EasyChair Preprint

№ 6251

Sustainable Design, a Tool for the Valorization of Natural Heritage Value Areas in the Southernmost Town in Austral Patagonia, Chile

Antonia Valencia, Roy Mackenzie, Miguel Troncoso and Tomás Espinosa

August 6, 2021

Sustainable design, a tool for the valorization of natural heritage value areas in the southernmost town in Austral Patagonia, Chile

Antonia Valencia[1], Roy Mackenzie[2], Miguel Troncoso [3] and Tomás Espinosa [1]

[1] *Antonia Valencia, Pontificia Universidad Católica de Chile. Coordinator Fab Lab Austral*
Santiago, Chile
arvalencia@uc.cl

[2] *Roy Mackenzie, Subantarctic Biocultural Conservation Program, Universidad de Magallanes*
Puerto Williams, Chile
roy.mackenzie@umag.cl
[3] *Miguel Troncoso, Coordinator Fab Lab Austral.*
Puerto Williams
mtroncoso280392@gmail.com

[1] *Tomás Espinosa, Pontificia Universidad Católica de Chile*
Santiago, Chile
tom@uc.cl

Abstract

The prevailing need to guide human change processes towards environmental, cultural and social sustainability, proposes the duty to act in the generation of favorable conditions for collective life.
As designers and social innovators we have an ethical and political responsibility to collaborate in the re-make of human dwelling and its relationship with the environment. Puerto Williams is located in Navarino island, south of Tierra del Fuego, at the end of the supply chain. This area is known worldwide for its diversity of Bryophytes (mosses, liverworts and hornworts) and Lichens, fungi and other small plants, some of them unique in the world.

The current environmental crisis is a call to move from methods centered on individuals to one oriented on the ecosystem, emphasizing collaboration and cooperation. The new paradigm of ecological transition and sustainability involves using the intrinsic local characteristics of individuals, elements, geographic conditions and territory. We have the challenge of valuing and protecting the ecosystems that surround us. In this work, we disclose a multidisciplinary approach to conceal an intervention in public spaces combining local capabilities on sustainable design and biodiversity conservation. The intervention is meant to foster the knowledge on native bryophytes and lichens, closing the gap between nature and society in a remote island in Subantarctic Patagonia. This project consists of the development of experimental prototypes to establish local microhabitats for environmental education and scientific research, with emphasis in conservation of the Magellanic biodiversity in Puerto Williams, by bioprospecting different biomaterials and moss plants growth capabilities. Using digital fabrication techniques there is a seek to generate and distribute urban resilience from the southernmost digital fabrication laboratory - FabLab Austral.

Keywords Puerto Williams, Moss gardening, Biomaterials, Sustainable design

Introduction

The intersection between design spaces, digital technology and ecology biology offers us new opportunities for interaction and dissemination of scientific, digital and environmental knowledge; Through research and artistic intervention located in Puerto Williams, it is expected that the tests carried out will be a bridge for the valuation and recovery of natural spaces in urban environments. .

This article exposes the union between design, technology and biology in order to seek a compatibility of native subantarctic mosses with biomaterials for the construction of permanent artistic interventions in an urban wetland in the city of Puerto Williams. An analysis of the species found in the subantarctic territory is developed, then the experimental methodology using digital fabrication that serves as a connecting bridge

Context

Puerto Williams, located in latitude 54 ° 55 ”South, is the southernmost city in the world (INE, 2019), capital of the Cabo de Hornos commune and of the Chilean Antarctic province. With a population of 2,063 inhabitants (Chilean Census, 2017), 517 are under 15 years of age. In 2005, the Cape Horn area was declared a World Biosphere Reserve within the UNESCO Man and the Biosphere program, which is characterized by hosting subantarctic temperate forests that have been identified as one of the most pristine ecoregions in the world, for the uniqueness of biota in the extreme south of America, being at the end of the supply chain worldwide with high levels of dependence on its supply.

Puerto Williams, due to its political-administrative condition, has a Provincial Government and Municipality; it also has three (3) kindergartens, a basic and secondary education establishment, a fire company, a police station, a hospital center, religious centers and a Court of Justice, among others (INE, 2019). The main sources of employment developed are professional activities, public administration and national defense; at the same time, the main productive activities are artisanal fishing for spider crab, construction and tourism (Data INE, 2018).

This territory has been inhabited for more than 7,000 years BP, for thousands of years its human inhabitants were the Yagán canoe people. From the seventeenth century, with the expeditions of F. Drake, the encounters and interactions between both worlds began. In the 19th century, Anglican settlements began in the territory, profoundly altering the way of life of its inhabitants and since 1950 the State of Chile installed a Naval District.

The cultural, natural, political, social and geographical complexity make this a place with particularities highlighted by people and institutions from all over the world, in this context FabLab Austral arises, with the mission of “Being a center of creativity and local production and autonomous, at the end of the supply chain, with a focus on communities, ecosystems, sciences, arts, and digital technologies ”, which is why actions to conserve biodiversity and improve the quality of life become essential in our work. Through the use of digital technologies we have the opportunity to strengthen the appreciation of the various forms of life, developing greater ownership and connection with the territory.

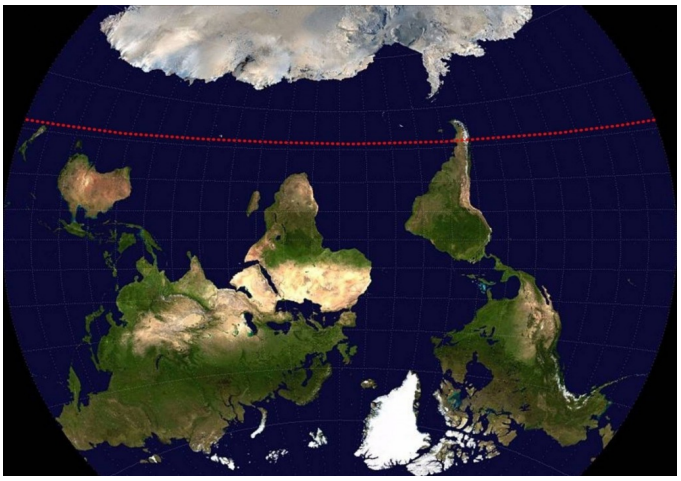

Figure 1: World map showing the subantarctic region as the tip of the southern hemisphere. ”Cape horn: A biogeographic melting pot at the southern end of the Americas”. Rozzi, 2018

The Bryophytes from Cape Horn Biosphere Reserve

Bryophytes are an ancient lineage of land plants, known as lower plants or non-vascular plants, including three divisions: liverworts, mosses and hornworts (Rensing et al. 2008). There are over 890 mosses, 553 liverworts and 14 hornworts in Chile (Hässel de Menendez, 2009; Müller, 2009). In the Sub-Antarctic region (48° - 56° S latitude), the bryophyte flora is highly diverse and comprises a significant fraction of endemic species. This area constitutes a biodiversity hotspot of bryophytes recognized since 2005 by UNESCO, called the Cape Horn Biosphere Reserve (CHBR. Hargrove et al., 2008). This protected area of 5 million terrestrial and marine hectares has been identified as one of the 24 most pristine regions of the planet (Mittermeier, 2003). Inside the boundaries of CHBR there are three National Parks: Alberto de Agostini NP, Yendegaia NP and Cabo de Hornos NP. The Omora Ethnobotanical Park is located near the only city inside the area, and is dedicated to conservation, research and environmental education. Omora park is part of an international research network focused on the biocultural ethics and long-term monitoring of biodiversity (Rozzi et al. 2014). The current ecological understanding on sub-antarctic biodiversity obtained after almost 20 years of *in situ* research by the Sub Antarctic Biocultural Conservation Program in Puerto Williams, has encouraged local ecotourism on unperceived biodiversity. This research program is a source of cutting-edge content on climate change ecology and biodiversity conservation, and requires further communication efforts with key local and resourceful collaborators.

Gardening bryophytes

Most bryophyte species are shade-loving plants and have very specific growing conditions, difficult to recreate in greenhouse or lab conditions. But there are many native moss species that are also cosmopolitan and can be found even in polluted urban environments in large cities. Species of acrocarpous mosses such as *Tortula muralis*, *Ceratodon purpureus* and *Funaria hygrometrica* are specialized colonizers in disturbed places like roadsides, cement and burned areas. These species have strong rhizoids to attach to the substrate, can be grown anywhere on acid ground or peat, and have adapted to direct sunlight (Fletcher, 1991). *Tortula muralis* grows well in brickwork, lime, chalk and clay substrates. We propose to grow these species according to the recommendations in *Moss Grower’s Handbook* (Fletcher, 1991), to study the biomaterial design and composition that better suits moss growth in containers and outdoor conditions.

Sustainable design in Austral Patagonia

On the other hand, Fab Lab Austral provides tools for sustainable design, allowing a conscious development by reducing negative impacts on the surroundings and making available to use top digital fabrication techniques. Innovative tools in environmental education, including digital fabrication and prototyping, is key in the education for sustainability, encouraging creative ideas and solutions for local problems (Soomro et al. 2021).

In this project, we attempt to combine the knowledge on the ecology of native bryophytes, their suitable substrates and growth conditions, with design thinking, digital fabrication and prototyping, resulting in a perfect arena to develop sustainable ideas in a multi- and trans-disciplinary approach.

Flora in Public spaces

Public spaces in Chile, where collective life is to be fostered, are often badly designed not only in function, but also because of the absence of local features in the design and building materials used to create such biocultural environments. The use of fast-growing plants in urban parks and public spaces, such as lawn grass and exotic trees, are water-consuming and dependent on permanent gardening cares. Moreover, the replacement of native species for exotic and world popular species in most parks elsewhere, deepens the cultural homogenization process, followed by the loss of local biocultural knowledge, and the socio-ecological problems that arise because of the disconnection of local community with its surrounding biodiversity.

The intervened public spaces, as described in this paper, will support local biodiversity conservation efforts by providing a close-by and accessible public area for environmental education and biocultural ethics, based on the aesthetic singularity of living forms under the extreme austral conditions. By means of social innovation and science communication projects, we expect to successfully transfer biological concepts on bryophytes and lichens to tourists, students and local community in an urban park context, and become a powerful tool to communicate more complex issues towards a socio-ecological equilibrium.

Distributed Design and Digital Fabrication

The centralization that characterizes Chile could be identified with the theory of networks: centralized, decentralized and distributed. In a centralized network, all nodes are peripheral, except the central one. These nodes can only communicate through the central node and its channels. If the central node suffers a fall, the rest of the nodes stop having flow. This happens in Chile, with Santiago, which acts as the central node of the country, concentrating political, economic, health, education, infrastructure power, among others (Baer, Toloza and Torralbo, 2013). For the purposes of this project, work will be done with an isolated territory specifically of an extreme zone under the order of a centralized network.

Puerto Williams has become a potential digital community as a global benchmark. The establishment of the FabLab Austral thanks to the initiative of the Center for Bits and Atoms of MIT in conjunction with the Pontifical Catholic University of Chile among other actors, opened the possibility of creating a community around doing in a sustainable, collaborative, autonomous and decentralized way. Promoting resilience through the processes of design, manufacture and implementation of high-impact solutions and interventions (FabLab Austral, 2019). The installation of a digital laboratory raises the possibility to respond to the needs of the community and to develop an intersection between the need of the community and the strength of the digital fabrication, reducing the gap between the extreme territory thus distributing the fabrication process. The connection of the Fab Lab with the local resources and the community of Puerto Williams pushes the model of digital manufacturing laboratories to the limit in search of being able to reduce as much as possible the importation of physical materials by means of ships and increase local production and research with an impact on the community directly. The development of this model seeks to be replicable in other territories with a more sustainable look for urban development.

Experimental methodology

Methodological proposal: Search

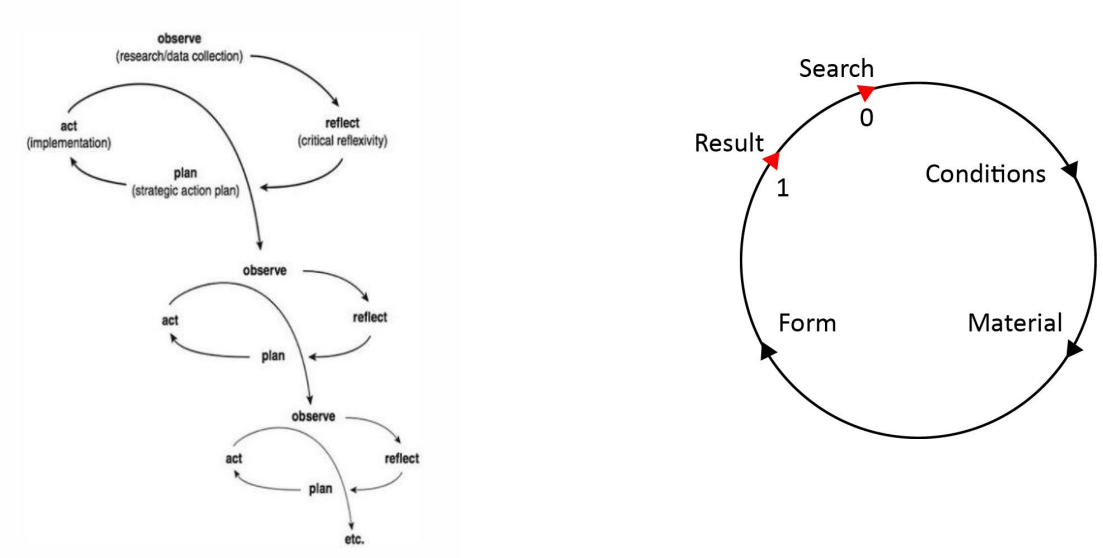

Figure 2: Cyclical diagram of the design methodology and research

From the species to the ecosystem; from the ecosystem to society, to revalue our species. Identity to empower yourself.

This project seeks to encourage that the processes of creation and construction of the dwelling are linked to the locality in question, and to everything that it entails (people, society and culture, species, geo-climatic conditions, materiality and temporality).

The methodological proposal has to do with observation and cyclical iteration as a design process to establish a search loop that improves itself. It is made up of four segments, each dependent on the previous one: conditions search, material search, form and invoice search and result.

Conditions

The search for conditions has to do with the investigative process to interpret it in a solution. The objective being the formation of a habitat for species that can survive in the city. Collection of key parameters to minimize the impact on the moss, and the search for material qualities that allow optimal acclimatization of the species in an urban context.

It should be noted that each particular geography has an ideal climatic condition, and therefore the conditions vary according to the species to be treated and the climatic-geographic location in which they are found.

Taking into account the subsistence requirements and potential proliferation of the moss (cool, humid and shady spaces), the decision was made to work with local soil. As it is a heat dissipative, water and air purifier, acoustic and electromagnetic insulating material, it precisely matches the requirements of a mother structure for native species in urban environments.

The option of working with a local clay soil brings advantages and reinforcements for the project: being an element from the same area, together with its construction process, the ecological impact of the production is minimal.

Plant Material

The acrocarpous moss species *Tortula muralis*, *Ceratodon purpureus* and *Funaria hygrometrica* will be collected from urban areas in Puerto Williams. Spores will be obtained from sporophytes in the

fruiting season (spring and autumn) and diluted in water. The spores will be then sprayed on biomaterials several times until obtaining moss growth. Different frequency and nutritive mediums will be studied. In parallel, gametophytes of mosses will be carefully chopped and cultured into different biomaterials. Moss growth will be determined in lab conditions under artificial light, followed by an outdoor prototype exposed to direct sunlight.

Material

Material experimentation speaks of the iteration process for construction with raw earth. The objective of this experimentation is to find methods to prototype nurse structures for moss species; and to manufacture and disseminate through local digital fabrication. The first part of the creative cycle corresponds to the first tests to understand the properties of the material. Based on research on adobe, ancestral constructions with earth, and clay work.

The first step consists in the collection of the material, the earth with which the structures and prototypes of this project were generated were selected from the steep and clayey northern slopes of the capital's foothills. After this, the collected soil goes through a sieving process, which consists of separating the material by granulometry. The smaller the grain size, the greater the solidity and rigidity of the raw earth block.
The first structural approximations were carried out in order to observe the resistance and capacity of the sieved grain, for this, different mixtures of sieved earth were extruded in a similar way. (Fig.3 left) Having defined the proportions and formulas, the extrusion of the material was taken to a digital process, this in order to analyze and submit the material to tests that approximate the invoice method that it will have (Fig.3, middle picture).

The first prototyping, with encouraging results, reinforces the structural capacity of the raw earth, where with a material mixture from water and sieved earth a rigid structure composed of cavities generated through a linear extrusion by digital manufacturing is achieved (Fig3. right).

Figure 3: Analogue Extrusion and printing first results

Form

After defining the materiality (given the conditions), its proportions and formulas, the constructive construction testing process, subjected to variations in size and spatial conformation to integrate into the environment and act as a mother structure (Fig. 4 left, picture). The search is intended so that the tool made from digital manufacturing generates varieties of cavities and semi-programmed vaults in the object in question (Fig. 4, right picture).
The investigation of the form focused on the search for the invoice of an organic-parametric figure (and its respective redeemable attributes of the form-materiality) for the future implantation of Magellanic moss in it (Fig. 4, middle picture)

The programmed randomness of the form generated in the possibility of a nurse structure is rescued.

Figure 4: Form varieties from the modeling, render of one of the infinite results and printing test of the complex form

Invoice and result

We worked while maintaining the idea of a nurse and sculptural character of the confection, hence the shape of the block of raw earth, which is presented as a solid block with interior vaults, where the repetition and composition of this depending on the terrain in question, generates long and hidden cavities or narrow and varied. The purpose of the formation of the set of modules is that the various agents that participate in the project can make the type of construction that seems most attractive and / or functional to install in the respective place (Fig. 5).

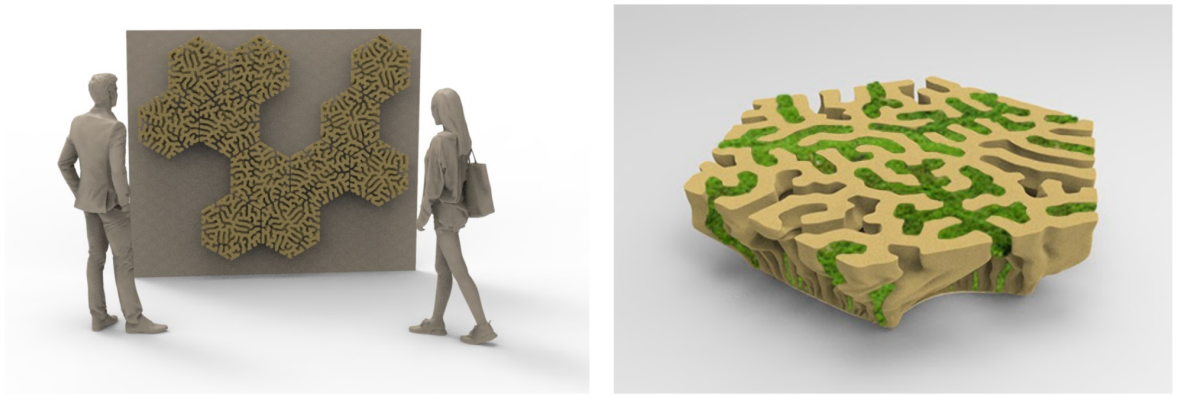

Figure 5: Digital approximation of the installation and render of the printed module with moss in it

This project seeks to use the tools and design processes applied, to move to more sustainable ways of living and making homes, and aware of the ecosystem environment. Thus, with this application, make visible forms of coexistence and collaboration between species in order to establish symbiotic relationships at the urban level. In this way, not only reconnecting fragmented environments and geographies in practice, but also reconnecting human, cultural and social processes, to the environment and natural climatic context in question.

Natural systems have been in specific geography for millions of years, evolving together and developing techniques for collaboration and subsistence. "Human ingenuity can make many inventions, but it will never achieve more beautiful, simpler and more appropriate inventions than those made by nature, in whose achievements nothing is incomplete and nothing is superfluous", Leonardo Da Vinci's thoughts, where he leaves for the reflection on the importance of observation

and work in conjunction with nature, with humans being part of it. The resilience that natural forms show us invites us to stop manipulating the factors of the biosphere in a selfish way, and let local natural forms intervene in our systems in order to strengthen them. From the design disciplines such as design and architecture, among others, we must take into account this capacity of nature in the modifications, creations and constructions that we propose to a specific environment. The landscape is not imposed, the geography and its climate define it in every sense, from materiality to form and function.

Conclusion and Digital Laboratory

Fablab Austral's mission is to create a community around making and prototyping sustainably and collaboratively, based on local resources and knowledge. Since 2019 it has strived to build a participative and interdisciplinary approach, and a conscious fabrication focused in a three phase implementation: Digital literacy, products and services and finally research. This will gradually involve different actors in the community, impacting and developing different types of projects, and favouring biocultural integration. It also seeks to activate technological urbanization processes through the digital transfer of content and information for the development of prototypes, biomaterials, products, and systems (Vivanco & Yuan, 2020).

Fab Lab Austral has gradually transformed into a space of social interaction for the local community. In this project, an interdisciplinary team was capable of questioning and prototyping the compatibility of native subantarctic mosses with local biomaterials for the construction of permanent artistic interventions in an urban wetland park in the city of Puerto Williams. According to what it was funded for, Fab Lab Austral has become an open space for the creation, design, and production of prototypes, projects or entrepreneurship products, something unprecedented and unique in the southernmost city in the world (Vivanco & Yuan, 2020).

Throughout the investigation, a triangulation of biology, technology and design (Fig. 6) is generated where the central node or meeting point is the Fab Lab. The new paradigm of ecological transition and sustainability involves using the intrinsic local characteristics of individuals, elements, geographic conditions and territory. We have the challenge of valuing and protecting the ecosystems that surround us.

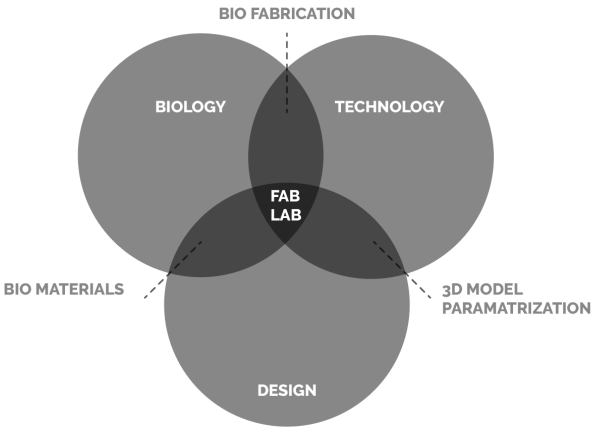

Figure 6: Three noded intersection: Biology, Technology and Design where the center node is the FabLab Austral

Further research

As FabLab Austral we face the opportunity to contribute to the sustainable development of Puerto Williams, being part of the process of valorisation and recovery of urban natural spaces essential for current living conditions. In January 2020, the State of Chile promulgated the Law of Urban Wetlands, providing territorial planning instruments that integrate wetlands as "spaces for the protection of

natural value", for the implementation of this law it is required to have an Urban Wetlands Committee and Municipal declarations of wetlands.

Around the conjugation of objectives and with a view to strengthening community and institutional networks, FabLab is presented as a space for meeting, creativity and today with the opportunity to implement prototypes of sustainable design in urban wetlands in pursuit of valuation and restoration of these, being not only an intervention for Puerto Williams, but also an experience for the rest of the world.

Acknowledgement

Fabhaus digital laboratory in Pontificia Universidad Católica de Chile.

References

Fletcher, M. (1991). Moss Grower's Handbook. Seventy Press. Berkshire, UK. 83 pp.

Hargrove, E. C., Arroyo, M. T. K., Raven, P. H., & Mooney, H. (2008). Omora Ethnobotanical Park and the UNESCO Cape Horn Biosphere Reserve. Ecology and Society, 13(2).

Hassel de Menéndez, G., and M. Rubies. (2009). Catalogue of the Marchantiophyta and Anthocerotophyta from Chile, Argentina and Uruguay. Nova Hedwigia 134: 1-672.

Mittermeier, R. A., Mittermeier, C. G., Brooks, T. M., Pilgrim, J. D., Konstant, W. R., Da Fonseca, G. A., & Kormos, C. (2003). Wilderness and biodiversity conservation. Proceedings of the National Academy of Sciences, 100(18), 10309-10313.

Müller, F. (2009). An updated checklist of the mosses of Chile. Archive for Bryology 58: 1-124.

Rensing, S. A., Lang, D., Zimmer, A. D., Terry, A., Salamov, A., Shapiro, H., ... & Boore, J. L. (2008). The Physcomitrella genome reveals evolutionary insights into the conquest of land by plants. Science, 319(5859), 64-69.

Rozzi, R., Armesto, J. J., Goffinet, B., Buck, W., Massardo, F., Silander, J., & Arroyo, M. T. K, Russell, S., Anderson, CB, Cavieres, LA & Callicott, JB (2008). Changing lenses to assess biodiversity: patterns of species richness in sub-Antarctic plants and implications for global conservation. Frontiers in Ecology and the Environment, 6, 131-137.

Rozzi, Ricardo. (2018). Cabo de hornos: Un crisol biogeográfico en la cumbre austral de américa. Magallania (Punta Arenas), 46(1), 79-101. Soomro, S.A., Casakin, H., Georgiev, G.V.(2021) Sustainable Design and Prototyping Using Digital Fabrication Tools for Education. Sustainability , 13, 1196.

Rozzi, R., Massardo, F., Contador, T., Crego, R. D., & Méndez, M. (2014). Field environmental philosophy : ecology and ethics in LTSER-Chile and ILTER networks. 35(3), 439–447.

Vivanco, T., & Yuan, P. (2020). Digital urbanization of remote rural cities through design as a catalyst for sustainable development: The case study of Puerto Williams, Chile. IOP Conference Series: Earth and Environmental Science, 588, 042028.