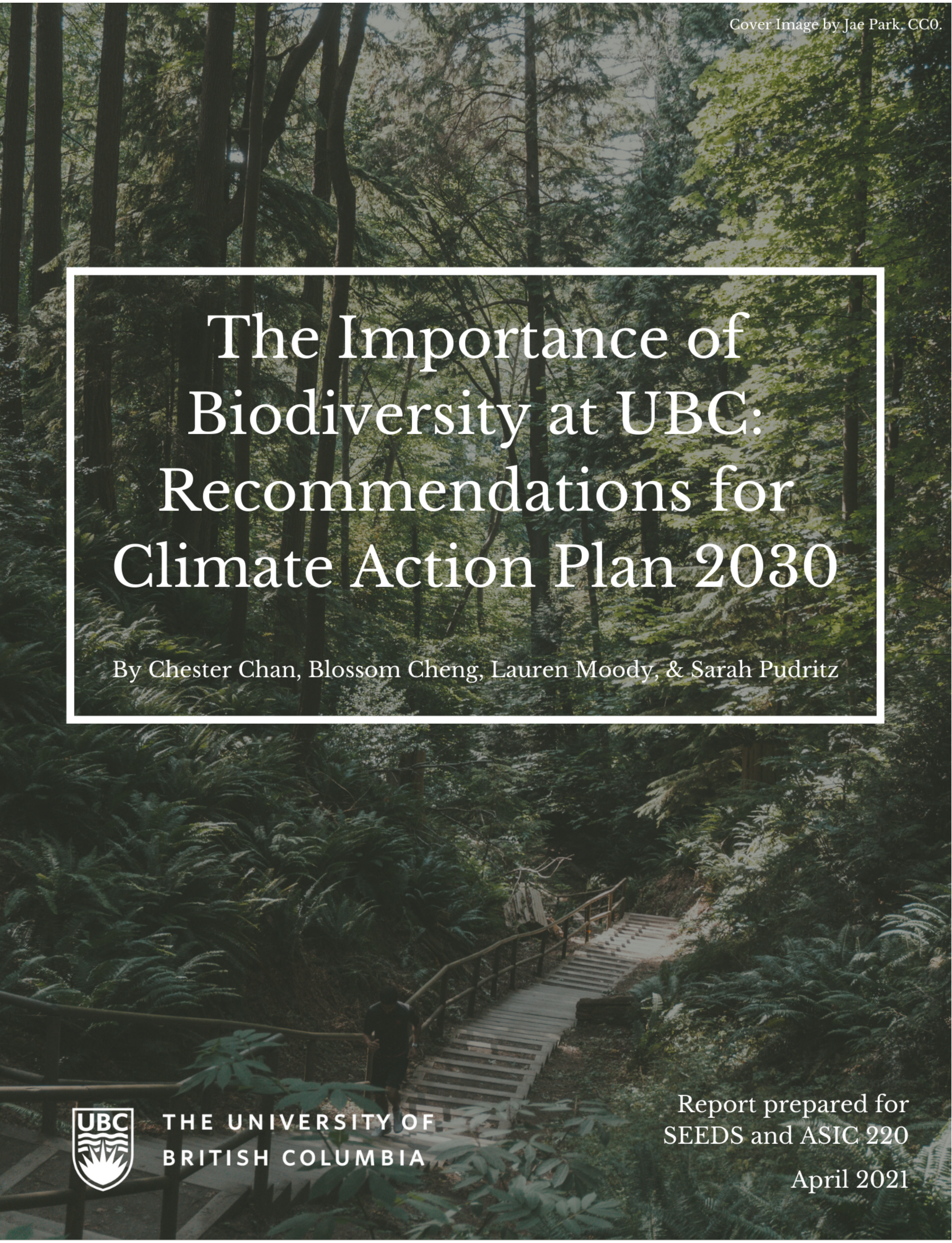



# The Importance of Biodiversity at UBC: Recommendations for Climate Action Plan 2030

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THE UNIVERSITY OF BRITISH COLUMBIA

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# Executive Summary

With the consequential threats of global climate change expected to alter ecosystems and societies around the world, the University of British Columbia (UBC) has listed climate action as one of their priorities. With UBC currently planning their next steps in addressing climate change through their development of the Climate Action Plan 2030 (CAP 2030) it is critical that UBC addresses biodiversity in this plan. CAP 2030 currently lacks sufficient consideration for biodiversity as a key aspect for mitigating and adapting to climate change. Therefore, the purpose of this report is to inform UBC of the importance of biodiversity to all aspects of the UBC community. We have chosen four pillars that UBC should consider when planning for biodiversity conservation. These pillars are social, cultural, economic, and environmental perspectives for biodiversity. Our team has done a literature review of peer reviewed papers addressing the interconnections between biodiversity and each of our four chosen pillars. Additionally, we reviewed UBC's current actions that address biodiversity. In consultation with UBC's Social Ecological Economic Development Studies (SEEDS) Sustainability Program, we have prepared this report to guide UBC in their integration of biodiversity action into CAP 2030.

## Key Findings

**Social Perspectives of Biodiversity**

Biodiversity plays a significant role in promoting social cohesion, social and physical wellbeing, health, as well as employment opportunities within society. As evident from literature on biodiversity and its social implications, UBC should consider the social role in which the maintenance and improvement of richness in biodiversity on the Vancouver campus has on those who live, work, and study at the university.

**Cultural Perspectives of Biodiversity**

Biodiversity and conservation play a large role in Indigenous reconciliation and sovereignty. It is worth considering the role of Musqueam knowledge in maintaining and enhancing biodiversity within UBC's Vancouver campus. Historically, Indigenous knowledge and role in maintaining pre-settler colonial ecosystems have been disregarded. Reconciliation has the power to acknowledge settler changes to the land and people, which can also encourage biodiversity development.

**Economic Perspectives of Biodiversity**

Biodiversity yields notable economic value through the provision of ecosystem services, particularly in its role as a regulator of ecosystem processes. Such regulatory ecosystem services include macroclimatic regulation, microclimatic regulation, and hydrological regulation; these processes not only have numerous co-benefits for climate mitigation and adaptation but also offer reduced costs and other economic benefits.

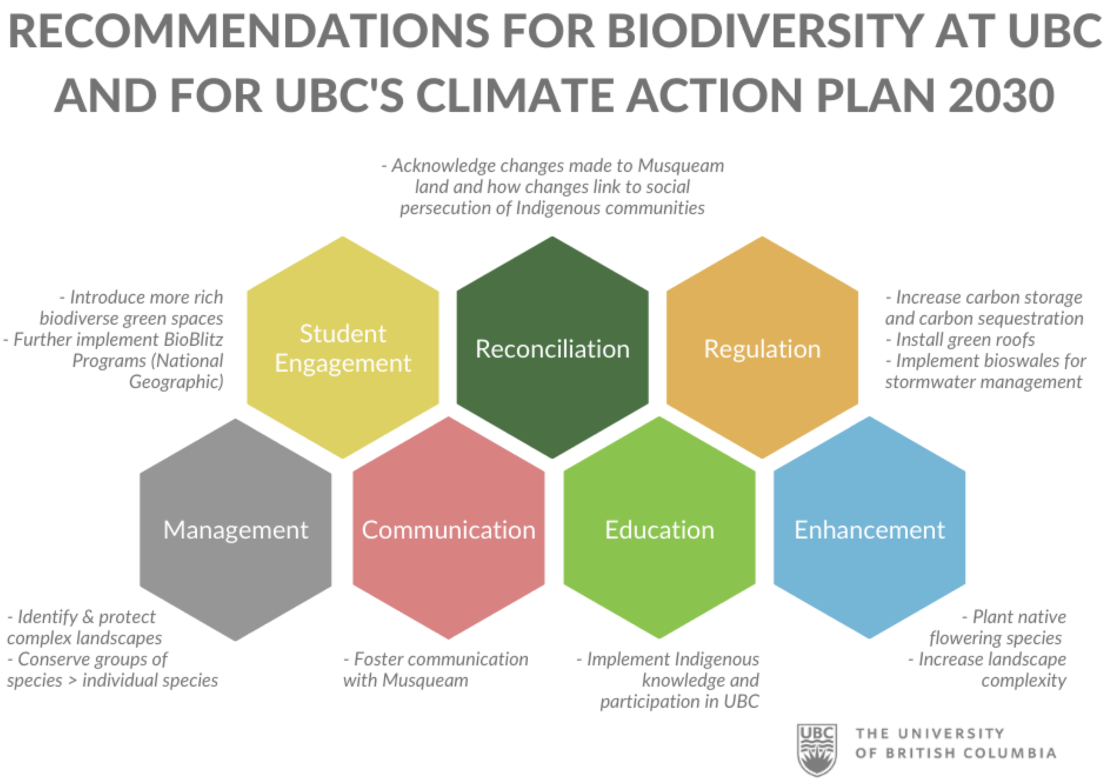
**Environmental Perspectives of Biodiversity**

Biodiversity is vital for maintaining ecosystem health since many ecosystem functions and services are enhanced by increased biodiversity. However, climate change is accelerating the rate of biodiversity loss which then hinders an ecosystem's ability to adapt to climatic change. Implementing biodiversity action at UBC is thus an essential step for ensuring that the campus' natural ecosystems persist and thrive under a changing climate.

# Recommendations

- Management of Existing Biodiversity: Conserve complex landscapes, habitats and species. Additional efforts towards conservation can also create more employment opportunities.
- Methods of Enhance Biodiversity: Increase rates of native pollinators through planting native flowering species. Increasing landscape complexity this way can also increase natural pest control and conserve biodiversity.
- Encourage Student Engagement: Increase engagement through biodiverse social greenspaces and educational programs.
- Education of Indigenous Knowledge: Teach and implement Indigenous knowledge on conservation and science into all disciplines. Expanding past social science disciplines allows for Indigeneity to exist past colonialism and be recognized for their technologies.
- Communication with Musqueam: Increase communication so Musqueam can define biodiversity and establish their vision and values of conservation, allowing them to reconnect with the land.

- Regulation: Implement technologies and strategies to enhance macroclimatic, microclimatic, and hydrological regulatory processes and consequently enhance urban biodiversity, reduce carbon emissions, and provide economic benefits.
- Reconciliation: Acknowledge the changes made to the land and its effects in displacing Indigenous communities while altering the ecosystem.



# Introduction

**Definitions of Biodiversity**

Anthropogenic activity has caused biodiversity to decline at a rate 1,000 times faster compared to during the fossil record (Millenium Ecosystem Assessment, 2005). This rapidly declining biodiversity is accelerating the rate of climate change. In turn, increasing climatic change is causing biodiversity to be lost at a faster rate. Biological diversity is thus an integral part of maintaining the health of ecosystems in the face of global climate change. As humans rely heavily on healthy ecosystems for survival and wellbeing, ensuring that biodiversity is preserved will be crucial under a changing climate. Biodiversity can be understood in different ways however a common definition comes from the United Nations' Convention on Biological Diversity. They define biodiversity as the "variability among living organisms from all sources including [terrestrial and aquatic] ecosystems and the ecological complexes of which they are part; [including] diversity within species, between species and of ecosystems" (Convention on Biological Diversity, 2006).

**UBC's Efforts Towards Biodiversity**

To our knowledge, there is no specific definition of biodiversity used by The University of British Columbia (UBC). However, there are several biodiversity initiatives currently underway across UBC's Vancouver campus. Most notably, UBC's Beaty Biodiversity Museum displays a collection of over two million specimens (Beaty Biodiversity Museum). Additionally, the Biodiversity Research Centre investigates the role of biodiversity on ecology and conservation (UBC, Biodiversity Research Centre). The UBC Botanical Garden and the Nitobe Memorial Garden both house diverse plant species representing hundreds of different taxa (UBC Botanical Garden, 2016). Further, UBC Farm is leading long-term monitoring efforts of biodiversity (UBC Farm). While these initiatives are all important in understanding biodiversity, UBC should enact broader, campus-wide strategies in order to further integrate biodiversity into UBC's priorities.

Neither UBC's Climate Action Plan 2020 nor the Final Report and Recommendations (2021) that emerged from the UBC Climate Emergency Engagement process incorporate biodiversity management practices into their proposed policies at a meaningful level. While other institutions have included biodiversity or ecosystem management as a strategic category in their climate policies — such as the inclusion of a “Landscapes and Ecosystems” category in McGill’s Climate and Sustainability Strategy (McGill University, 2020) — UBC has historically neglected to include biodiversity in its climate policies. Fortunately, UBC has recently committed to the development of a biodiversity strategy to support climate mitigation and adaptation targets for CAP 2030, as discussed briefly in the CAP 2030 Emerging Directions and Draft Targets document (2021). In addition, the new UBC Climate Crisis in Urban Biodiversity initiative has incredible potential to spark interdisciplinary solutions that address both the climate and biodiversity crises, and in collaboration with the UBC Campus Biodiversity Initiative: Research & Demonstration (CBIRD), such actors will likely help foster partnerships and innovation for advancing urban biodiversity and climate action. However, for UBC to be a true leader in both urban biodiversity management and climate action, relevant policy frameworks in each discipline (such as the CAP 2030) must include and prioritize strategies that address the critical connections between biodiversity and climate.

**Intended Outcomes of this Report**

This report intends on offering UBC with recommendations to develop their biodiversity strategy for CAP 2030 based on a literature review that incorporates varied perspectives of biodiversity. The perspectives of biodiversity represented in this report are (1) social, (2) cultural, (3) economic, and (4) environmental. These four pillars of biodiversity effectively encompass wellbeing for the environment and individuals. In addition, these four perspectives are inextricably connected, which is critical as biodiversity cannot be considered through only one lens. It is important to consider such a holistic approach when proposing policy recommendations for systemic issues at large institutions like UBC. This report represents the finding from a literature review of peer reviewed papers, existing policies, and international sources. Our research subsequently provides recommendations for UBC’s next steps in implementing relevant biodiversity practices on campus both to inform UBC’s CAP 2030 and to improve overall social, cultural, economic, and environmental wellbeing.

# Social Perspectives of Biodiversity

While biodiversity certainly allows for the functioning of ecosystems, it also has many social implications within society. Biodiversity offers significant benefits towards human wellbeing and health. Human health and biodiversity are in fact "inextricably linked" (Campbell et al., 2011). Fuller et al.'s (2007) collected data from participants across 15 parks who reported experiencing psychological benefits in environments with greater richness and diversity of species, plants, birds, and butterflies, suggesting an association with the biodiversity of natural areas and human wellbeing. In fact, participants were able to recognize and accurately estimate levels of diversity within the park, demonstrating the importance levels of biodiversity is. Biodiversity also serves as a natural restorative environment for those who experience attention fatigue (Kaplan, 1995). A restorative environment must have 'extent' — meaning that it has sufficient richness of biodiversity to appear natural and unique from the usual environment that may be linked with stressors. If humans are able to perceive an area as having richer biodiversity, it is more likely to impact their wellbeing due to perceived extent. This suggests the importance human perception has on the response to the environment and how it impacts their wellbeing. This can be applied to the UBC context as UBC may seek to explore the ways in which they can improve the 'extent' of biodiversity within campus, keeping in mind that doing so could improve student's mental wellbeing, as well as prevent attention fatigue, which could help with academic performance. (Institute for European Environmental Policy, 2016).

Greater biodiversity also offers more opportunities to engage in recreational activities, which in turn further promotes health and physical wellbeing (Institute for European Environmental Policy, 2016). In fact, physical activity is a key mechanism that explains the potential health benefits that are associated with urban nature areas. A Canadian study found that participants who lived in areas with the highest quartile of greenness engaged in more leisurely physical activity compared to those living in the lowest quartile. The correlation was especially strong among young female adults in particular (McMorris et al., 2015). Extensive literature suggests a positive association between exercising in green biodiverse areas and mental health.

Biodiversity also plays a significant role in employment opportunities. Jobs are directly linked to biodiversity in that people are employed in order to allow for the maintenance and conservation of protected areas. In fact, there is an indirect link where increasing numbers of employment in industries relating to biodiversity has led to ecosystem service provision — such as water purification (Institute for European Environmental Policy, 2016). This can be applied to the UBC context as in order to maintain the richness of UBC's existing biodiversity, it must be effectively managed. This can be achieved by employing individuals to aid with maintenance and conservation of certain areas.

Lastly, biodiversity may promote social cohesion among various social groups (Institute for European Environmental Policy, 2016). Research indicates that green spaces provide an environment in which people are encouraged to interact, which can strengthen relationships within communities — allowing people from various ethnic and/or cultural backgrounds to better integrate and identify with their community. By seeing and meeting one's neighbours at local parks and green spaces, one is able to develop a sense of commonality and familiarity which allows for more opportunities for future engagement. As a result, green spaces were shown to promote social interactions through creating social behavioural norms that promote more neighbourhood interaction (Bennet et al., 2012). Another study looked into the impact of community gardens and allotments specifically and its implications towards social cohesion. Results indicated that such community gardens fostered intercultural communication, brought people out of isolation, and provided a platform for broader discussion of community issues — suggesting improved social cohesion (Institute for European Environmental Policy, 2016). Since UBC is a diverse community of students coming from all over the world and from all walks of life, social cohesion is extremely important. An emphasis on biodiversity may allow UBC students to find a common ground and connect, thus allowing for greater social cohesion.

# Cultural Perspectives of Biodiversity

UBC has made active efforts to promote Indigenous reconciliation with its Indigenous Strategic Plan (ISP). However, most of the issues discussed in the plan only consider the social issues of Indigenous colonial histories. Biodiversity and conservation play a large role in Indigenous reconciliation and sovereignty. Therefore, it is worth considering the Indigenous perceptions of biodiversity to further support reconciliation efforts UBC has. This section will consider how Indigenous nations around the world are implemented into biodiversity development and how it can relate to UBC's Vancouver campus.

Implementing biodiversity and conservation policies should integrate Indigenous values. Heiner et al. outlines methods to incorporate "biodiversity and cultural/social values into a development planning process" (Heiner et al., 2019, p.2) in Indigenous Australian land. While the article focuses on new land development rather than existing changes to Indigenous land such as UBC, the article argues that impact assessments should "include social and cultural values with systemic frameworks and standards" (Heiner et al. 2019, p.2). According to the Musqueam website, all "projects within Musqueam's territory are not developed without the community's Free, Prior, and Informed Consent". By outlining species that hold cultural value or other conservation practices, Musqueam would have the opportunity to play an active role in what happens on their traditional, ancestral and unceded land. The UN Declaration of The Rights of Indigenous Peoples — which according to the ISP, UBC is required to implement — mentions that "Indigenous peoples have the right to self-determination. By virtue of that right they … freely pursue their economic, social and cultural development" (UNDRIP 2007, p.8). It can be argued that cultural development is connected to the land and therefore efforts towards maintaining and developing biodiversity should include the demands of Musqueam.

Maintaining biodiversity fits in as a result of maintaining Indigenous cultural heritage sites and the protection of culturally sacred and endangered species. Cultural beliefs in the sacredness of animal and plant species also play a role in conservation. An example Kelbessa used is the taboo against cutting down trees around religious institutions in Indigenous Ethiopian cultures, these beliefs "in turn contributes to biodiversity conservation" Kelbessa (2015, p.146). Therefore preserving Indigenous cultures and conservation can become synonymous, and can allow for Indigeneity to be reestablished while improving the environment. Using the Healthy country planning framework (Heiner et al., 2019), which uses a multi-step process for development planning, Indigenous communities are given the opportunity to define their values. Heiner et al. looked at the Nyikina Mangala community, who defined " a set of seven natural, cultural, and socio-economic targets that collectively represent" (2019, p. 4) their vision and values. By adopting similar frameworks, UBC would be able to understand the Musqueam definition of biodiversity and conservation and would also have a framework to build their own biodiversity plan.

Neoliberal priorities towards corporations and colonial powers have prevented Indigenous communities from claiming intellectual property over their methods and knowledge to guarantee and legitimize ownership of land. Kelbessa claims that "in order to encourage peasant farmers to conserve, manage and develop social and natural diversity, the existing… property law should be revised and include local knowledge entitlements" (Kelbessa 2015, p.150). According to Kelbessa, there is a link between Indigenous knowledge and modern science to promote biodiversity and conservation. The Indigenous communities of Ethiopia have "managed to maintain biological diversity in their environment… very effectively over a long time" (Kelbessa 2015, p.144). Developments in biodiversity should implement Indigenous methods of conservation, which would reconnect the land with Indigenous histories. While UBC does not have the power to change legislation to legally recognize Indigenous methods in science and conservation, UBC does have the power to recognize the importance of Indigenous knowledge within the campus context and implement these methods into student's learning and future developments in biodiversity. "One does not need to look far to recognize the value that has been placed on Eurocentric approaches to teaching and research to understand why so many do not see themselves reflected in the classroom and workplace" (ISP 2020, p. 9). By implementing Indigenous knowledge and methods of conservation, UBC has the power to facilitate active reconciliation that can reconnect the land with its Indigenous histories and rightful caretakers. In addition, students and staff could be able to see themselves and their values represented and taken seriously, as biodiversity and conservation efforts towards the land affects all who learn and live on it.

In addition to future efforts towards reconciliation, historical effects of colonialism on biodiversity should also be considered. McCune et al. (2013) discusses the misconception that the ecosystems of the New World were pristine and untouched. In reality, Indigenous communities have played a huge role in maintaining biodiversity and the survival of many species. As mentioned by McCune et al. (2013) "the overwhelming ethnographic evidence of the importance of plant foods and materials in Coast Salish culture has forced ecologists to realize that people were influencing… ecosystems long before" the arrival of the settlers (2013, p.296). Conservation efforts during the colonial era in the United States included driving Indigenous people out of their lands and creating national parks, where the ecosystems were left untouched. These actions were fueled by the misconception that the ecosystems of the New World were pristine and untouched. The article shows how removing Indigenous communities from these ecosystems endangered plant species, "with continued lack of disturbance… [it creates] conditions that are too shady for oak seedlings to survive" (McCune et al. 2013, p.297). In addition to considering action for the upcoming climate plan, it is incredibly important that UBC acknowledge the historic changes to Musqueam land.

Changes to the land have not only displaced Indigenous communities, but have also contributed to their genocide, persecution and discrimination that still exists today. Selemani writes about how the knowledge of Indigenous communities is often overlooked in scientific and academic research. The dismissal of Indigenous scientific knowledge alludes to patterns of diminishing of Indigenous sovereignty, land use conflicts and poverty and emerging pandemic diseases (Selemani, 2020) and how Indigenous knowledge and customs have been historically dismissed. However it also relates to the patterns of dismissal towards other aspects of Indigeneity, such as intergenerational trauma. The failure to address the historical role UBC has had on the forced assimilation and destruction of Indigenous culture has made UBC "complicit in its perpetuation" (ISP, 2020, p.9). Reconciling with the role UBC has "played in colonization is important to put the Indigenous Strategic Plan into context" (ISP, 2020, p.8). The social destruction of Indigenous culture should not be the only issue to focus on, UBC has a responsibility to acknowledge how their settlement into Musqueam territory has stripped Musqueam from their land and how it has perpetuated other issues including epidemics such as drug and alcohol use, intergenerational trauma and many more. The Climate Action Plan should consider how the removal of Musqueam has historically altered the ecosystem and how to facilitate reconnection to not only improve biodiversity conservation, but also to facilitate reconciliation.

# Economic Perspectives of Biodiversity

In an economic context, the term "biodiversity" is often used interchangeably with the concept of "ecosystem services". Ecosystem services are the benefits that humans derive from ecosystems and can be divided into four categories: provisioning, regulating, cultural, and supporting (Mace et al., 2012). On the other hand, biodiversity represents the variety of all life on earth and is not equivalent to the dollar value of nature-derived human benefits.

Mace et al. (2012) outline two approaches to this debate around the language used to differentiate biodiversity and ecosystem services. The first approach - the "ecosystem services perspective" - views biodiversity and ecosystem services as the same and maintains that the management of ecosystem services will have benefits for biodiversity and vice versa. The second approach is the "conservation perspective" and posits that biodiversity in itself has intrinsic value and is an ecosystem service. Both approaches are problematic; the ecosystem services approach neglects to value biodiversity beyond its human benefits and the conservation approach doesn't account for biodiversity's functional role and instead views it as a one-dimensional good.

In this section, biodiversity will be examined as a regulator of ecosystem processes rather than a final ecosystem service or a good. This perspective recognizes the fundamental role that biodiversity plays in regulating an ecosystem's functionality and in turn accounts for the role that ecosystem functionality plays in ecosystem services. Examples of ecosystem services that rely on these regulatory processes include clean air and water, healthy soils, and climate regulation. For purposes of clarity, from this point forward any reference to "ecosystem services" can be interpreted as regulatory ecosystem services whose function depends on biodiversity to exist.

Regulatory ecosystem services are of particular interest in this section because they have notably high economic value. Comprehensive global estimates suggest that ecosystem services provide benefits of 125-140 trillion US dollars every year (OECD, 2019). However, the loss of biodiversity and habitat has also resulted in an estimated loss of 4-20 trillion USD per year in ecosystem services between 1997 and 2011 (OECD, 2019). These losses will only be exacerbated as changes in the global climate intensify and conditions become unlivable for many species, with studies estimating that 5-16% of species are at risk of extinction from climate change depending on the severity of warming (IPBES, 2019). However, the relationship between biodiversity and climate change is not one directional; biodiversity is also a key regulator of ecosystems that sequester carbon and that have considerable value for mitigating and adapting to climate change. The loss of such biodiversity could thus have immensely detrimental impacts for climate mitigation.

Fortunately, many biodiversity management practices have considerable climate co-benefits as well as economic benefits. Such biodiversity-supported ecosystem services that help to regulate climate include:

- Macroclimatic regulation (e.g. carbon sequestration)
- Microclimatic regulation (e.g. urban temperature regulation)
- Hydrological regulation (e.g. stormwater management)

**Macroclimatic Regulation**

Regulation of macroclimatic processes can occur through ecosystem processes that sequester carbon. For example, the University of Toronto accounts for carbon capture by trees on all of its properties in its Low-Carbon Action Plan (University of Toronto, 2019) and has plans to increase the number of trees on campus in order to maximize the quantity of stored carbon while also protecting biodiversity. Trees on the U of T campus sequester over 1000 tonnes every year, which make up 2.46% of the university's planned annual emission reductions (University of Toronto, 2019). A recent study aiming to assess above-ground carbon storage by urban trees at UBC found that an average of 5.27 kilograms of carbon per square meter is stored on campus (Gülçin and Bosch, 2021); for a campus 4 square kilometres in size, this equates to 21,080 tonnes of stored carbon. Carbon storage and sequestration not only have benefits for the climate but can also have economic benefits due to lower carbon taxes and the social costs of carbon. Increasing the number and variety of trees on the UBC campus will therefore strengthen biodiversity, sequester carbon, and have subsequent economic benefits.

**Microclimatic Regulation**

While macroclimatic regulation may be difficult to implement at a meaningful level at the scale of a university campus, microclimatic regulation by biodiverse ecosystems has been shown to have numerous positive effects. The implementation of green roofs helps to regulate urban temperature and as such has valuable climate adaptation benefits. The University of Toronto's Green Roof Innovation Testing Lab has found that the surface of green roofs is on average 2 degrees Celsius lower than the air temperature and can be as much as 50 degrees Celsius cooler than an ordinary rooftop (Sommerfield, 2018), assisting in the cooling of buildings as temperatures - particularly in urban environments - increase. An experimental study conducted by BCIT on the west coast of BC found that the implementation of green roofs resulted in a 66% decrease in annual energy consumption (Connelly and Liu, 2005). In another study that included the viability of green roofs in Vancouver, researchers found that annual energy consumption could be reduced by 6.22% and the heating load would be reduced by 12.5% (Mahmoodzadeh et al., 2020). Energy savings could not only have huge economic benefits for the university but reducing UBC's energy usage will also help it reduce its emissions.

Green roofs also have recorded benefits for urban biodiversity (Williams et al., 2014), far more than conventional roofs, as they provide microhabitats and "stepping stone" ecosystems for wildlife in urban areas (Köhler and Kzesiak-Mikenas, 2018). The implications of green roofs for biodiversity depend heavily on how the green roofs are constructed, as many green roofs are not installed for biodiversity purposes and can consequently be low in plant diversity (Köhler and Kzesiak-Mikenas, 2018). As such, considerable intention must be given to enhancing biodiversity when considering the installation of green roofs at UBC; consultation with biodiversity groups at UBC such as the Biodiversity Research Centre and Beaty Biodiversity Museum (which also has a green roof) could be of considerable benefit here.

**Hydrological Regulation**

Hydrological regulation is another ecosystem process made functional by biodiversity. Ecosystem-based stormwater management systems can increase biodiversity while also minimizing urban flooding, an issue that is likely to become more severe as the effects of climate change intensify. Green roofs have been found to retain up to 70 percent of rainwater which may help reduce urban flooding (Sommerfield, 2018) and are also a strategy for Low Impact Development (LID) stormwater management systems. UBC's Integrated Stormwater Management Plan (UBC, 2017) was created to adapt to the additional rainwater on campus and reduce the impacts of stormwater flow off-campus. Bioswales are an example of a strategy that could be implemented as part of this plan; bioswales are vegetated areas that collect and filter stormwater runoff and are often located near impermeable surfaces such as roads. They also enhance urban biodiversity in comparison to alternative stormwater management technologies and when constructed using native vegetation, can be more cost effective due to reduced maintenance costs (Feit, 2018). A SEEDS project executed in 2017 proposed the implementation of bioswales along Agronomy Road on the Vancouver campus, citing the benefits for urban biodiversity and improved stormwater management (Chui et al., 2017). The report also evaluated a variety of case studies for ecosystem-based stormwater management and examined the environmental, social, and economic benefits such studies could provide for UBC. In the context of biodiversity, we recommend that UBC focuses on stormwater intervention strategies such as bioswales and green roofs that can assist in increasing urban biodiversity as well as improving adaptation for increased rainwater and urban flooding due to climate change.

**Economic Valuation of Regulation**

While all of the above ecosystem services have inferred economic value due to the regulatory functions they serve both for urban biodiversity conservation and climate adaptation and mitigation, many of these strategies also have quantifiable economic value. For example, a valuation study performed at the University of Michigan found that in the span of 40 years a green roof would save around $200,000, mostly due to reductions in energy costs (National Park Service, n.d.). An analytical study executed as part of the SEEDS program found that the carbon stored in a year by trees on the UBC Vancouver campus provided an economic value of $498,000 CAD annually (Liu, 2020). The City of Philadelphia implemented Low Impact Development stormwater management systems including bioswales and has saved approximately $170,000,000 in sewer overflow costs since 2006 due to the reduced runoff volume associated with ecosystem-based stormwater management strategies (Environmental Protection Agency, 2013). As such, not only do these regulatory processes have noted biodiversity and climate benefits, but they could also provide economic value for UBC; however, further research regarding the full extent of the economic benefits of these strategies at UBC is needed. It is also critical to address UBC Technical Guidelines when considering the implementation of the aforementioned regulation strategies.

# Environmental Perspectives of Biodiversity

Biodiversity is commonly addressed from the environmental perspective. In recent decades, the literature on biological diversity from the environmental lens has increased dramatically (Heller & Zavaleta, 2009). Ecologists, conservationists, and biologists are interested in determining how genes, species, populations, communities, ecosystems and biomes have and will respond to climate change. The consensus from these experts is that biodiversity preservation will be integral for our natural environment to remain stable and functioning. A healthy ecosystem in turn aids humans as we rely heavily on the environment for our survival.

**Ecosystem Functions and Services**

Ecosystem functions are services that are integral to every ecosystem and every society. An ecosystem function is defined as “the capacity of natural processes and components to provide goods and services that satisfy human needs, directly or indirectly” (De Groot et al., 2002). Ecosystem services are services provided to humans by the natural environment (i.e., from ecosystem functions. Millenium Ecosystem Assessment (2005) categorizes ecosystem services into four groups: (1) provisioning services such as the availability of food, water and building materials; (2) regulating services such as climate regulation and disease regulation; (3) supporting services such as soil formation and primary production; and (4) cultural services such as education, recreation, and spiritual enrichment. To reiterate, ecosystem functions are natural processes that occur in the natural environment, and these ecosystem functions result in ecosystem services which are benefits to humans from the natural environment. Both ecosystem functions and ecosystem services are heavily dependent on the amount of biodiversity housed within an ecosystem. Researchers have highlighted that ecosystem functions are necessary for stabilising ecosystems (Cardinale et al., 2012; Hunt & Wall, 2002). Further, a meta-analysis conducted by Balvanera et al., (2006) indicate that biodiversity has a positive effect on ecosystem processes. While these positive effects are not very evident at species levels, community level functioning increases with biodiversity

(Balvanera et al., 2006). More specifically, the stability and productivity of communities increase when the number of species present in an ecosystem increase (Balvanera et al., 2006).

An example of an ecosystem function that relies on biodiversity is pollination. Pollination is an ecosystem function vital to ecosystem health as wild plants depend on pollination to reproduce (Ollerton et al., 2011). Further, with the demand for biotic pollination increasing in agriculture (Aizen & Harder, 2009), sustainable food production will depend on the resilience of pollinator species to persist through the changing environmental conditions due to climate change. Unfortunately, wild bee species and managed bee populations have been declining in the past few decades; without these pollinator species, ecosystem collapse is inevitable (Cameron et al., 2011). As pollinator biodiversity increases, so do pollination services. Research by Brittain et al., (2013) demonstrates how biodiversity is essential for pollination, especially under variable climatic conditions. Their research highlights that different species of pollinators exhibit spatial complementarity. Spatial complementarity in ecology is when resources are used more efficiently because different species have different niches (i.e., species have different roles in the ecosystem) (Brittain et al., 2013). They also demonstrated that biodiversity in pollinator species is necessary in ensuring that pollination continues to occur under variable environmental changes like increased wind speeds (Brittain et al., 2013).

UBC can support pollination services by taking measures to increase pollinator biodiversity. Brittain et al., (2013) suggest that Osmia species management aids with the diversification of pollination services. The Blue Orchard Bee (*Osmia lignaria*) has been found in southern British Columbia (B.C. Conservation Data Centre) and thus would be able to survive in UBC's climate. Additionally, it is suggested that sustaining pollination services into the future is best achieved through a broad conservation approach rather than focusing on a single species approach (Chapin et al., 2010).

Apart from pollination, the literature suggests that many other ecosystem functions are bolstered by high levels of biological diversity. For instance, proper functioning of nutrient cycling relies on biodiversity. With many plant and microbe species playing key roles in breaking down organic wastes, and some species even transforming chemical pollutants into usable nutrients for ecosystems (Pimentel et al., 1997), it is clear that nutrient cycling is vital to the functioning of ecosystems. Under perturbations in nutrients, ecosystems housing greater biodiversity were able to remain more stable than ecosystems with less biodiversity (Balvanera et al., 2006). Further, an ecosystem's natural ability to control pests and invasive species increases with increased biodiversity. In a literature review of biodiversity and pest control in relation to landscape composition by Bianchi et al. (2006) reveal that the conversion of complex landscapes into simplistic landscapes reduces biodiversity and natural pest control functions. Specifically, natural enemy populations to pests are enhanced with increased landscape patchiness, increased wooded habitat, and decreased agricultural land in approximately 70% of the cases presented in the literature review (Bianchi et al., 2006).

**Climate Change**

Biodiversity loss and climate change are inextricably linked, with increased severity of climate change causing accelerated biodiversity loss, this reduction in biodiversity subsequently increases climate change (Bellard et al., 2012). While there are methods for which species can adapt to a changing climate, the literature warns that these adaptations may not be enough for ecosystems to persist under climatic changes. Therefore, human intervention is necessary in preserving biological diversity.

There are three ways in which species can adapt to climate change (Bellard et al., 2012). First species can alter when their life cycle events occur (Bellard et al., 2012). Species that rely on the timing of certain ecological events like migration, hibernation and flowering of plants have been witnessed to alter their timing to account for the delays or advancements in abiotic factors (Charmantier et al., 2008). Second, some species have shifted their spatial range in response to climate change including moving poleward and increasing in altitude (Bellard et al., 2012). However, spatial shifts are more suitable for species who can disperse easily, like birds and insects (Parmesan, 2006). This means that many species will not be able to move in response to climate change, and thus are at higher risks of extinction as the planet warms. Third, species can adapt to changing climate conditions like increased temperature and reduced precipitation through behavioural or physiological adaptations (Bellard et al., 2012). However, these adaptations rely on high levels of genetic diversity within an ecosystem for a population to adapt to altered environments (Steffan et al., 2013). Additionally, a larger variety of species within an ecosystem may allow for a greater ability for populations to persist because they can consume and rely on other species when certain species go extinct.

While there are diverse methods for species to persist through changing climatic conditions, the speed of climatic change will likely outpace the speed in which many species can adapt to their new environmental conditions (Salamin et al., 2010). Species that aren't able to adapt will inevitably go extinct locally and even globally (Bellard et al., 2012). Further, since biodiversity has already declined at rapid rates in the past few decades due to habitat degradation, increasing climate change certainly poses a great threat to further accelerating biodiversity loss (Bellard et al., 2012).

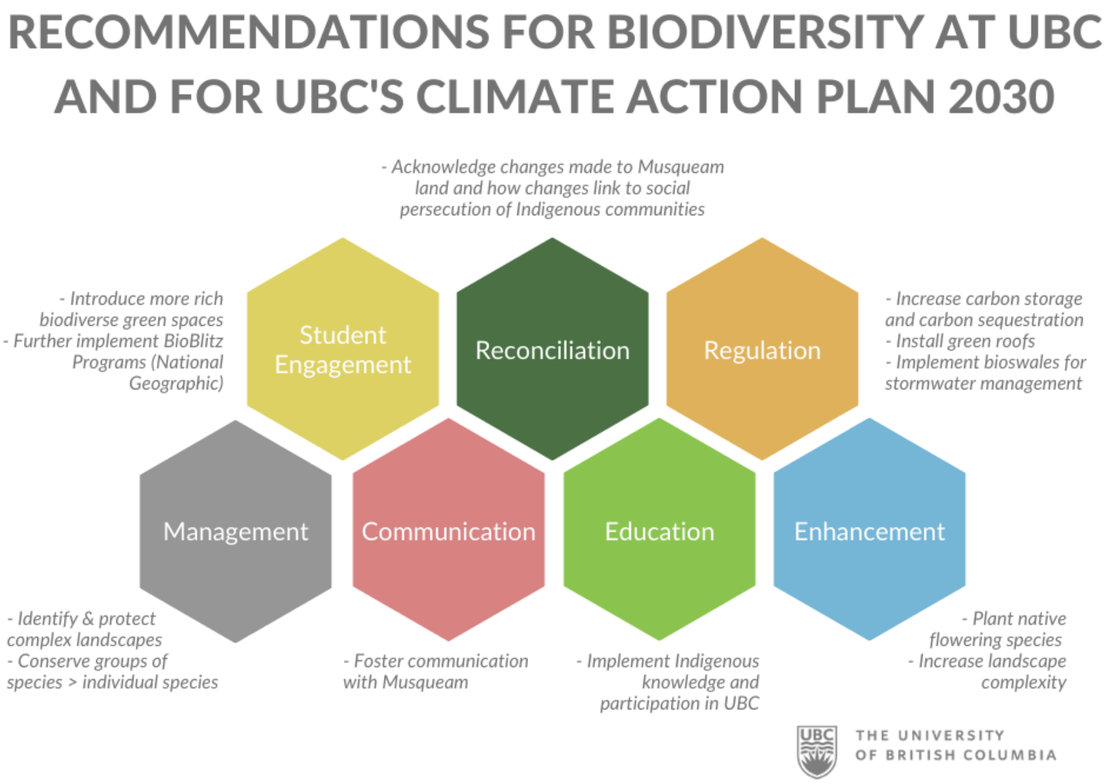
In a literature review of management strategies linked to climate change and biodiversity, Heller & Zavaleta (2009) identified the most common management strategies suggested by scholars to best address biodiversity loss in the face of climate change. Among these strategies, the three most widely suggested were (1) regional planning, (2) promoting ecosystem resilience, and (3) planning for climate change (Heller & Zavaleta, 2009). Regional planning between multiple regional actors (like UBC and the City of Vancouver) is necessary for biodiversity preservation because species, in the face of climate change, are expected to migrate more (Heller & Zavaleta, 2009). Therefore, coordination between multiple regional actors could involve setting up wildlife corridors for species to move between ecosystems (Heller & Zavaleta, 2009) or collaborating on efforts to identify which ecosystems are most vulnerable to climate change so efforts can be made to protect them. Next, promoting ecosystem resilience is a preferred method for preserving biodiversity because it enables ecosystems to adapt better to climatic change (Heller & Zavaleta, 2009). Focusing on ecosystem resilience means applying more broad management to populations, communities and ecosystems rather than trying to conserve individuals. Lastly, planning for climate change is vital to biodiversity planning. Any new management strategy for bolstering biological diversity should consider climate predictions for the next few decades and how ecosystems might respond to these changes (Heller & Zavaleta, 2009).

**Overarching Impact of Biodiversity on the Environment**

In all, research has suggested that biodiversity enhances many ecosystem functions which in turn enhance ecosystem services. The clear message from the scientific research community is that biodiversity management should be acted upon immediately (Balvanera et al., 2006) because once a species has gone extinct, that genetic material is gone forever. Additionally, immediate action on preserving biodiversity is integral to climate action. Although there remains some uncertainty concerning the degree to which biodiversity loss can affect ecosystem health there is sufficient evidence to conclude that biodiversity is integral to the functioning of ecosystems and the resilience of ecosystems under climatic change.

From an environmental standpoint, preserving biodiversity is highly valuable to UBC as every ecosystem function and ecosystem service relies on biodiversity to some capacity. Implementing biodiversity conservation into UBC's CAP 2030 will ensure the sustainability of the ecosystems at UBC and the effects will also benefit the UBC community at large. UBC campus sits on the University Endowment Lands which covers over 3,000 acres of land (UBC Building Operations), including UBC campus being surrounded by Pacific Spirit Park which acts as a valuable buffer for UBC's biodiversity being protected from the city. This presents UBC with an exciting opportunity to preserve and enhance biological diversity in Vancouver. UBC should take measures to support important ecosystem functions and services by taking action to preserve and increase biodiversity on campus. UBC should also follow the suggested management strategies presented in this section in order to protect biodiversity under the threats of global climate change.

# Recommendations




## Management of Existing Biodiversity:

- Identify and protect complex landscapes (i.e., landscapes with a large number of species).
- Conserve groups of species and habitats rather than individual species. While conserving individual species may have unintended positive benefits on biodiversity, preserving broader groups ensures biodiversity is preserved and increases ecosystem resilience to climatic change.
- Collaborate with the City of Vancouver or other regional actors that have jurisdiction over land management to plan biodiversity strategies. This can include creating wildlife corridors between ecosystems from Vancouver to UBC.
- Determine the future climatic conditions at UBC and the expected responses of UBC's ecosystems to these changing conditions. Incorporate this site-specific knowledge into all biodiversity management strategies implemented by UBC.
- Allows for employment opportunities within biodiversity via the continued monitoring and management of biodiversity.

## Methods to Enhance Biodiversity:

- Introduce and increase the abundance of native pollinators at UBC by planting native flowering species throughout campus. The diversity of pollinator species increases the amount of pollination and aids pollination under environmental change. This would aid the reproduction of plants at UBC and would aid crop production at the UBC Farm.
- Increase landscape complexity by minimizing the amount of land where one or two species are prevalent over a large area to increase the functioning of natural pest control, invasive species control and conservation of biodiversity.

## Methods to Encourage Student Engagement Within Biodiversity:

- This can be achieved by introducing biodiverse greenspaces with a focus on its 'extent' and richness throughout campus that allow for social cohesion of diverse student populations.
- Explore further implementing BioBlitz and citizen science programs on campus which provide students with opportunities to look for and observe different species around campus through using the iNaturalist Canada app. Not only will the biodiversity records be compiled into data sets for researchers and policy-makers — it also serves as an opportunity for students to engage in biodiversity and allow for social cohesion between students.

## Education of Indigenous Knowledge:

- Teach and implement Indigenous knowledge and methods of conservation into all disciplines. Indigeneity is often only considered in social science disciplines, however there is great value in Indigenous scientific knowledge towards biodiversity and conservation. Teaching Indigenous knowledge through Indigenous educators to disciplines such as science would help facilitate reconciliation with the land, its history and its original caretakers while showing Indigenous students and staff that UBC values Indigenous knowledge.

## Communication:

- Musqueam can be given the opportunity to define what biodiversity means to them, what targets they would like to set and what their vision is in terms of the development of biodiversity within UBC should look like.
    - In addition, Musqueam can also outline what plant or animal species are culturally important, to ensure conservation and thus maintaining native biodiversity.
    - These efforts would foster self-determination, and can thus allow for a space where Musqueam can control how their natural resources are being used, stepping beyond treaty obligations and actively showing UBC's efforts of reconciliation.

## Regulation:

- By implementing ecosystem-based strategies for regulation of macroclimatic, microclimatic, and hydrological processes, UBC can increase urban biodiversity, reduce its carbon emissions, and save money through reductions in energy use and costs for maintenance of stormwater management and roofing infrastructure
    - Macroclimatic regulation can be implemented by increasing the number of trees on campus to increase carbon storage and sequestration
    - Microclimatic regulation can be improved through the installation of green roofs; examples can be taken from the Beaty Biodiversity Museum and Centre for Interactive Research on Sustainability
        - We recommend more research to be done on green roofs at UBC due to differing reports of efficacy depending on techniques used, types of flora, and climate; this is likely under researched at UBC
        - Additional research should also be done to measure biodiversity in green roofs on campus as different types of green roofs have differing implications for biodiversity
    - Hydrological regulation strategies can be used to improve biodiversity and help adapt to increased rainwater induced by climate change; such strategies include implementation of green roofs, bioswales and stormwater ponds

# Reconciliation:

- UBC should acknowledge how the land has changed since settlement in regards to biodiversity and the ecosystem. Changes to the land is directly related to the displacement and social persecution of Indigenous communities. Reconciling with the physical consequences of colonization at UBC beyond the Residential Schools allows UBC to paint a better picture of its actions and can thus prompt change where the land can be reconnected with Musqueam.

# Conclusion

In conclusion, conserving and enhancing urban biodiversity at UBC is critical to maintaining social, cultural, economic, and environmental wellbeing. Failure to sufficiently act on biodiversity could have negative impacts for all four of these vital pillars. Additionally, many of the recommendations above have numerous co-benefits for climate and as such could offer great value in informing the biodiversity strategy for UBC's CAP 2030. Because of the interconnected nature of the biodiversity and climate crises, acting on the recommendations above would allow UBC to enact multidirectional change, as many of these suggestions either target the root causes of systemic issues (e.g. reconciliation) or provide tangible strategies that have interdisciplinary benefits (e.g. student engagement with biodiversity). All things considered, this report lists many recommendations and it would be difficult to tackle too many at once; therefore, it would be more appropriate to consider which recommendations UBC finds most pertinent to management of urban biodiversity and its related impacts on holistic well-being at UBC. It is also important to note that there is a critical need for further research on the relationship between biodiversity and climate change at UBC, including research on the efficacy and applicability of many of the above recommendations. The interconnections between biodiversity and climate change are undeniable, thus it is critical that UBC incorporates biodiversity into its upcoming CAP 2030 at a meaningful level to help mitigate and adapt to the climate crisis and enhance well-being for all.

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