

UNIVERSITY OF OREGON

LANDSCAPE ARCHITECTURE

PHOEBE CHUANG

BEYOND THE GLOW

EMBRACING DARKNESS

& RECONCILING NOCTURNALITY

IN MORE-THAN-HUMAN CITIES



ACKNOWLEDGE- MENTS

This project has been quite a journey, and I definitely enlisted an army of people's time and effort to help me complete it.

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Finally, heartfelt thank you and love to my entire cohort of 2024, who has been nothing short of supportive and awesome.

PRELUDE

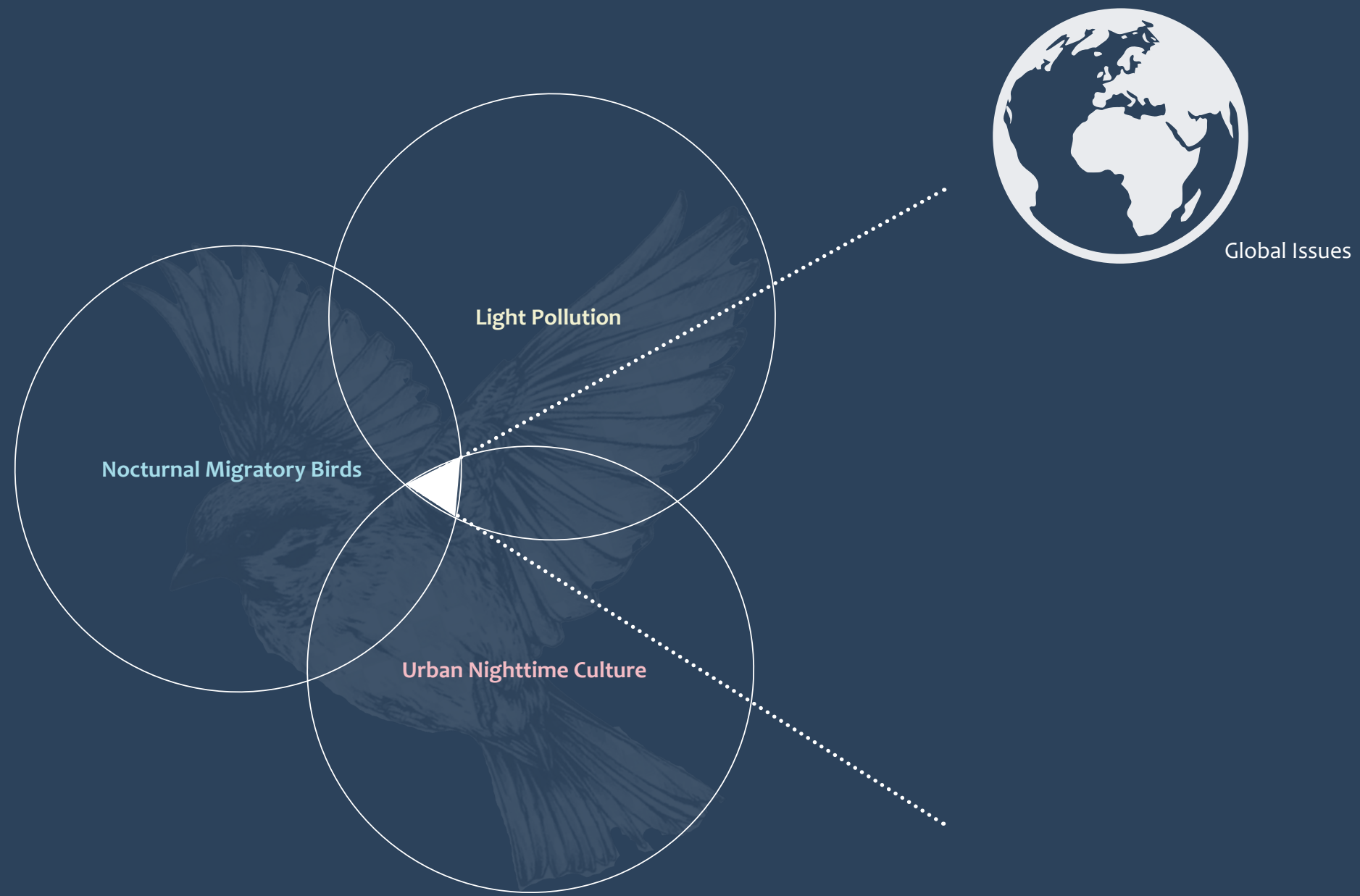
AS YOU CLOSE YOUR EYES AND BRACE FOR THE CRASH, YOU ARE MET WITH THE SOUND OF BLOWING WIND AND YOUR OWN HEARTBEATS. BUT NO IMPACT. OPENING YOUR EYES AGAIN, THE MOON AND STARS ARE HANGING RIGHT ABOVE, SO CLOSE THAT YOU CAN ALMOST TOUCH IT. THE LAND UNDERNEATH STRETCHES ALL THE WAY TO THE HORIZON, VEILED IN A GRADIENT OF DARKNESS WITH OCCASIONAL GLISTENING FROM WATERBODIES. THE SCENERY UNFOLDED IN FRONT OF YOU PROVOKED A SENSE OF FAMILIARITY, EVEN THOUGH YOU HAVE NEVER BEEN TO THIS PART OF THE WORLD BEFORE. YOU HAVE ARRIVED AT A PLACE YOU CAN CALL HOME.

Image Source: Katherine Harrison

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THE PROBLEMS



What are the problems associated with light pollution, nocturnal migratory birds, and urban nighttime culture, and how wide-spread are they?

LIGHT POLLUTION: THE EXTENT

0.1 THE FIRST WORLD ATLAS OF THE ARTIFICIAL NIGHT SKY BRIGHTNESS

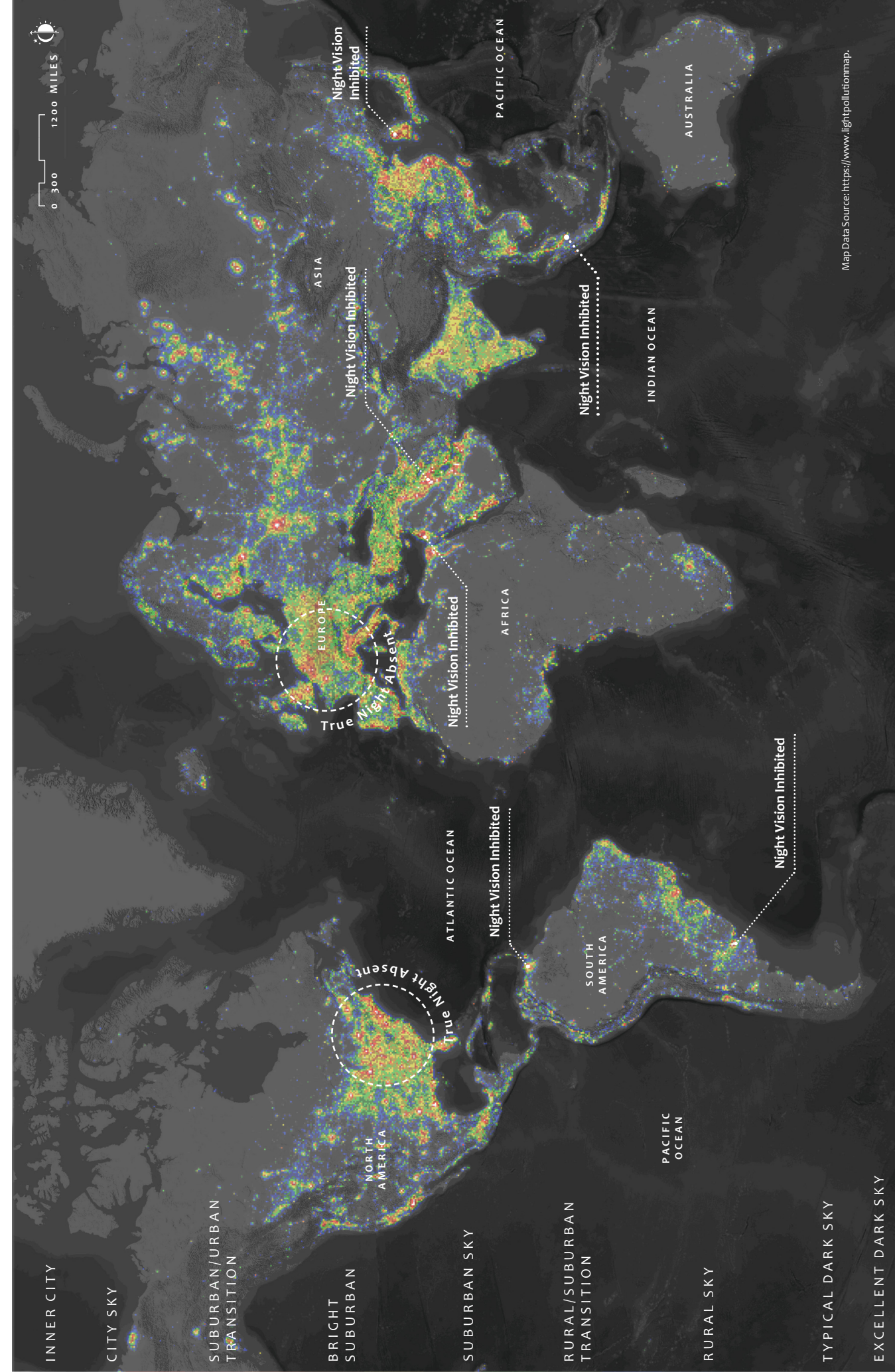
Few people would disagree that urban areas and cities are contributing to light pollution that is impacting our environment. However, the extent and magnitude of both light pollution and its impact on the natural world is often unclear to most.

In 2001, a team of researchers sought to quantify and visualize the impact of light pollution on a global scale. Using satellite data taken between 1996 to 1997, as well as population density data from the United States Department of Energy, the researchers were able to generate the world's first *Atlas of Artificial Night Sky Brightness*. Along with a map showing locations of night lights on earth, a list of statistics and comparisons was made available to provide insights into the issues of light pollution both globally and at the human-scale. For instance, the *Atlas* showed not only the developed countries are the source of light pollution, so were the developing ones. Furthermore, roughly two-thirds of the world population (including over 99% of the U.S. and EU population) lives under polluted night skies. What is more is that for more than one-fourth of the people in the world (including 80% of the U.S. and two-thirds of the EU population) experienced night sky brightness greater than that of the full moon. According to researchers Cinzano and the team, "Night never really comes for them."

1. Cinzano, P., Falchi, F., & Elvidge, C. D. (2001). The first world atlas of the Artificial Night Sky Brightness. *Monthly Notices of the Royal Astronomical Society*, 328(3), 689-707. <https://doi.org/10.1046/j.1365-8711.2001.04882.x>

GLOBAL LIGHT POLLUTION IN 2022

Most of the pollution in the world are located in Europe, Middle East, India and Eastern Asia, as well as the Eastern half of North America.



LIGHT POLLUTION: THE PROGRESSION

0.2 ACCELERATING BRIGHTNESS AT NIGHT

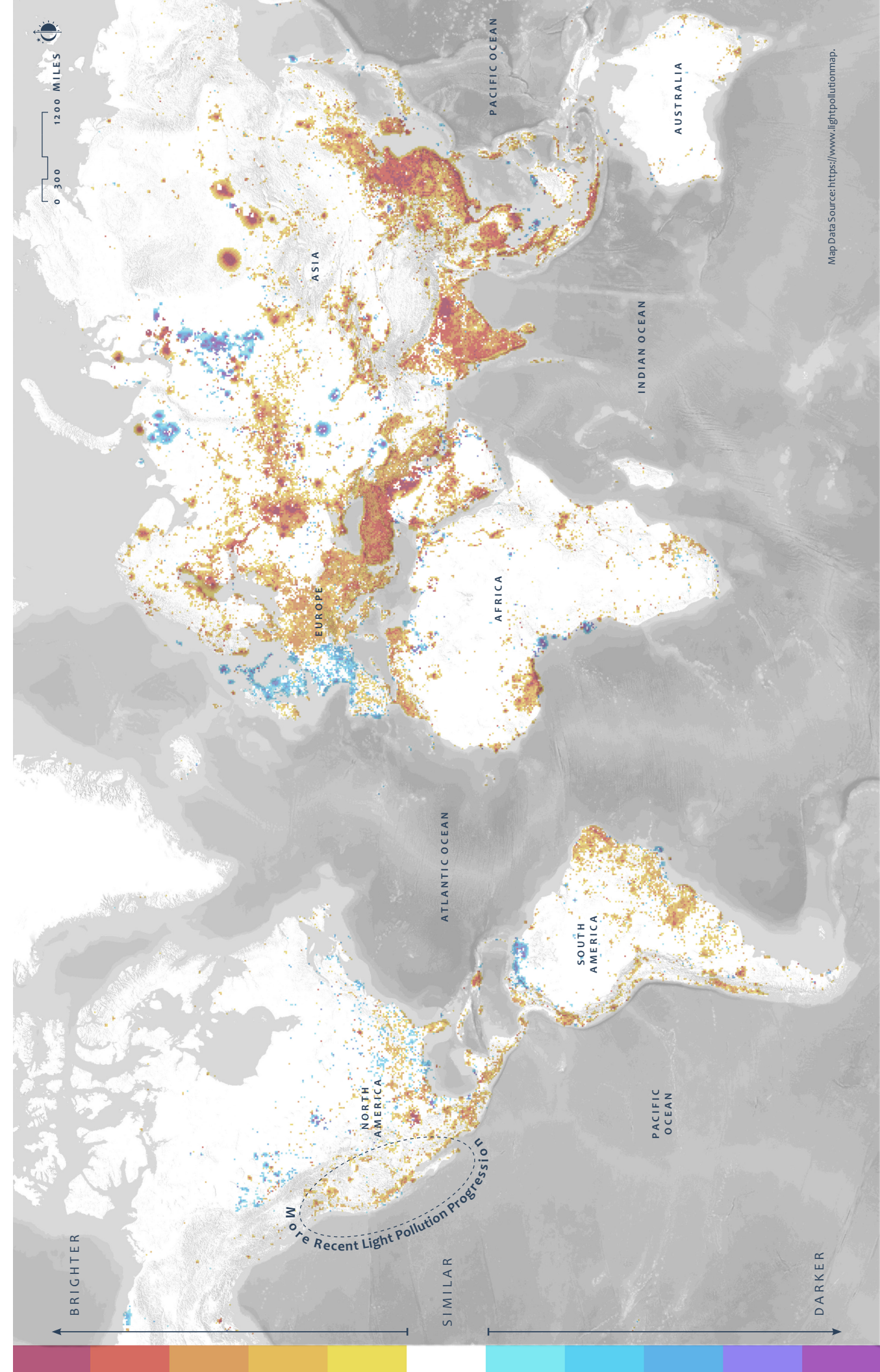
Light pollution has not only intensified but also accelerated quickly in its short history since the inception of electric lights. To put it into perspective, every generation of human beings until about 200 years ago experienced a sky filled with stars every night.² A study conducted 15 years after the initial *World Atlas of Artificial Night Sky Brightness* showed that 83% of the global population now live under light-polluted night skies (a 17% increase in a span of 20 years). Moreover, places like Singapore, Kuwait, Qatar, United Arab Emirates, Saudi Arabia, South Korea, Israel, Argentina, Libya, Trinidad and Tobago all have more than half of their residents living under night skies so bright that their eyes cannot fully adjust to the dark and night vision.³

Not only is the acceleration of light pollution a concern, so are the impacts of sky glow: artificial light scattered in the atmosphere. The visibility of the light domes from Las Vegas and Los Angeles in Death Valley National Park in California serves as an example of the far-reaching impact of sky glow from cities on otherwise pristine natural environments. In addition, when combined with the overcast skies, the sky glow can be increased sevenfold, which has further implications on how local weather may amplify the intensity of light pollution beyond the current observed baseline.⁴

2. Trembley, B. (2021, April 7). *History of light pollution*. Vatican Observatory. <https://www.vaticanobservatory.org/sacred-space-astronomy/history-of-light-pollution/>
3. Falchi, F., Cinzano, P., Duriscoe, D., Kyba, C. C., Elvidge, C. D., Baugh, K., Portnov, B. A., Rybnikova, N. A., & Furgoni, R. (2016). The New World Atlas of Artificial Night Sky Brightness. *Science Advances*, 2(6) <https://doi.org/10.1126/sciadv.1600377>
4. See footnote 3.

WORLDWIDE LIGHT POLLUTION PROGRESSION FROM 2013 TO 2022

Despite the greater light pollution concentration on the Eastern and Southeastern North America, most of the pollution increase in the recent decade are occurring along the west side of the continent.



URBAN NIGHTTIME CULTURE: THE SUBLIMITY OF NIGHT

(background) Taking Theiry Cohen's work "Darken Cities" as inspirations, the night sky of rural places was merged with the city of Los Angeles, showing the true night sky above it. The comparison between the two scenarios illustrates the geographical dualism of nighttime sublimity.

THE TECHNICAL V.S. NOCTURNAL SUBLIME AFTER DARK

From fire to candles and oil lamps, to light bulbs and then electric lights, ALAN has played a crucial role in people's nightlife for as long as cities have existed. Much like the sewer infrastructure in late 1800s Paris⁵ that was laden with metaphors and cultural meanings of the society at the time, so is the artificial lighting that drove away the darkness at night. The desire of Parisians to control the flow of water in their city had established 'a new set of relationships between the body, technology, and urban architecture' for them⁶, which is not so different from people's instinct to banish darkness with urban lighting infrastructure and creating new relationship between us and the environment today.

Similar to how the built environment has created a geographical dualism that separates people from nature, the excess ALAN in cities has also blocked our connection to natural darkness, shifted our nighttime culture, and deprived us of the easily accessible, therapeutic awe-inspiring moments that are often an ingredient for a better quality of life. Therefore, the act of restoring natural darkness in cities is not only a form of urban restoration, but also a chance to create a "city aesthetic that is in sync with the natural rhythm"⁷, allowing us to experience the natural darkness and its sublimity.

5. Gandy, M. (1999). The Paris sewers and the rationalization of urban space. *Transactions of the Institute of British Geographers*, 24(1), 23–44. <https://doi.org/10.1111/j.0020-2754.1999.00023.x>
6. See footnote 5.
7. Stone, T. (2018). Re-envisioning the Nocturnal Sublime: On the ethics and aesthetics of nighttime lighting. *Topoi*, 40(2), 481–491. <https://doi.org/10.1007/s11245-018-9562-4>

URBAN NIGHTTIME CULTURE: DARKNESS TOPOLOGY

CLOSER LIGHT SOURCE



FURTHER LIGHT SOURCE



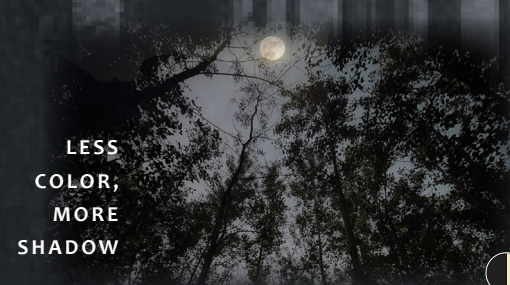
FAR & INDIRECT LIGHT SOURCE



MORE COLOR FOCUSED



LESS COLOR; MORE SHADOW



LIGHT/DARK CONTRAST



CLOSE LIGHT SOURCE + COLOR AS MAIN STIMULUS



FURTHER LIGHT SOURCE + MORE SHADOW AS MAIN STIMULUS



FAR LIGHT SOURCE + LIGHT/DARK CONTRAST AS MAIN STIMULUS



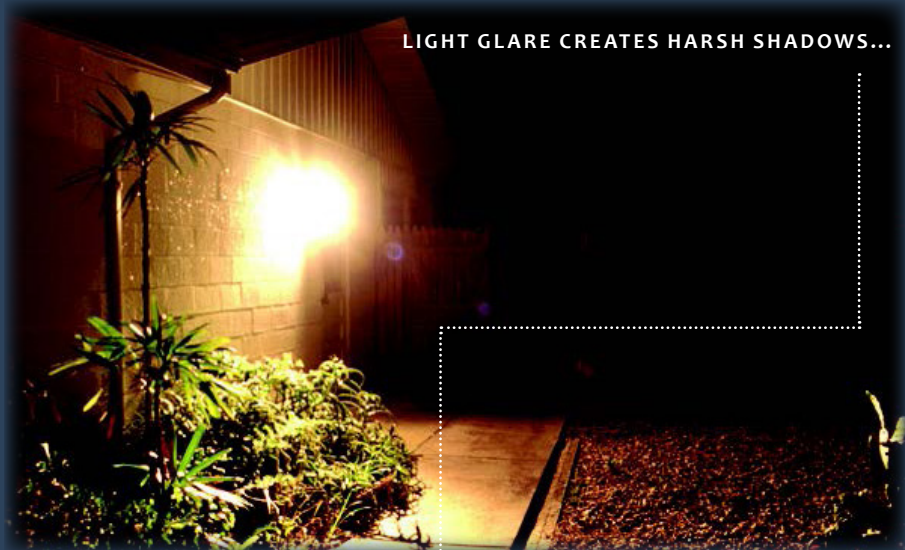
AT THE EDGE OF LIGHT LIES THE DARKNESS

What comes to mind when we think about darkness? For most people, the image that comes up is likely a dark cloud of nothingness or worse. But is that really accurate? We can clearly see with our own eyes that at the edge of light exists the shadows, but what truly lies beyond the glow?

The most immediate factor that contributes to our experiences after dark is the light. The location and type of the light source that illuminates the nights can go from the streetlight right next to us to the moonlight reflecting off a lake in the distance. As the light source becomes further away and the surrounding gets darker (typically at the ambient light level of moonlight and starlight⁸), our eyes undergo physiological changes that allow us to switch from photopic to scotopic vision⁹, or color to grayscale, and the light versus dark contrast becomes the visual focus. Lastly, the combination of light source intensity and vision focus allows us to enjoy various activities at night. From a night walk with friends in cities, to grouped night hikes and star parties with like-minded people, each of them requires a specific type of darkness, as well as an adventurous mindset to experience new perspectives.

8. Stockman A. & Sharpe L.T. (2006). Into the twilight zone: the complexities of mesopic vision and luminous efficiency. *Ophthalmic & Physiological Optics*, 26, 225-39.
9. See footnote 8.

URBAN NIGHTTIME CULTURE: SAFETY AFTER DARK



LIGHT GLARE CREATES HARSH SHADOWS...



...THAT INCREASE INVISIBILITY AT NIGHT



AN EMPTY, DARK MOVIE THEATRE



AN EMPTY CITY STREET AT NIGHT



A FULL, DARK MOVIE THEATRE



AN ACTIVE CITY STREET AT NIGHT

THE RELATIONSHIP BETWEEN DARKNESS & SAFETY

Outdoor lighting is often strongly associated with the perception of safety, as darkness has long been the symbol of danger and fear since the beginning of human history. While ALAN has played a crucial role in the well-being and urban night experience of people for as long as cities have existed, in many modern cases, more light does not necessarily mean more safety; instead, better control of ALAN in both intensity and direction has a greater effect than simply the brightness of the light itself¹⁰. In addition, the increased nighttime brightness has reduced our night vision sensitivity, ironically making it harder for us to see in the dark to the best of our natural abilities.

Although the presence of light does reduce the fear of crime at nighttime to some degree, combinations of factors such as the presence of adult human figures and the environment settings (built vs. natural) also have an influence on the human fear response of the nighttime landscape¹¹. In contrast with the common perception that a space shrouded in darkness is unsafe, there are a multitude of activities that bring positive experiences to people that can only be done in the dark. Whether it is a night walk in the city street, a movie in the dark theatre, or a star party out in the park after dark, the space in which host these activities does not always share the same degrees of light and darkness. Rather, it is the perception of the common experience that people share with each other within the same space that defines the sense of safety and content for the visitors. While outdoor lighting can make us feel safe in some cases, it does come with a price tag, and we are not the only ones that pay for it.

10. Staff. (2014, September 8). Outdoor lighting at night doesn't do what you think it does to reduce crime and increase safety. DarkSky International. <https://darksky.org/resources/what-is-light-pollution/effects/safety/>
 11. Kim, M., Cheon, S., & Kang, Y. (2019). Use of electroencephalography (EEG) for the analysis of emotional perception and fear to nightscapes. *Sustainability*, 11(1), 233. <https://doi.org/10.20944/preprints201809.0461.v1>

Image Source (Top & Bottom Left): George Fleenor, <https://www.chromatherapylight.com/dark-sky-light-pollution>.

NOCTURNAL MIGRATORY BIRDS: URBAN ECOLOGY AFTER DARK

0.1 THE NIGHTSHIFTS OF WILDLIFE IN CITIES

Contrary to the popular belief that cities and urban satellite areas are the source of destruction as well as the opposite of natural ecology, they are increasingly recognized as a part of a young, novel ecosystem with its own resources and a web of organisms that utilize them. However, the homogeneity of most modern urban environments and the lack of baseline research of these places tend to spark debates on the benefits of these urban ecosystems for urban wildlife and global biodiversity long-term.

To further complicate the issue, a 2018 research¹² discovered that across the globe, animals had increased their nocturnality by an average factor of 1.36 due to human activities and disturbances. This means that if an animal was previously 50/50 in day/night activity level, they would have become 32% active during the day, and 68% active at night as the animals adjust to the urban lifestyle. The result combined with the sharp increase in animal sightings in cities across the globe during Covid-19 shows not only the impact of human activities on animals, but also the growth of urban wildlife population that has continued in the past century in European, East Asian, and North American cities.¹³

As more and more urban animals opt for the nocturnal lifestyle, the impact of artificial light at night grows. It is documented that ALAN¹⁴ in cities changes the behavior of animals in ways that are both predictable and unexpected. For animals with behaviors that require light, such as foraging and communicating, ALAN may accidentally extend their activity period into the night. This could be an advantage to some animals because it provides extra time for their activities. But at the same time, the extended photoperiod can create additional competitions and predations, especially when urban wildlife is adapting to the nocturnal lifestyle worldwide.



WILDLIFE IN CITIES AT NIGHT AROUND THE WORLD

On the left, from top to bottom: Leopards in Mumbai, India; Macaque Monkeys in Lopburi, Thailand; Smooth-coated Otters in Singapore. On the right are wildlife in American cities such as American Black Bears in Aspen, Colorado; Moose in Anchorage, Alaska; and Diamond-backed Terrapin in Manhattan, New York. Shown in the background (left) a Hippo and (right) an African Elephant crossing roads in South African cities.

12. Gaynor, K. M., Hohnowski, C. E., Carter, N. H., & Brashares, J. S. (2018). The influence of human disturbance on Wildlife Nocturnality. *Science*, 360(6394), 1232–1235. <https://doi.org/10.1126/science.aar7121>

13. Alagona, P. S. (2024). *Accidental ecosystem: People and wildlife in American cities*. University of California Press.

14. ALAN stands for "Artificial Light at Night".

Image Source: Plimsoll Productions. (2020). Night On Earth "Sleepless Cities." Netflix. Retrieved May 8, 2024.

NOCTURNAL MIGRATORY BIRDS: URBAN ECOLOGY AFTER DARK

0.2 ALAN & ITS RAMIFICATION ON BIODIVERSITY

As much as there are positive influences of ALAN on urban animals, the “ecological light pollution¹⁵”, which changes the natural diurnal cycle of light and dark in terrestrial and aquatic ecosystems, tends to bring more harm than good. Defined as “a phenomenon that is caused by human-made stimuli which interfere with the senses of other species”, “sensory pollution” is a direct consequence of ecological light pollution, and it greatly influences how animals navigate both in the environment and in life.¹⁶ Moreover, the rapid changes in the abundance of lights at night in the last 200 years had effectively ended a “4-billion-year streak¹⁷” of daily rhythms of light and dark on the planet, casting potential doom for countless species.

In their research, Sordello et al summarized that the immediate impact of ALAN includes the “Avoiding” or “Sink/ Crash barrier effect” that either repels the wildlife or attracts them.¹⁸ As a result, habitats are fragmented by ALAN or become the so-called ecological sinks that leads to a reduction in habitat patch size and suitability. Since lower habitat quality decreases species fecundity and survival rate, and ultimately leads to reduced population size and genetic diversity, the presence of ALAN would effectively form the “extinction vortex” that results in higher extinction probability and reduced biodiversity.

By drowning out other natural light sources at night with ALAN, humans have not only reduced the habitat quality for many species, but also “flattened¹⁹” the landscape and decreased its variation, which is one of the driving forces that create and maintain diversity of all life. Following that diversity in light at night helped create diversity in various traits such as vision, color, behavior and eventually the process of speciation, to tackle the problem of light pollution is to simultaneously preserve and increase biodiversity.

15. Parris, K. M. (2016). *Ecology of Urban Environments*. John Wiley & Sons Ltd.

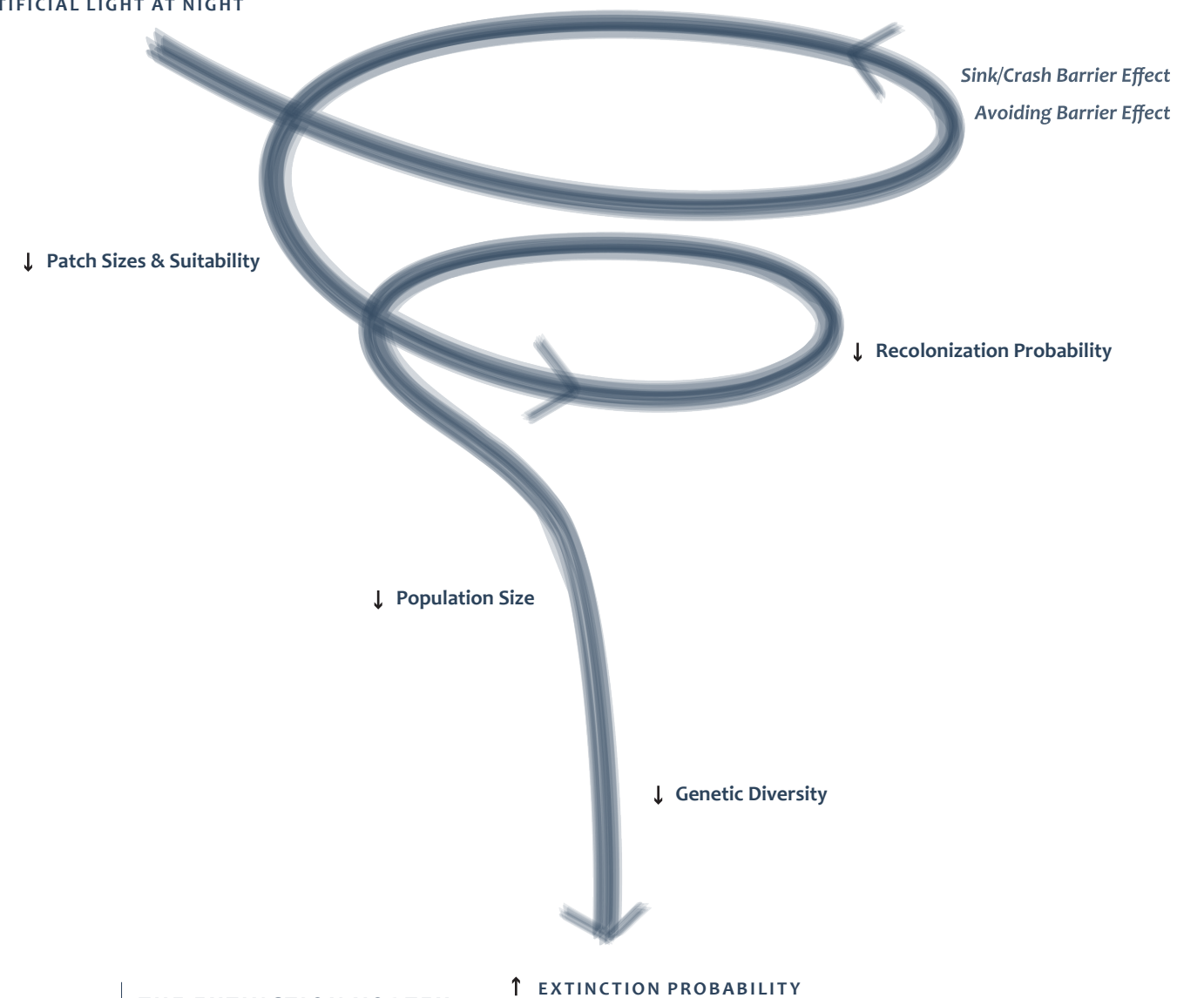
16. Yong, E. (2022). *An immense world: How animal senses reveal the hidden realms around us*; Random House.

17. See footnote 16.

18. Sordello, R., Busson, S., Comuau, J. H., Deverchère, P., Faure, B., Guetté, A., Hölker, F., Kerbiou, C., Lengagne, T., Le Viol, I., Longcore, T., Moeschler, P., Ranzoni, J., Ray, N., Reyjol, Y., Roulet, Y., Schroer, S., Secondi, J., Valet, N., ... Vauclair, S. (2022). A plea for a worldwide development of dark infrastructure for biodiversity – practical examples and ways to go forward. *Landscape and Urban Planning*, 219, 104332. <https://doi.org/10.1016/j.landurbplan.2021.104332>

19. See footnote 16.

ARTIFICIAL LIGHT AT NIGHT



THE EXTINCTION VORTEX

ALAN can trigger a cascading effect of ecological processes that eventually leads to species extinctions and lowers global biodiversity.

NOCTURNAL MIGRATORY BIRDS: AVIAN RED-EYE FLIGHTS



- Shorter Connection Between Wintering & Breeding range
- Longer Connection Between Wintering & Breeding range
- Artificial Light at Night

Navigation Cue: Star Positions

Trapped Nocturnal Migratory Birds in High Intensity Light

0.1 NOCTURNAL MIGRATORY BIRDS & THEIR JOURNEY OVER CITIES

As a group of highly visible wildlife in cities, birds are “some of the best-studied examples of rapid evolution among vertebrate animals in urban environment.”²⁰ Their relative abundance in urban areas and in the field of urban ecology research not only aided them to become the subject of fascination for many, but also made it easier to include them as users of urban spaces. However, like light pollution, there is a side of birds that most people are not aware of.

Because of our own physical limitations, life in the darkness has always been difficult to see and understand. Not only are most people unaware that some birds travel at night to great distances, even fewer realize the true scale and implication of such a natural phenomenon. For example, most of the birds (over half of 630 North American species²¹) we see during the day around us do in fact migrate at night biannually. The events involve billions of avian individuals, across taxa, size, age, and sex. Every fall and spring, birds of Americas travel under the cover of dark skies across the continents via major migratory flyways. According to Horton et al, these flyways are often over large cities including ones in the East Coast, the Southern and Midwestern United States, where high ALAN influences are found.²²

While light pollution on its own does not kill nocturnal migratory birds, it can interfere with their innate navigation mechanisms such as star positions, magnetic fields, and polarized skylights.²³ As a result, birds can get trapped in places outside of their migration routes, exhaust their energy reserves, and increase their chance of colliding with structures in the built environment. The high intensity artificial lights, such as the “tribute of light” at 9/11 memorial in New York, serves as an example of how ALAN disorients nocturnal migratory birds, traps them in place and forces them to deviate from their regular journey.²⁴

Navigation Cue: Polarized Skylight

WATERFOWL MIGRATION
CRUISING ALTITUDE MAX: 4000'

Navigation Cue: Magnetic Field

SONGBIRD MIGRATION
CRUISING ALTITUDE MAX: 2500'

SONGBIRD MIGRATION
CRUISING ALTITUDE MIN: 500'

WATERFOWL MIGRATION
CRUISING ALTITUDE

MIN: 2000'

City Buildings:
340 million

Cell Phone Towers:
6.6 million

Wind Turbines:
366,000

Power Lines:
22.8 million

Residential Buildings:
253 million

Image Data Source: Megan Bishop, Living Bird 2018

20. See footnote 13.

21. Horton, K. G., Nilsson, C., Van Doren, B. M., La Sorte, F. A., Dokter, A. M., & Farnsworth, A. (2019). Bright lights in the big cities: Migratory birds' exposure to artificial light. *Frontiers in Ecology and the Environment*, 17(4), 209–214. <https://doi.org/10.1002/fee.2029>

22. See footnote 21.

23. Rich, C., & Longcore, T. (2013). *Ecological consequences of artificial night lighting*. Island Press.

24. van Doren, B. M., Horton, K. G., Dokter, A. M., Klinck, H., Elbin, S. B., & Farnsworth, A. (2017). High-intensity urban light installation dramatically alters nocturnal bird migration. *Proceedings of the National Academy of Sciences*, 114(22), 41175–41180. <https://doi.org/10.1073/pnas.1702551114>

NOCTURNAL MIGRATORY BIRDS: AVIAN RED-EYE FLIGHTS

0.2 THE CHANGING DESTINATIONS

The impact of light pollution on nocturnal migratory birds does not just stop as soon as they reach their destinations. Not only does prolonged exposure of ALAN delay departure date of songbirds' migration²⁵, but the most important reason these birds migrate is often the availability of food sources such as insects and plants. Unfortunately, ALAN has a profound impact on both.

According to a recent publication²⁶, moths and other flying insects have a physiology that demands them to always fly with their backs to a light source at night. However, due to the point source nature of outdoor artificial lightings, they are often stuck in a loop around the light until either a crash occurs, or exhaustion sets in. Not only has ALAN been linked to an estimated 9 percent decrease of the global insect population in the past decade²⁷, plants pollinated by nocturnal pollinator insects such as moths, beetles, nocturnal bees, are also less likely to be visited if there are lights nearby. In a U.K. study²⁸, streetlights were found to half the moth abundance at the ground level while increase about 70 percent at the light sources, in addition to a reduction in pollination efficiency since 23 percent of moths were found carry pollens from at least 28 plant species nearby. Moreover, like animals, plants also have circadian rhythm and use light as a cue to organize their activities. Researchers have investigated a database containing 13 years of plant budburst data of selected deciduous tree species in U.K. demonstrated that ALAN plays a role in the early budburst of these plants.²⁹ The disruption of the plants' circadian rhythm can lead to changes in flowering and fruiting patterns, which in combination with reduced pollinations create the so-called "trophic mismatches" that influence the lives of migratory birds with great deal.

25. Smith, R. A., Gagné, M., & Fraser, K. C. (2021b). Pre-migration artificial light at night advances the spring migration timing of a trans-hemispheric migratory songbird. *Environmental Pollution*, 269, 116136. <https://doi.org/10.1016/j.envpol.2020.116136>

26. Fabian, S. T., Sondhi, Y., Allen, P. E., Theobald, J. C., & Lin, H.-T. (2024). Why flying insects gather at artificial light. *Nature Communications*, 15(1). <https://doi.org/10.1038/s41467-024-44785-3>

27. van Klink, R., Bowler, D. E., Gongalsky, K. B., Swengel, A. B., Gentile, A., & Chase, J. M. (2020). Meta-analysis reveals declines in terrestrial but increases in freshwater insect abundances. *Science*, 368(6489), 417–420. <https://doi.org/10.1126/science.aax9931>

28. Macgregor, C. J., Evans, D. M., Fox, R., & Pocock, M. J. (2016). The Dark Side of street lighting: Impacts on moths and evidence for the disruption of nocturnal pollen transport. *Global Change Biology*, 23(2), 697–707. <https://doi.org/10.1111/gcb.13371>

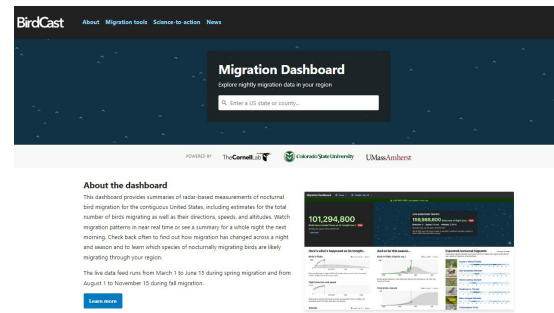
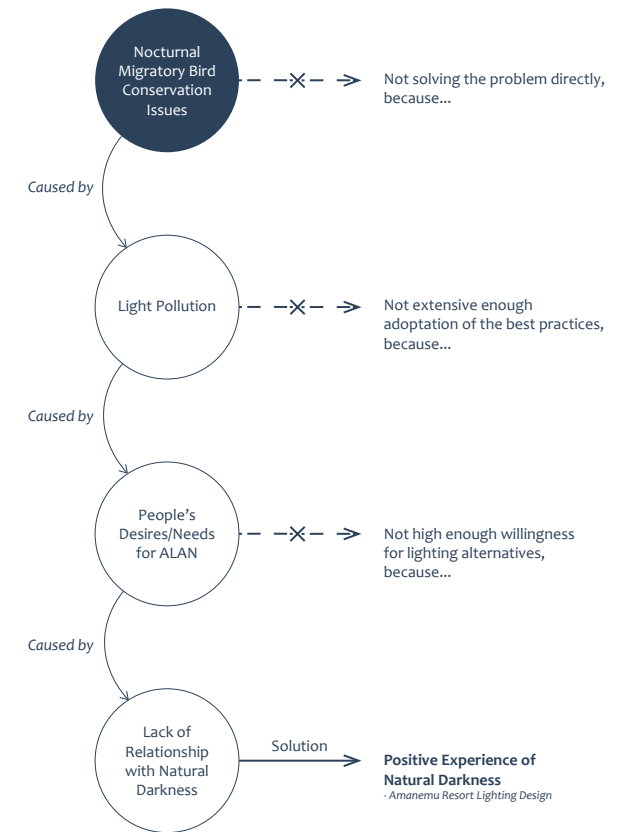
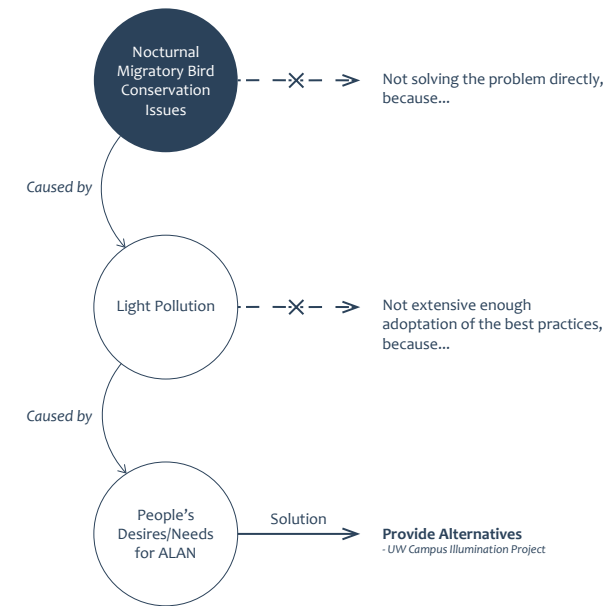
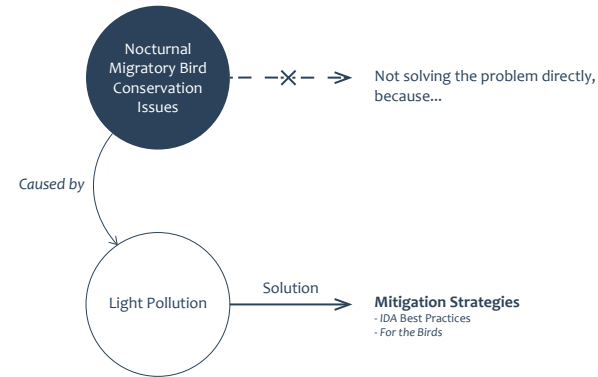
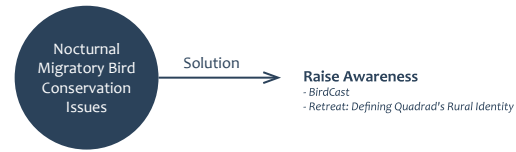
29. French-Constant, R. H., Somers-Yeates, R., Bennie, J., Economou, T., Hodgson, D., Spalding, A., & McGregor, P. K. (2016). Light pollution is associated with earlier tree Budburst across the United Kingdom. *Proceedings of the Royal Society B: Biological Sciences*, 283(1833), 20160813. <https://doi.org/10.1098/rspb.2016.0813>



ALAN impacting migratory birds' migration schedule, causing the "Trophic Mismatch" with natural resources they need to survive.

Background Illustration Source: M. Schumacher, <https://spatial.usc.edu/there-goes-the-night/>

THE CORE OF THE PROBLEMS



EXISTING TOOL & PROPOSED DESIGN WORK FOR RAISING MIGRATORY BIRDS AWARENESS

BirdCast documents and predicts U.S. bird nocturnal migrations using radar and machine learning. Meanwhile, student projects like "Retreat: Defining Quadrad's Rural Identity" support migratory bird habitats and community activities in Canada through design.

Image Source: (top) <https://dashboard.birdcast.info>
 (bottom) <https://www.asla.org/2021studentawards/3142.html>

CURRENT BEST PRACTICES & SAMPLE DESIGN PROJECT FOR LIGHT POLLUTION MITIGATION

Raising awareness of nocturnal migratory bird challenges is vital, with light pollution recognized as the core issue. Initiatives such as the outdoor lighting principles by International Dark Sky Association & Illuminating Engineering Society, along with projects like "For the Birds" exemplify this approach.

Image Source: (top) <https://www.darkskyvic.org/light-fixture-information>
 (bottom) <https://www.asla.org/2021studentawards/3275.html>

AN EXAMPLE OF ECO-FRIENDLY LIGHTING APPLICATION IN PACIFIC NORTHWEST

Outdoor lighting guidelines and efforts to combat light pollution exist, but limited adoption of these strategies due to societal preferences and the lack of awareness about the alternatives. Projects like UW Campus Illumination aim to balance these needs with environmental concerns.

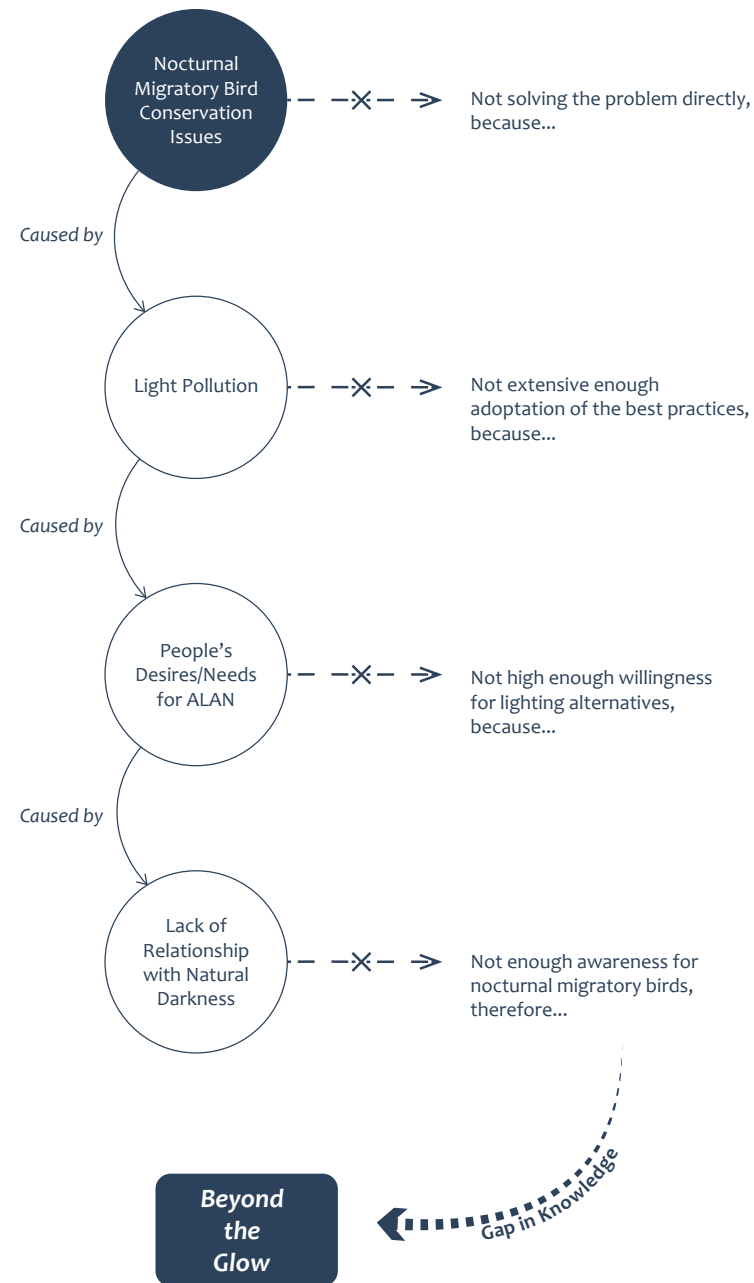
Image Source: <https://idl.be.uw.edu/campus-illumination-roadmap-sustainable-exterior-lighting-university-washington-seattle-campus>

A BUILT PROJECT THAT ADDRESSES BOTH THE DARKNESS QUALITY AND SAFETY

Awareness of alternative lighting practices has grown, but the challenge remains in adopting them due to limited familiarity and appreciation with natural darkness. Amanemu Resort in Japan aims to provide high quality darkness for visitors while ensuring safety.

Image Source: <https://www.artoftit.org/image-gallery/275142477169498/>

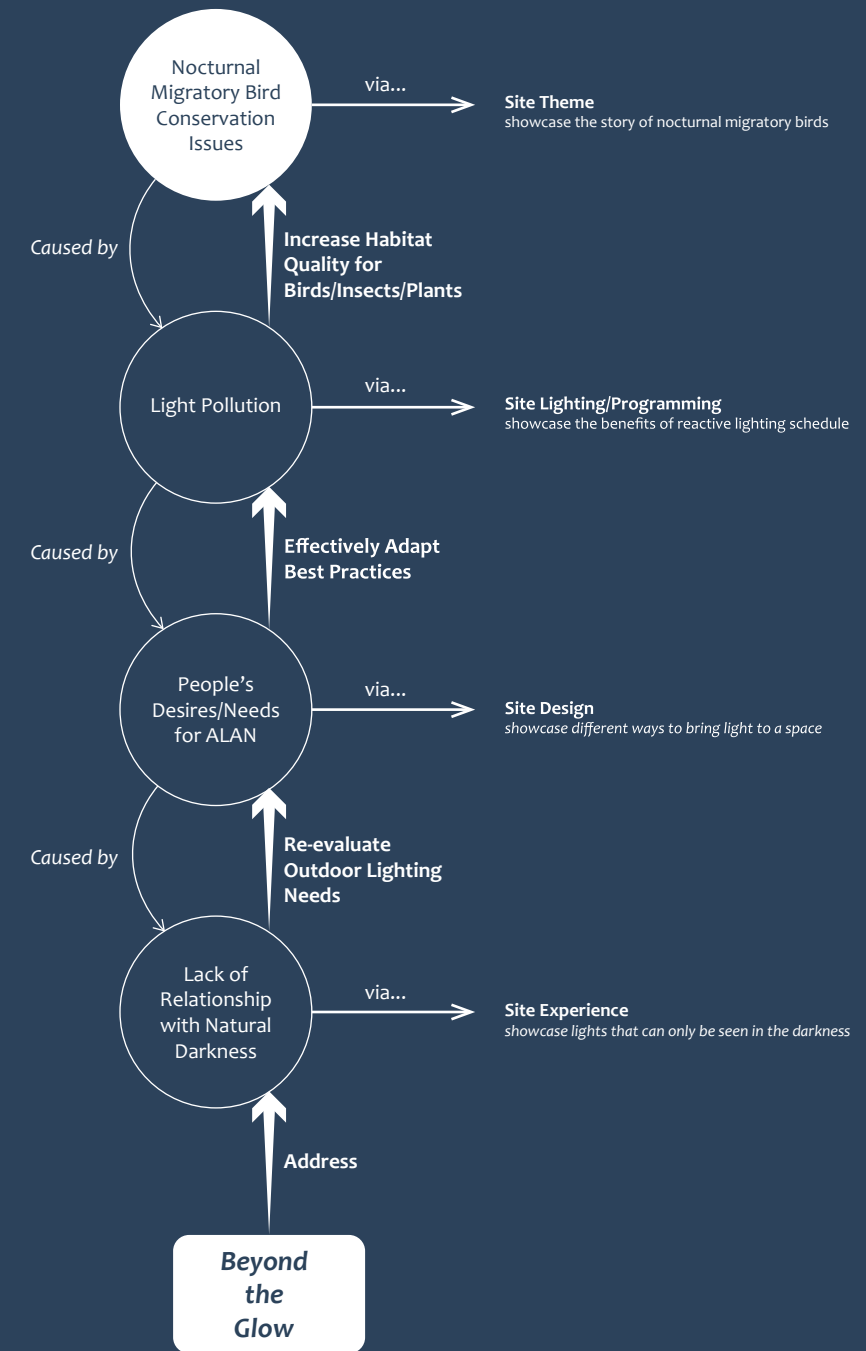
PROJECT GOALS



(right) By considering the role of outdoor lighting in landscape design carefully, we would bring awareness and insights into the issues faced by nocturnal migratory birds and finally tackle the problem of light pollution head-on.

REFRAMING OF THE ISSUES & GAP IN KNOWLEDGE

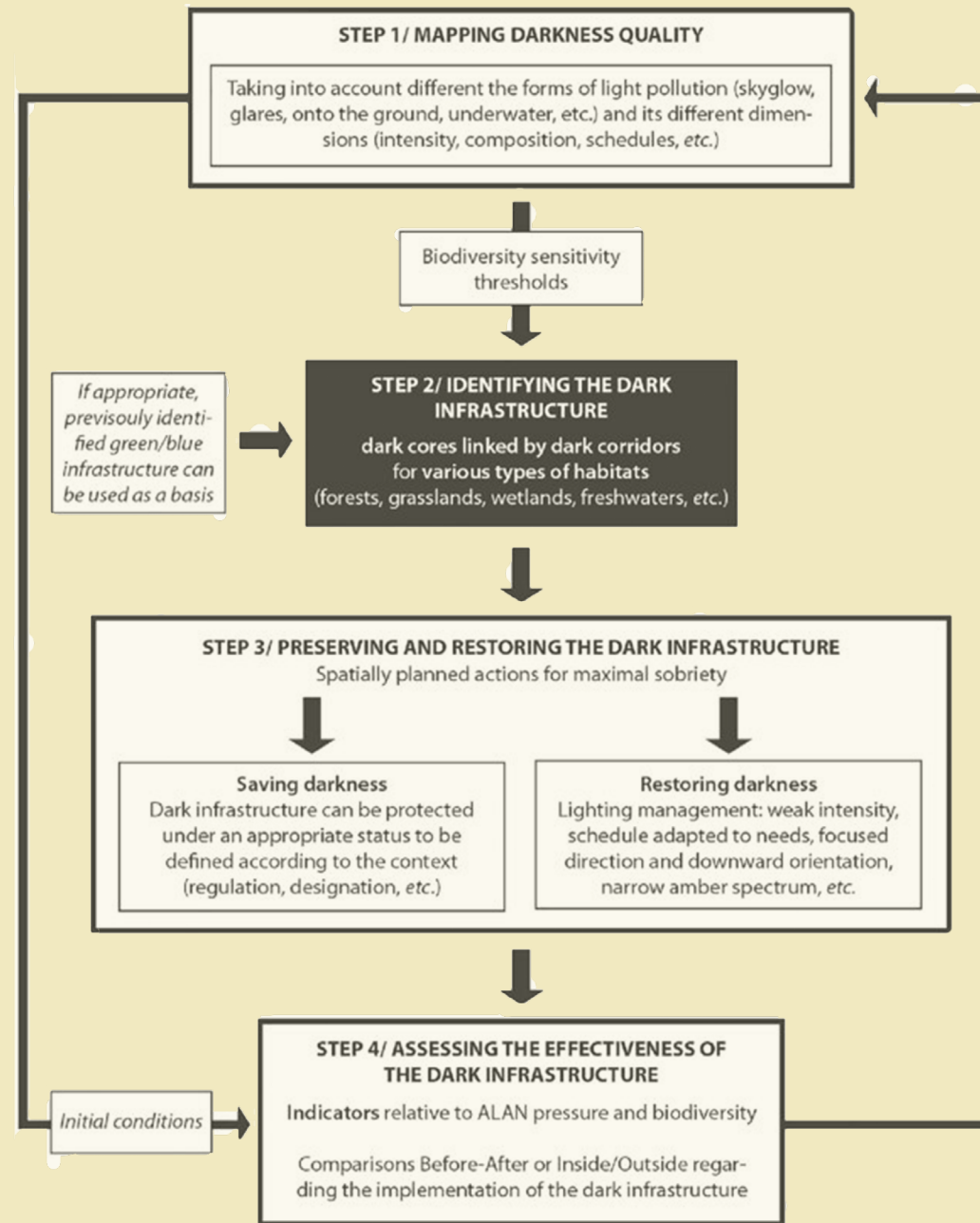
As a profession, landscape architecture has the ability to design better outdoor spaces that respect the needs of animals who share the space, and shed light on these seemingly invisible, but grandiose events of the natural world. To systematically address the challenges faced by nocturnal migratory birds, it's crucial to recognize that these problems stem from light pollution, driven by people's desires/needs for ALAN, and ultimately result from society's disconnection from natural darkness. With this understanding, we can develop more effective design solutions that tackle the root cause of the problems.



REVERSING OUR INABILITY TO CONNECT WITH DARKNESS

The goal of this project is to design urban outdoor spaces in the Pacific Northwest that not only promote natural darkness as a resource but also create places that are inclusive to the nocturnal wildlife, including nocturnal migratory birds. Specifically, the project aims to facilitate the positive natural darkness experience for people in Portland, OR, while showcasing alternative ways of bringing lights to outdoor spaces, and increasing awareness of the existence of the larger nocturnal migratory bird community.

METHODS OVERVIEW



URBAN DARK INFRASTRUCTURE PLANNING FRAMEWORK

Through the process of establishing dark infrastructure in places within cities where urban wildlife roams, we can create better connections to nature for people, allowing them to see darkness in a new light.

Image Source: see footnote 18.

PRESERVING THE NATURAL DARKNESS VIA URBAN DARK INFRASTRUCTURE

Urban green and blue infrastructures play a major role in helping cities mitigate the impact of climate change and achieve sustainability goals. Due to ALAN’s ability to fragment habitats of nocturnal wildlife, there has been calls for establishing a third kind of infrastructure: the dark Infrastructure.³⁰ Through the integration of dark infrastructure with the already existing green and blue infrastructure, higher quality ecological corridors can be created and enhance the effectiveness of cities’ green and blue infrastructure around the world. Moreover, by considering darkness as a resource and aesthetics for urban design, planners and designers can create a “New Urban Nocturnal Sublime”³¹ that breaks the geographical dualism of ALAN and natural darkness.

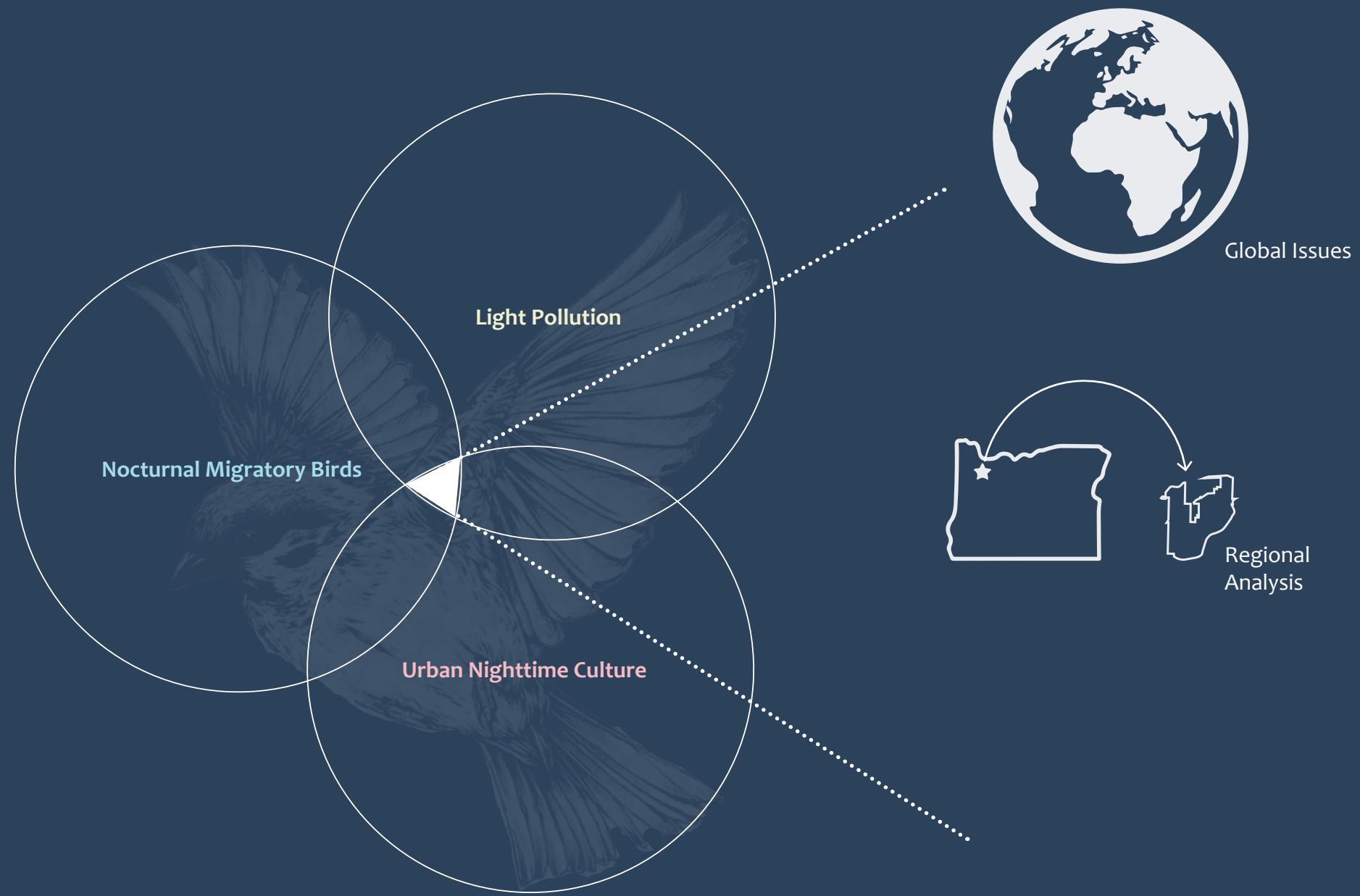
The initial phase of the project entails gathering existing knowledge and literature related to the topic of light pollution, nocturnal migratory birds, and urban nighttime culture. Adopting from the 4-step implementation process of dark infrastructure³², a context analysis of the region would be carried out using Geographic Information Systems and a site will be selected. Building upon the insights gathered from the analysis along with a closer look into the policy background of the site, a masterplan outlines the lighting and programming recommendations will be generated. By combining the masterplan with further GIS analysis and on-site assessments, a design focus area will be identified. With a thorough understanding of the design focus area and project goals, the final stage of the project involves programming and designing the site layout and amenities in order to fulfill the project’s objectives.

³⁰. See footnote 18.

³¹. See footnote 7.

³². See footnote 18 and the diagram to the left.

THE OPPORTUNITIES



What are the opportunities for Portland, Oregon to establish dark infrastructure for nocturnal wildlife and natural darkness, and where could they be located?

PORTLAND CONTEXT: LIGHT

0.1 STREETLIGHTS IN OREGON'S LARGEST CITY

For those who don't know, Oregon is home to the largest certified dark sky sanctuary in the world. As the largest metropolitan area in Oregon, Portland is an ideal city to test light pollution mitigation strategies because the local light pollution impacts millions of people and nocturnal migratory birds.

With GIS data of Streetlights and buildings from the City of Portland, a simulation of ALAN around downtown Portland was conducted to provide a glimpse of the city's night lights. Not surprisingly, the majority of artificial lights come from downtown Portland, sandwiching the Willamette River, while larger darker areas are found mostly on the west side of the city around Forest Park, Washington Park, and Marquam Nature Park, in addition to the Willamette River corridor.

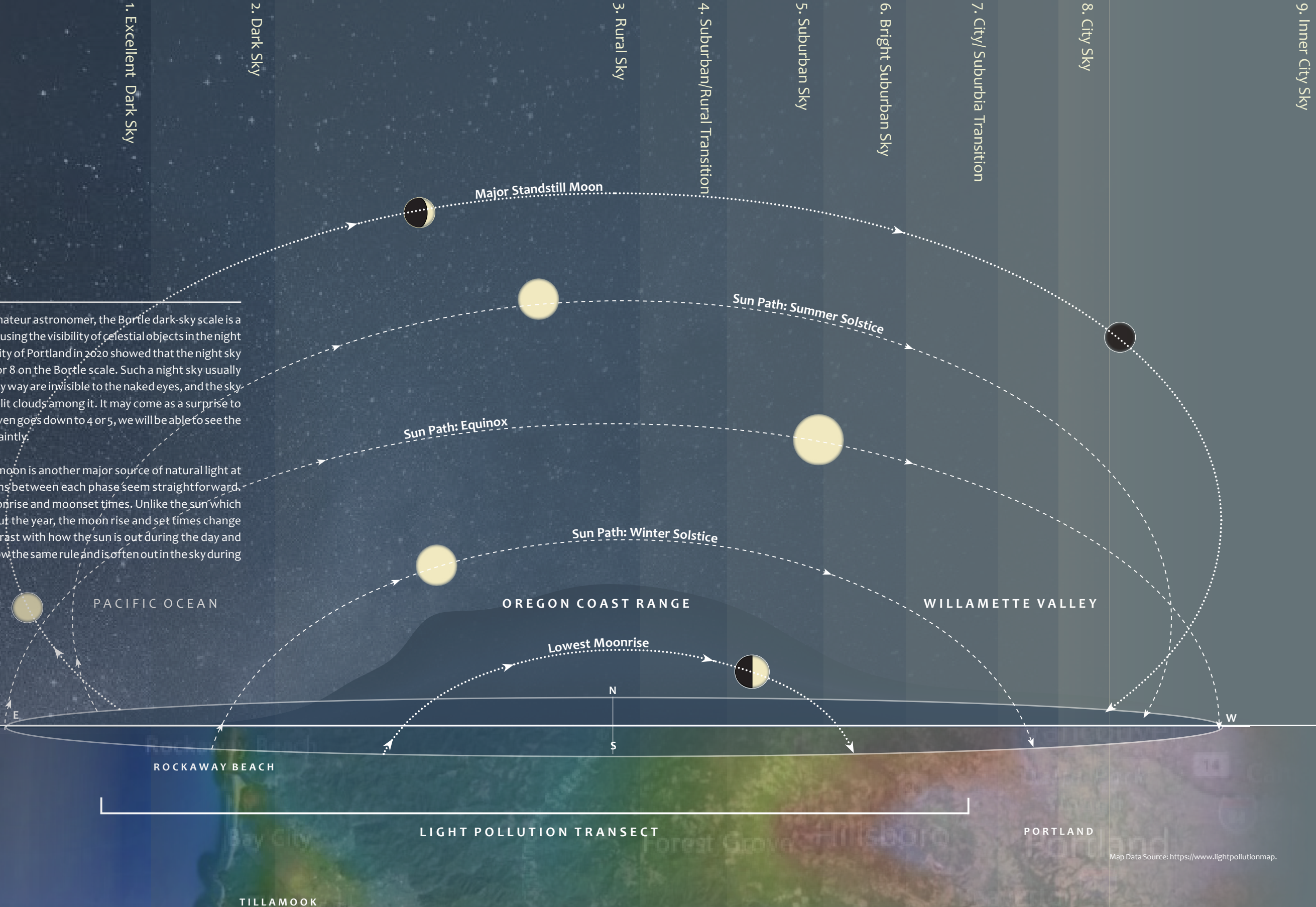


PORTLAND CONTEXT: LIGHT

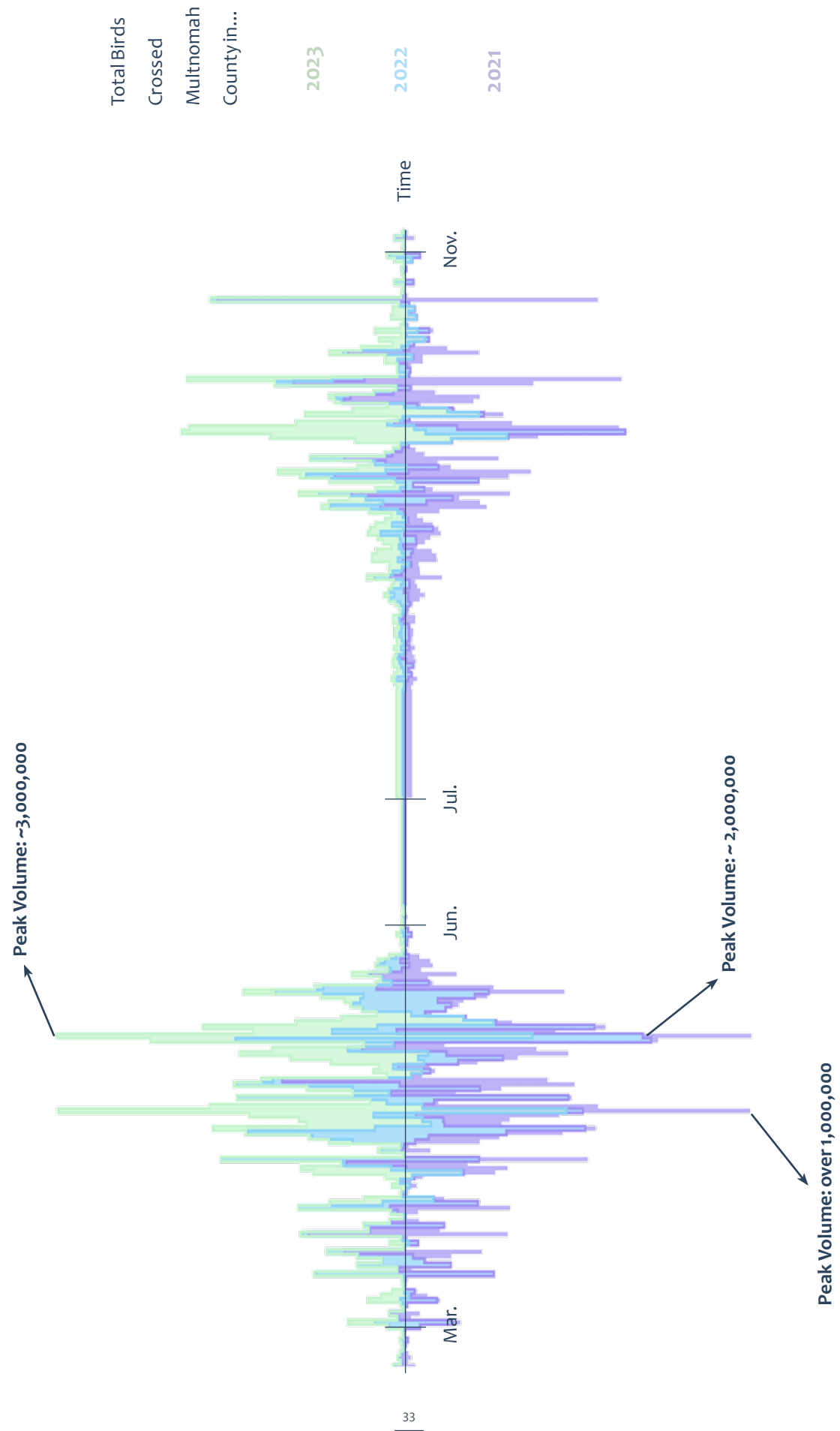
0.2 OF STARS AND MOON

Originally invented by John E. Bortle, an amateur astronomer, the Bortle dark-sky scale is a numeric way of measuring night sky quality using the visibility of celestial objects in the night sky as indicators. An assessment done by City of Portland in 2020 showed that the night sky of Downtown Portland is rated about a 7 or 8 on the Bortle scale. Such a night sky usually means that familiar constellations and Milky way are invisible to the naked eyes, and the sky is tinted light grey or orange with brightly-lit clouds among it. It may come as a surprise to most, but if Portland's Bortle scale rating even goes down to 4 or 5, we will be able to see the Milky way hanging above the city, ever so faintly.

Aside from stars and northern lights, the moon is another major source of natural light at night. The moon phases and the transitions between each phase seem straightforward. However, the same cannot be said for moonrise and moonset times. Unlike the sun which has a rise and set time that vary throughout the year, the moon rise and set times change throughout the month. Moreover, in contrast with how the sun is out during the day and gone at night, the moon itself does not follow the same rule and is often out in the sky during the day together with the sun.



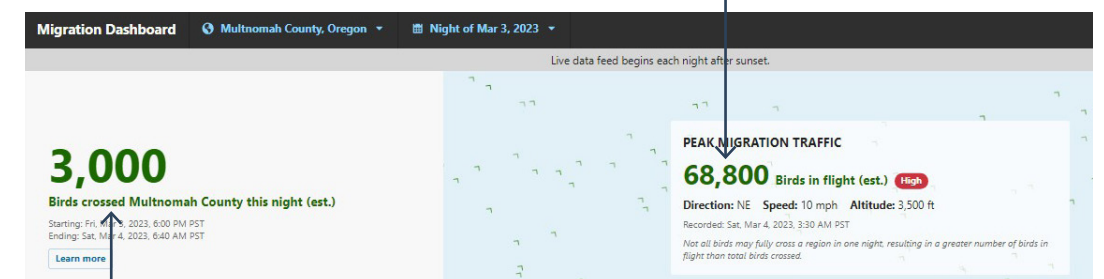
PORTLAND CONTEXT: BIRDS



AVIAN NOCTURNAL MIGRATION AT MULTNOMAH COUNTY

Using weather surveillance radar across the continental U.S. and recent artificial intelligence developments such as machine learning, scientists at BirdCast are able to record nocturnal migrations in great details and further predict when and where these birds will be before they even travel through the region. By analyzing the BirdCast data from 2021 to 2023, not only did we discover that birds do travel through the night sky of Multnomah County, but also the true scale of the migrations. While we do not have visual confirmations of these birds landing in places within the county in real time, the data comparisons between the *peak migration traffic* versus *total birds crossed* help to gain some insights into the stopover behaviors of the migrating birds when they pass through Multnomah County.

2. Greater number of birds in the air recorded at once



1. Smaller number of birds that have passed through the county BUT....

3. ...Means some nocturnal migratory birds have stayed in the county overnight

LOCATING DARK INFRASTRUCTURE



- Urban Growth Boundary
- MAX Light Rail
- Light Rail Stop
- Outdoor Recreation & Conservation Area (ORCA)

URBAN NATURE INTERFACE

Due to ALAN's ability to fragment habitats of nocturnal wildlife, the integration of dark infrastructure with the already existing green and blue infrastructure can create higher quality ecological corridors. After all, half of the park is after dark. By following the 4-step process of establishing effective dark infrastructure in places within cities where urban wildlife roams, we can create better connections to nature for people, allowing them to see darkness in a new light.

To locate the best place for dark infrastructure that augments the current green infrastructure, and increase nocturnal habitat connectivity, a closer look at green open spaces in and around Portland was carried out. This includes parks, open spaces, and conservation focus areas. Accounting for community access, the light rail system was overlaid on top of the green space map to help narrow down the selections. Combining with the streetlight investigation, Washington Park stood out because of its light rail stop and the close proximity to both nature from the Forest Park to the north, and urban from downtown Portland to the east.

Furthermore, the Park's 2018 Masterplan has included a Dark Sky Plan, which speaks to the need for establishing dark infrastructure at Washington Park.

Light Rail Line

Forest Park

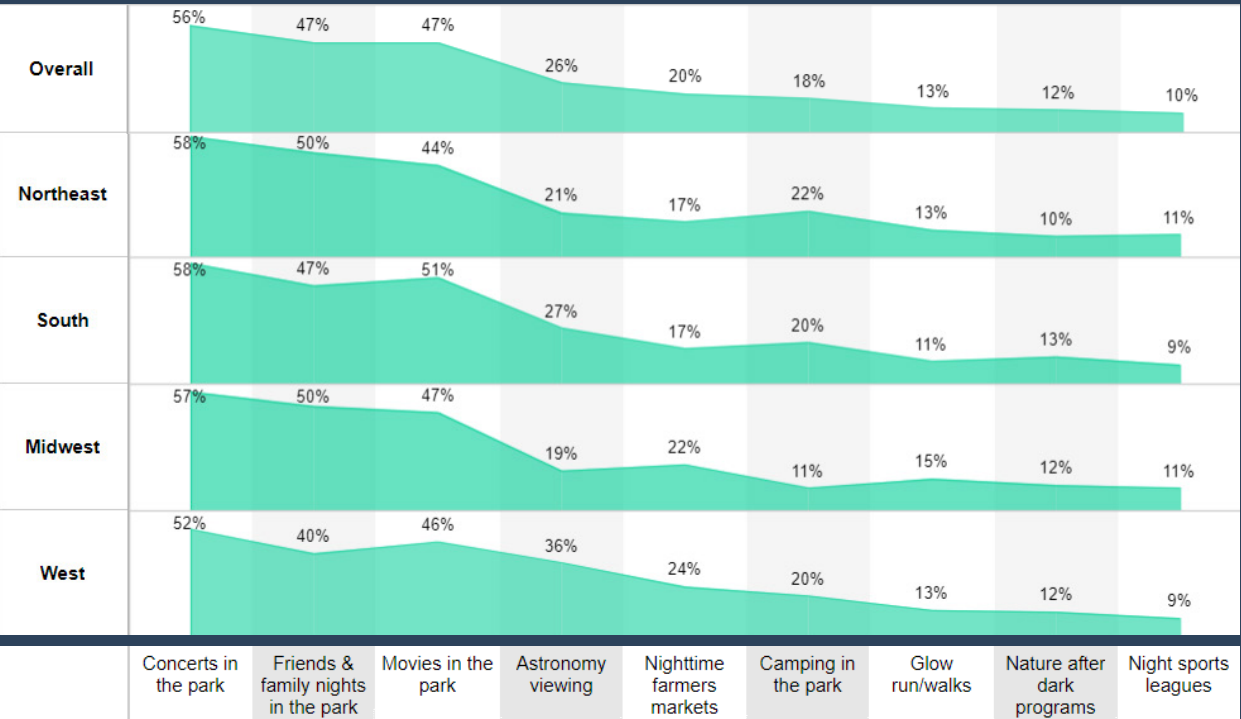
Smith & Bybee Wetlands Natural Area

Light Rail Stop



Map Data Source: City of Portland

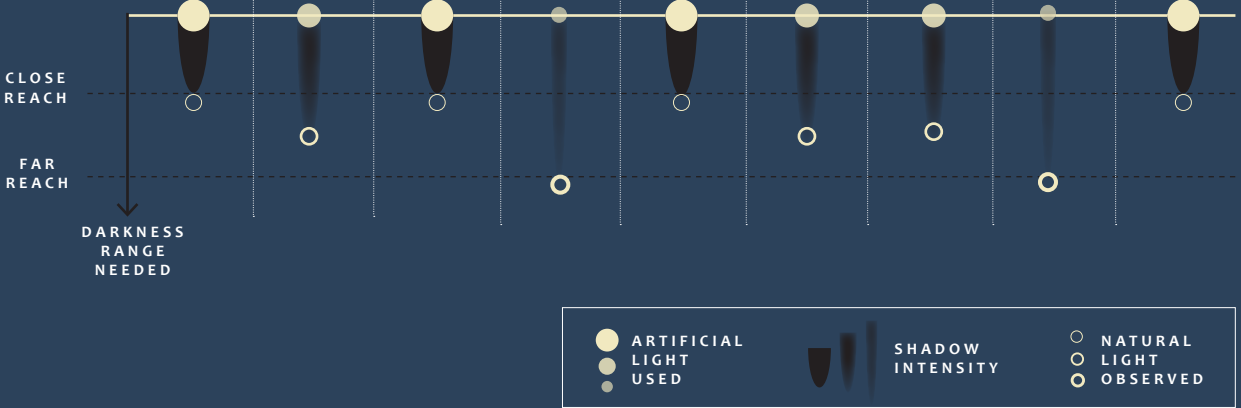
PARK ANALYSIS: PROGRAMMING



PARK NIGHTTIME USAGE TREND

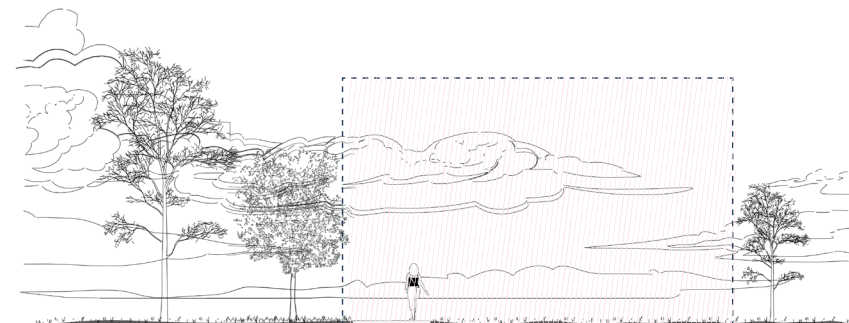
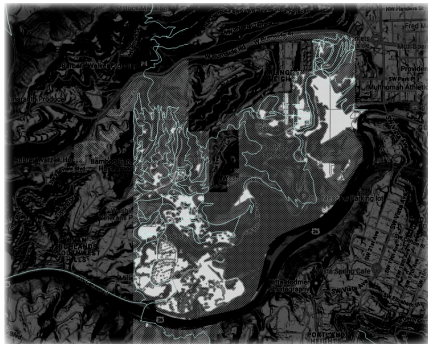
The National Recreation and Park Association had published a study in recent years about the nighttime activity preferences in open spaces such as parks. They found that 91% of respondents are interested in nighttime park activities, and the most popular choices are concerts, movies, and the bonfire social. In addition, those who live in the West are more likely to be interested in star gazing events than the rest of the countries, and parents with children are more likely to attend nighttime events in the park than those who don't. While the study did not engage with Portland community specifically, the results can be used to gather general expectations and preferences of outdoor nighttime space when designing places that improve Portland residents' relationship with night and darkness outside.

The specific relationships of light and darkness for each of these nighttime events are summarized in the diagram to the left. Activities such as Concerts and Movies in the Park, Nighttime Farmers Markets, and Night Sports require more intense artificial light and not much surrounding darkness, while Astronomy Viewing and Nature After Dark Programs require the opposite. Since stronger lights create harsher shadows, it also impacts the amount of natural light that is visually available to people participating in these events.

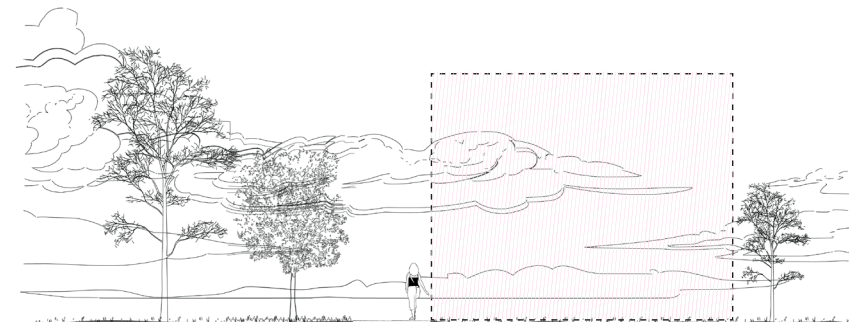
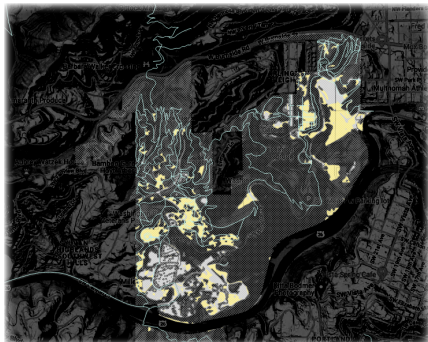


Top Image Source: <https://www.nrpa.org/publications-research/park-pulse/park-pulse-survey-parks-come-alive-at-night/>

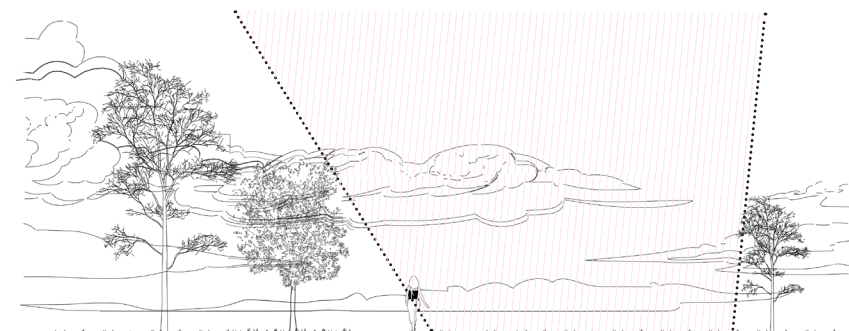
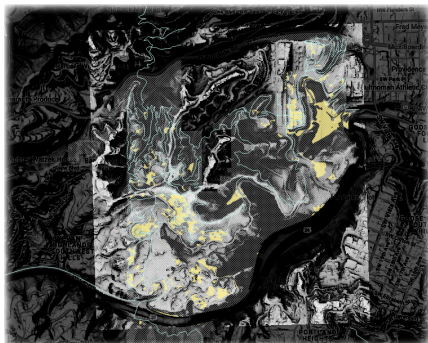
PARK ANALYSIS: OPEN SPACE



OPEN SPACE WITH NO CANOPY COVERAGE



OPEN SPACE WITHOUT IMPERVIOUS SURFACE

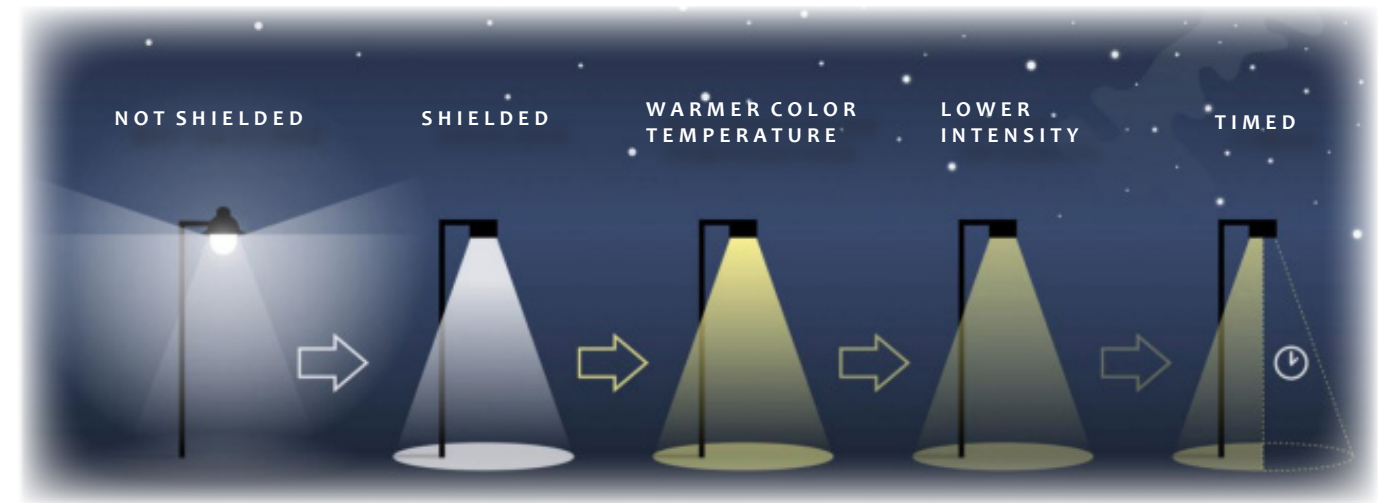


OPEN, PREVIOUS SPACE WITH GOOD SKY VISIBILITY

DARKNESS QUALITY & OPEN SKY

Since a major part of the Washington Park experience is the mature forest, it did not make sense to me to propose tree removals. Therefore, the park was analyzed based on its existing canopy and all the open spaces not covered by trees. Because most roads and parking lots are also not covered by tree canopies, these areas were removed from the selection and open space with soil were identified. Lastly, sky visibility analysis was used to locate areas that have the best access to the night sky.

RETHINKING DARKNESS AT WASHINGTON PARK



0.1 DYNAMIC LIGHTING STRATEGIES

According to the International Dark Sky Association, the strategy of using outdoor lighting should include shielding, warmer color Temperature, lower intensity, and Timed lighting schedule. In order to find out what lighting schedule is the best for Washington Park and the design focus site, a timeline of darkness availability, park hour and migration seasons of the birds is diagramed below.

Furthermore, using the data of daily visitors to paid attractions in Washington Park for the past 10 years, as well as sightings of selected nocturnal migratory birds on site, the preferred park usage timeframe for each user group is revealed and informed the lighting schedule. Because the park closes from 10pm to 5am, the light is recommended to be off to preserve the darkness. During the time when the park is open after the sun has set, light should be low in intensity unless specific events require more. Lastly, light should be absent during the nights of migration seasons, which is roughly from March to Jun, and then Aug to Nov, or at the very least turned off when large numbers of nocturnal migratory birds are predicted to be in the area.

Since GIS data for the lighting infrastructure inside of the park was not available, a series of field surveys were conducted using Avenza app to record the geolocation and appearance of every light pole within the park. By combining the result with the Portland Streetlight data, a gradient of dark and lighter areas of Washington Park emerges. The series of site analysis highlights a location with the greatest potential for both the darkness quality and accessibility within Washington Park, where the proposed design interventions take place.

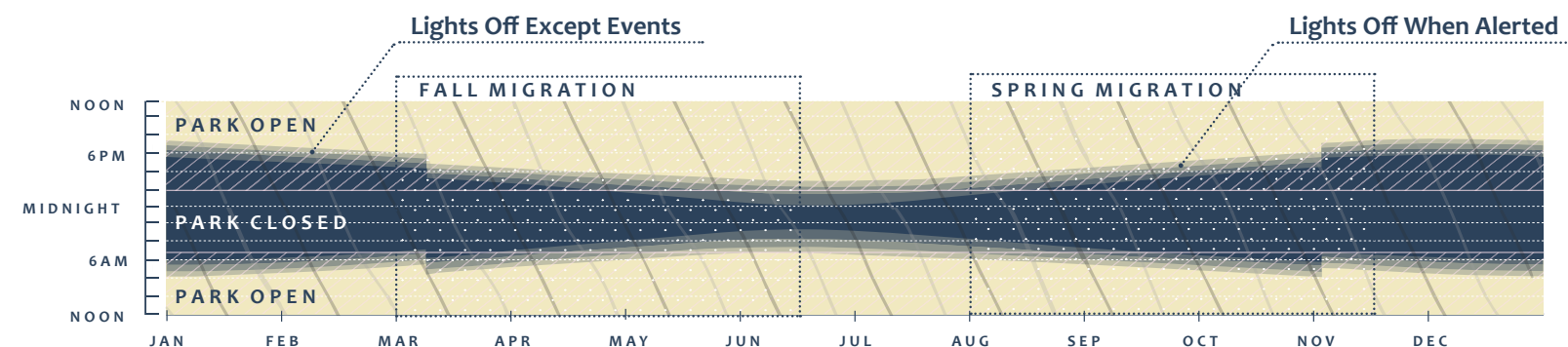
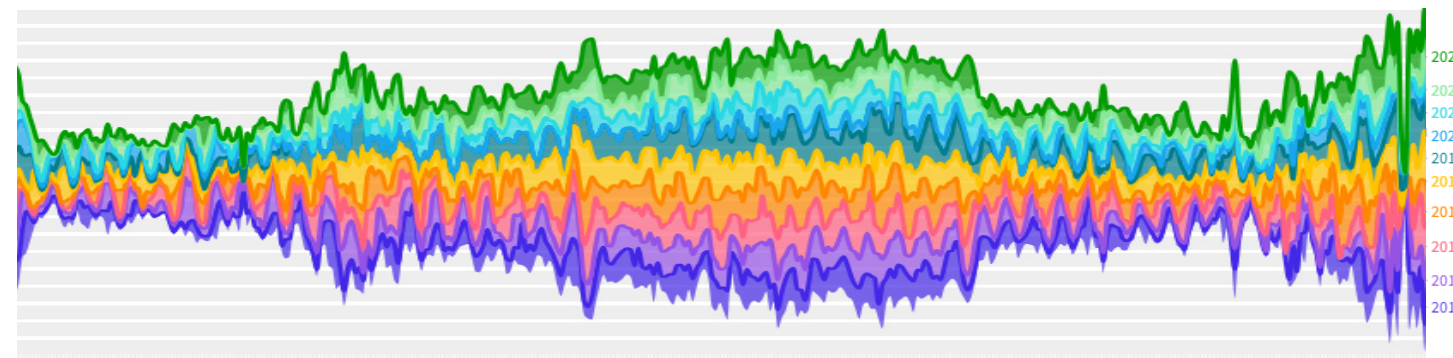
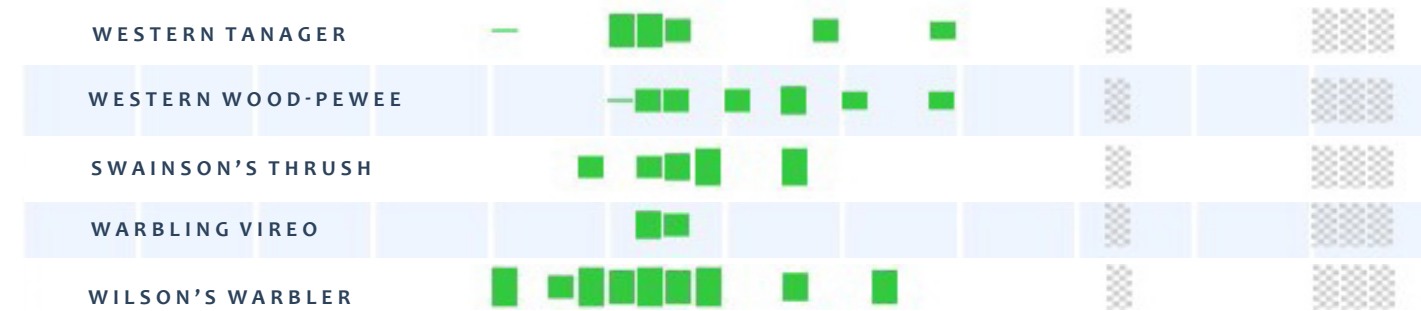


Image & Data Source: (top) Rémi Boucher, Mont-Mégantic International Dark Sky Reserve; (2nd) eBird; (3rd) Explore Washington Park; (bottom) <https://www.timeanddate.com/sun/usa/portland-or>

RETHINKING DARKNESS AT WASHINGTON PARK

0 180 720 FEET

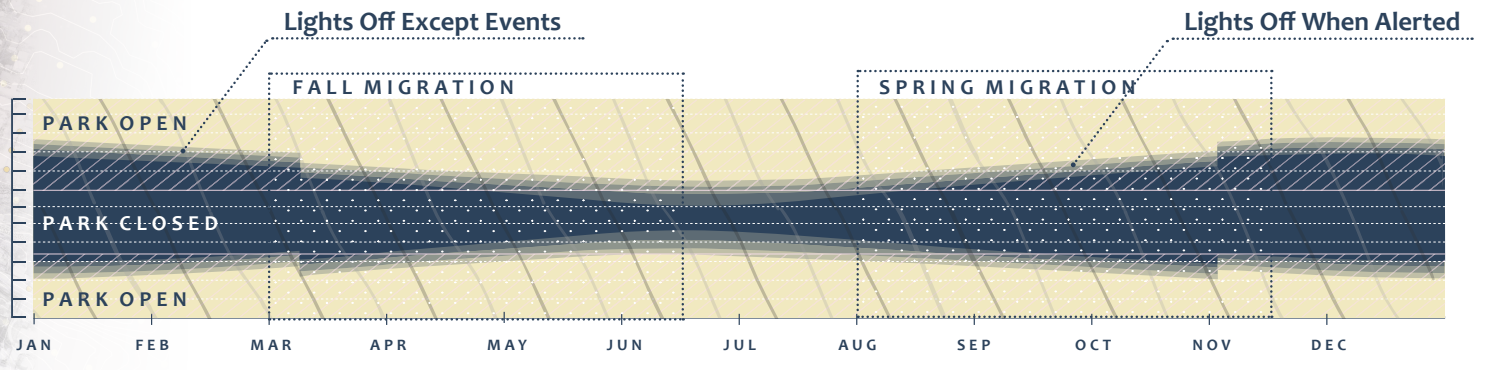
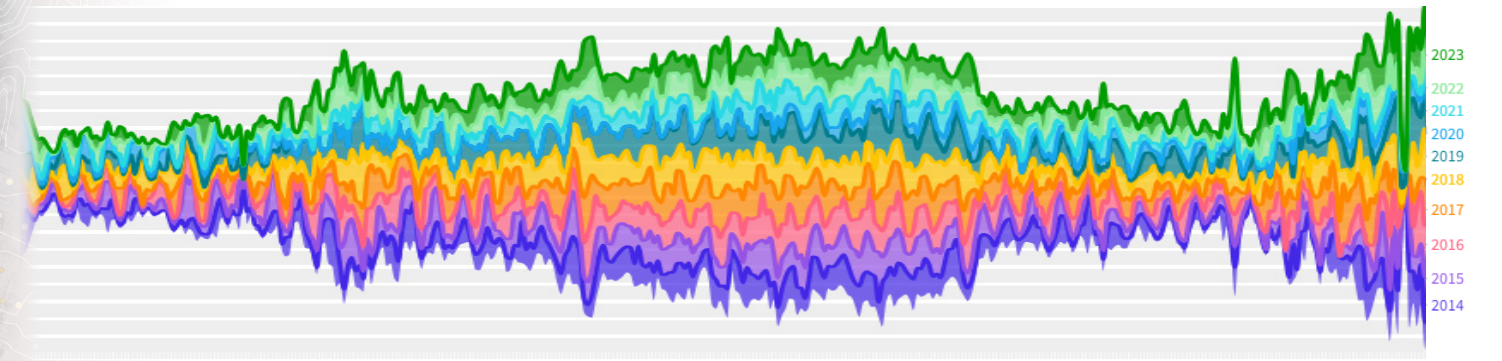
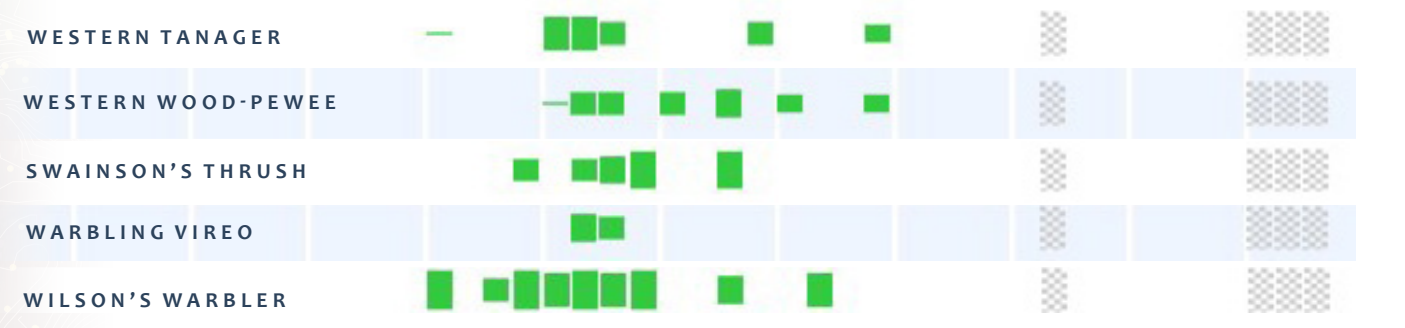
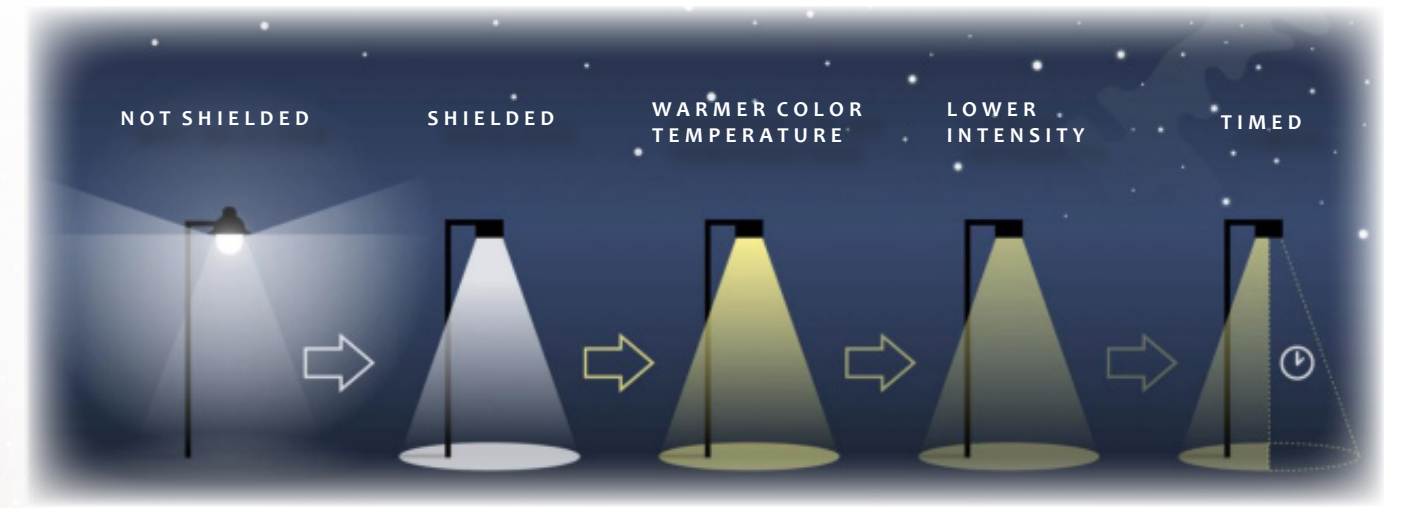
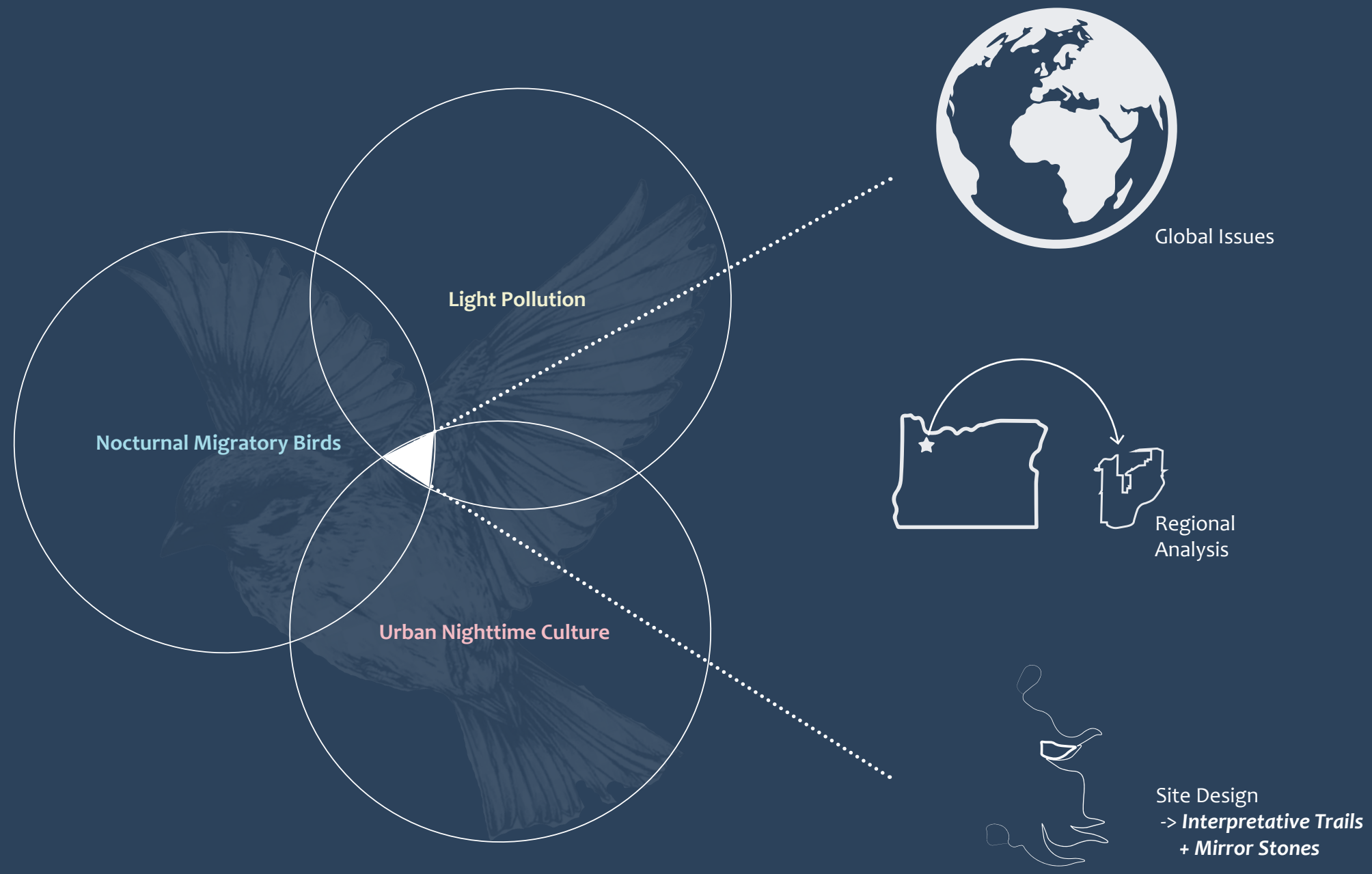


Image & Data Source: (top) Rémi Boucher, Mont-Mégantic International Dark Sky Reserve; (2nd) eBird; (3rd) Explore Washington Park; (bottom) <https://www.timeanddate.com/sun/usa/portland-or>

THE DESIGN



How would trail design and installation at the design focus site create an engaging environment for nighttime activity at Washington Park, while offering a positive experience of natural darkness?

MIGRATION NIGHT TRAIL

THE SENSORY EMBODIMENT OF NOCTURNAL MIGRATORY BIRDS

Taking inspiration from the epic journeys of selected nocturnal migratory birds that are found in the park while using the already existing ADA-accessible Overlook Trail, a migration night trail is proposed. As visitors travel along the trails up or down the hill at night, they would experience symbolically what it is like traveling at night across the landscape as a nocturnal migratory bird.

The existing lights from both upper and lower parking lot are brighter and sit on top of poles. In order to provide comfortable transitions for the eyes of visitors to adjust to the dark, a series of night vision-friendly red path lights that sit low to the ground near both entrances are proposed. The viewshed at the top of the hill is south facing, with tall trees surrounding the edges, blocking most of the light from Portland downtown.

With these lightings' characteristics, the site is then divided into lighting zones where timed, fully shielded lights are confined to Zone 1, which includes the parking lots on either end of the site as well as vehicular road. Zone 3 on the top of the hill destination is passive lights only, such as flashlights that visitors bring in with them. In between are zone 2 with motion-detected, wildlife-friendly warm color lights. The light and dark gradient across the site thus allow for a more comfortable visiting experience.

Lastly, a series of water stone installations are situated across the site, across lighting zone 2 and 3, providing a hint to another major dimension of the site experience.



WESTERN WOOD-PEWEE



WARBLING VIREO



WESTERN TANAGER



SWAINSON'S THRUSH



WILSON'S WARBLER



Image Source: All About Birds & Migration Explorer

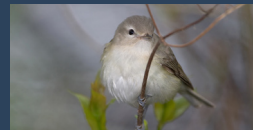
MIGRATION NIGHT TRAIL



WESTERN WOOD-PEWEE



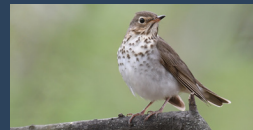
WARBLING VIREO



WESTERN Tanager



SWAINSON'S THRUSH



WILSON'S WARBLER



Upper Trail Entrance

Building

Top of the Hill

Lower Parking Lot Light

Lower Trail Entrance

Hoyt Arboretum Parking Lot Light

Overlook Trail

Building

Small Trail Path Light

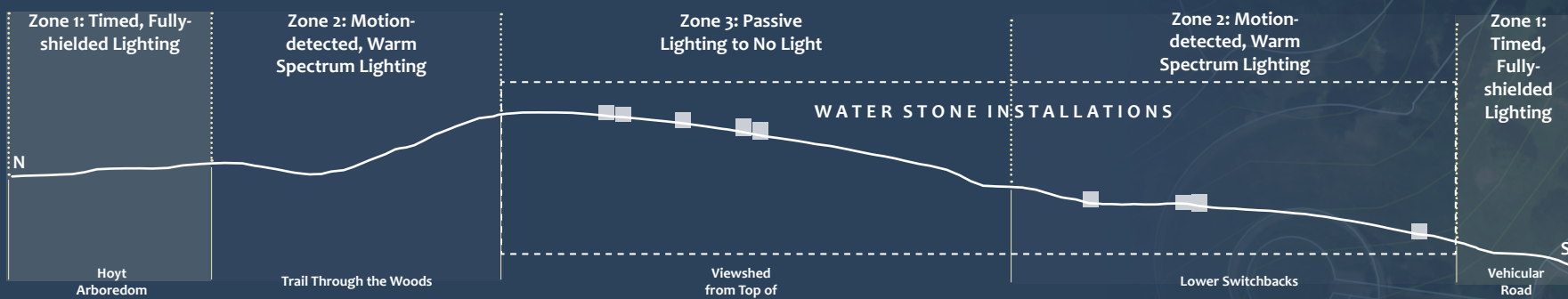


Image Source: (birds) All About Birds; (range map) Migration Explorer

MIRROR STONES



WATER FOR BIRDS AND PEOPLE

“Food, water, shelter” is a metric commonly used to evaluate the ability an environment can meet the needs of wildlife, and indirectly the likelihood for a site to attract them. From the perspective of the selected nocturnal migratory birds, the lack of open water source on site is the most prominent issue but also an opportunity for design intervention. In addition, the discovery of basalt on site, the common idea of bird bath, and the aesthetic of Water Stone by Isamu Noguchi each informs the materiality, function, and experience of my proposed design intervention, the Mirror Stone, which is a series of basalt columns with sculpted tops that hold water. Unlike Noguchi’s work, the Mirror Stone does not have flowing water, and the shapes of the sculpted basin are far from a perfect circle. Instead, it retains rainwater, and the shapes vary according to a different set of rules.

MIRROR STONES



BASALT
COLUMN



MATERIAL
LANGUAGE



BIRD
BATH



DESIGN
FUNCTION



WATER
STONE



EXPERIENCE
PRECEDENT

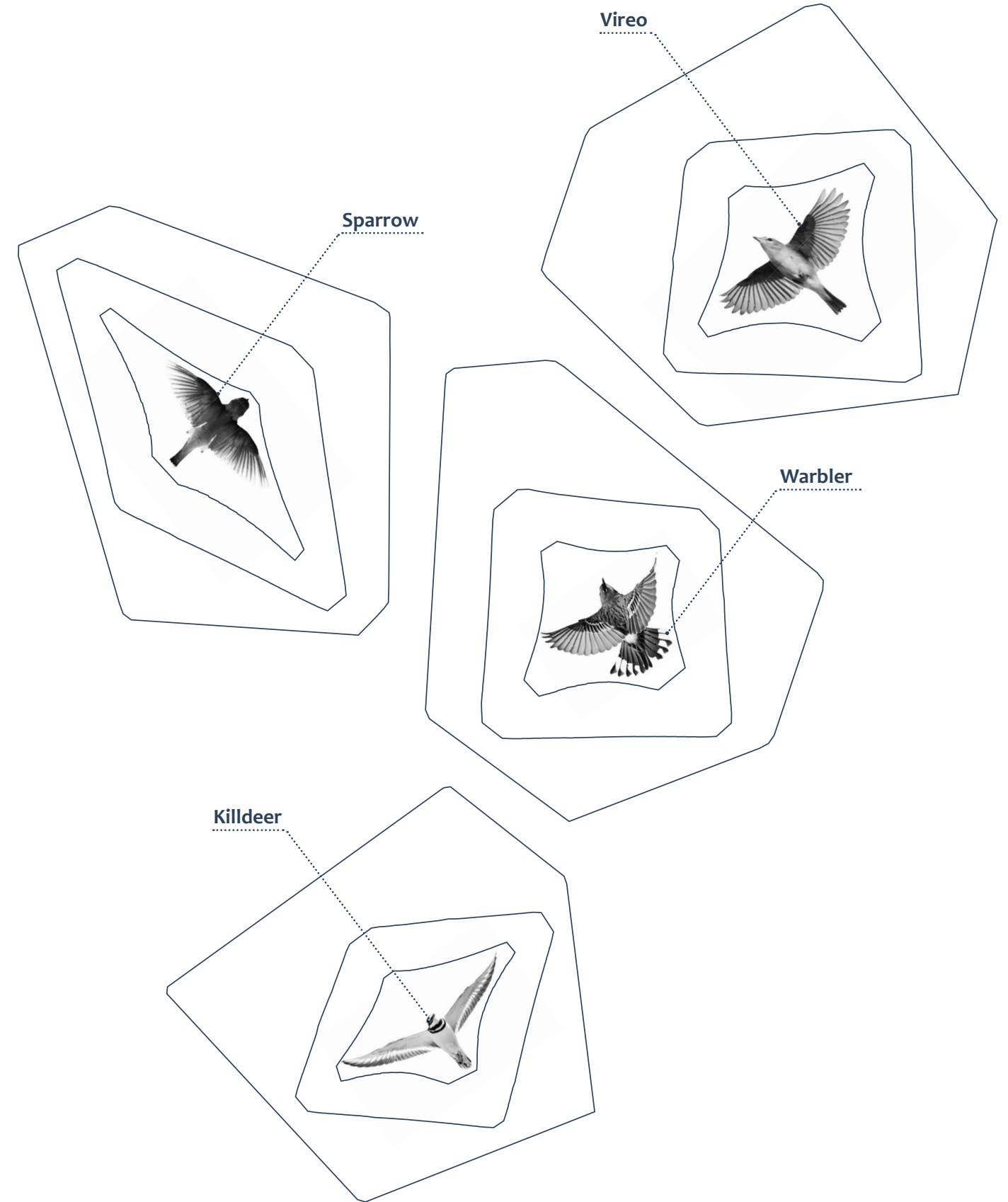


Photo Source: (top) Phoebe Chuang
(middle) <https://www.flickr.com/photos/bobistraveling/5429629511>
(bottom) <https://www.flickr.com/photos/wallyg/1626430943>

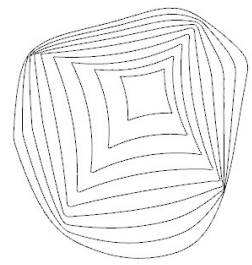
WATER'S EDGE VARIATION

THE MANY SHAPES OF NOCTURNAL MIGRATORY BIRDS

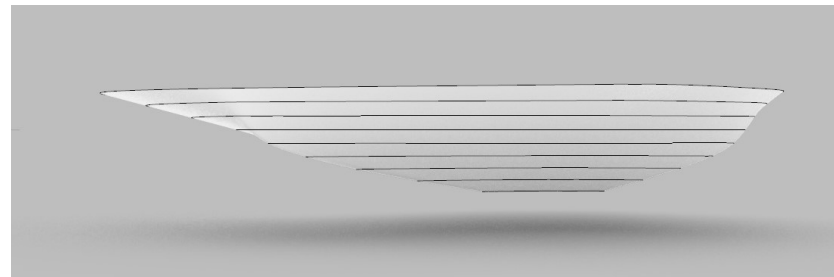
In the early days of radar technology development, migrating birds often appeared as dots on the screen with confusing movements and dubbed as “angels”. This is because a bird’s body can scatter the pulsed microwave back like a raindrop. Taking the idea that birds are just really big raindrops on radar, the basin of the Mirror Stones are designed to resemble shapes of various nocturnal migratory bird species. As the water level changes due to rain or evaporation, the shape of the changing water’s edge adds to the complexity of site experience over time.



WATER'S EDGE VARIATION



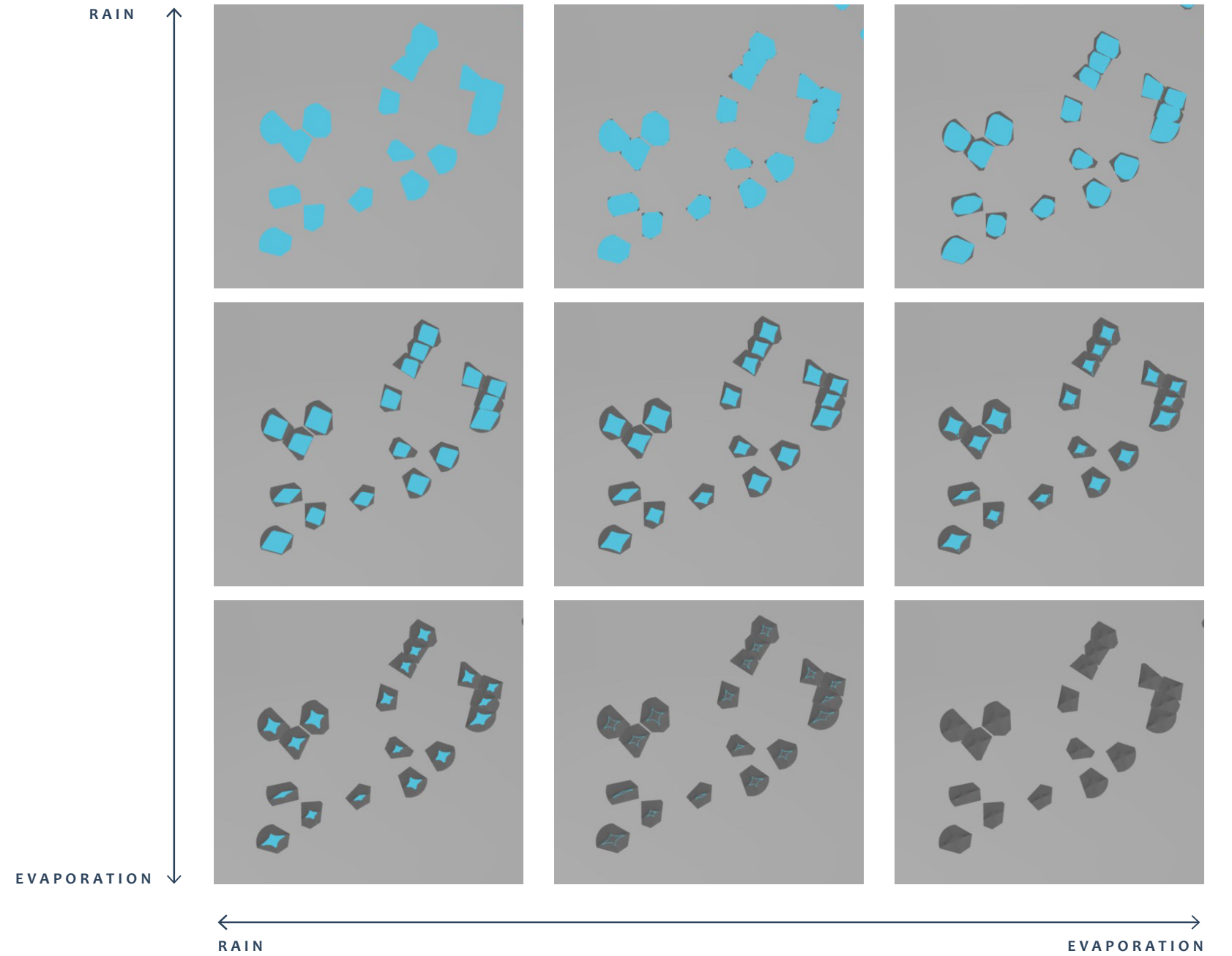
BASIN CONTOUR



BASIN SIDE VIEW



WATER'S EDGE VARIATION PATTERN



WATER MIRRORS

MIRROR SURFACE STUDY



SHADOW TEST



MIRROR STONE CLUSTER MODEL



REFLECTIVENESS STUDY

FROM REFLECTION TO SHADOW

Given the water surface's ability to reflect lights and mirror its surroundings, the next step of the design iteration was to test how not one, but multiple Mirror Stones would impact the site experience, specifically the reflections and shadows. When looking at the surface of the water at specific angles against the light, the reflective sheen of the water and at some point, a mirror image of the background should be visible. Together with the reflective surfaces of the water, these design elements provide ways to highlight natural light sources not only during the day, but also at night, such as the moon.



MIRROR STONE CLUSTERS DURING THE DAY

WATER MIRRORS



MIRROR STONE CLUSTERS AT NIGHT

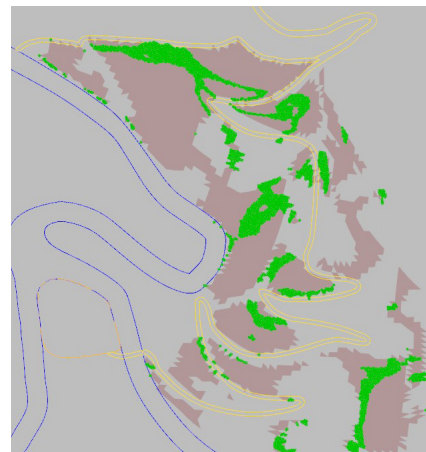
FLOCKS IN THE LANDSCAPE

MIRROR STONE PLACEMENT METHODOLOGY

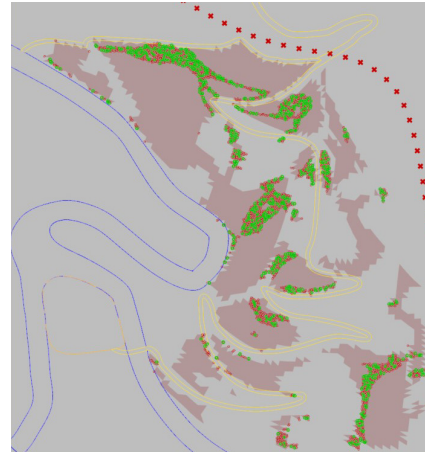
The last step of the design process is to place these Mirror Stones across the site. Canopy cover was first to be considered, followed by slope. In order to not take up valuable flat spaces, the stones were placed up and down the hills where the slope is between 17 to 21%. Then, sky view availability is used as further selection logic to maximize the stone's exposure to the night sky. The overall form of Mirror Stone installation thus magically resembles a flock of migrating birds' midflight. Lastly, specific positioning of the basin in relation to the landscape allows the water's edge to constantly point to the Top of the Hill location, symbolizing the birds' repeated arrivals and departures to the site. The reflected lights off the Mirror Stones highlight such movement across the landscape.



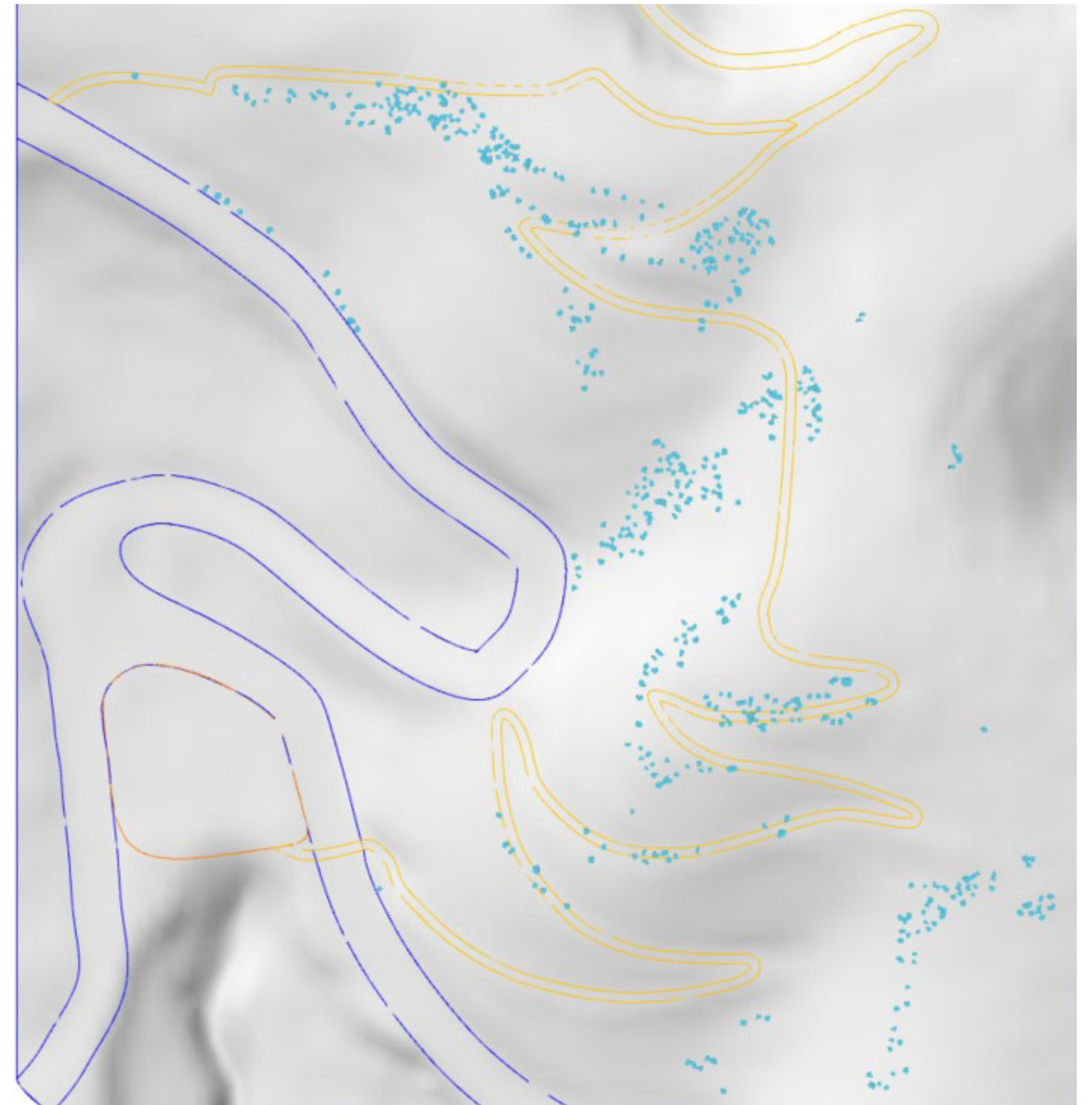
NO CANOPY COVER



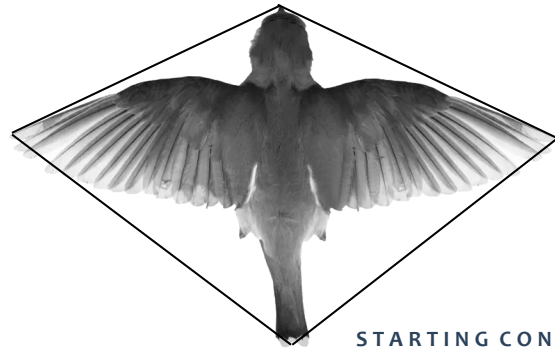
NO CANOPY COVER
+
SLOPE = 17 ~ 21%



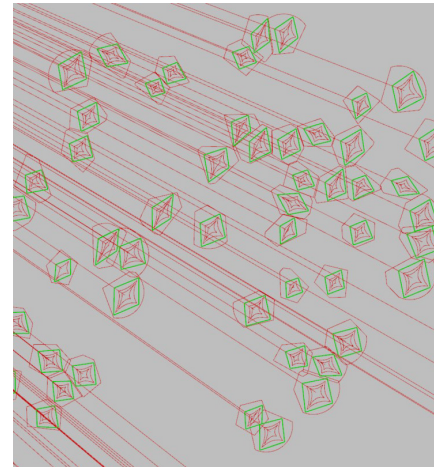
NO CANOPY COVER
+
SLOPE = 17 ~ 21%
+
DISTANCE TO
HIGH SKYVIEW
AVAILABILITY ZONE



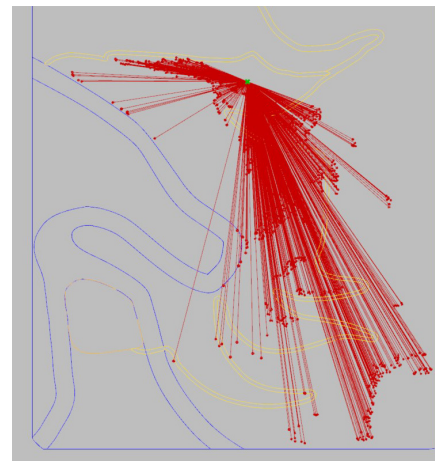
FLOCKS IN THE LANDSCAPE



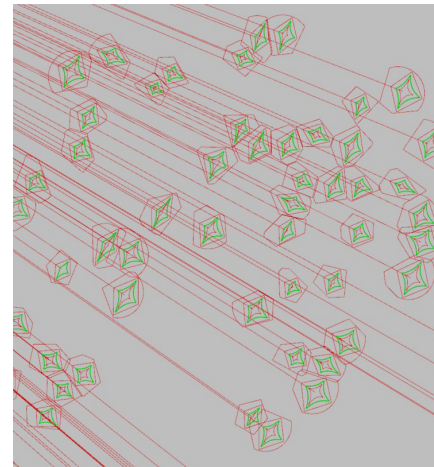
STARTING CONCEPT



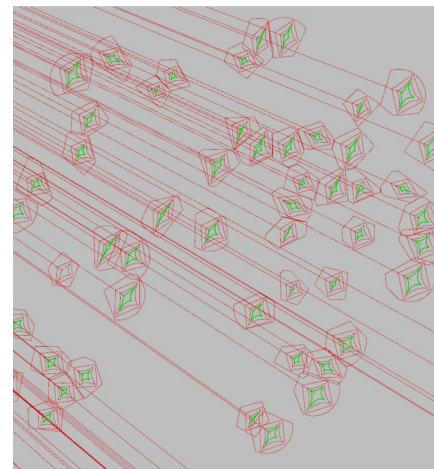
ALIGN 1ST BASIN CONTOUR



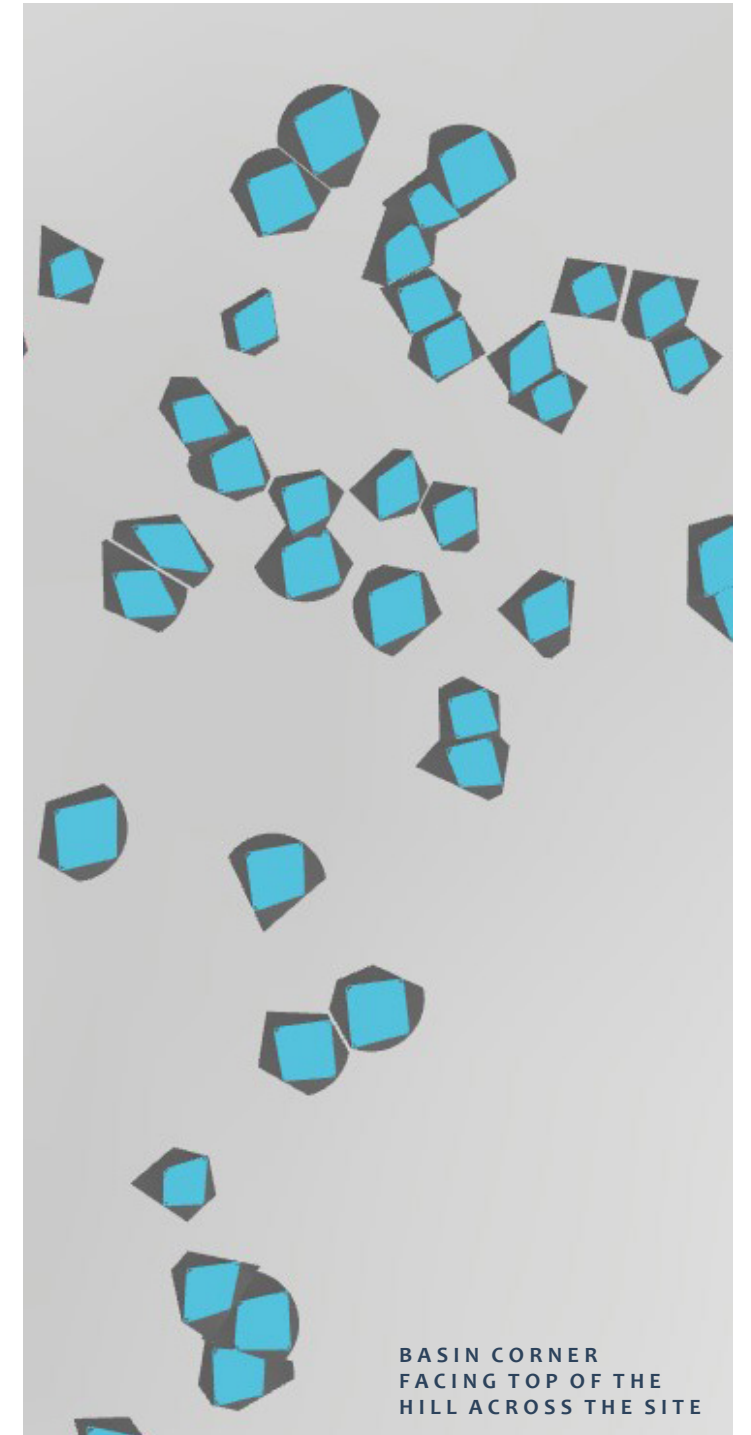
ATTRACTOR ON TOP OF THE HILL



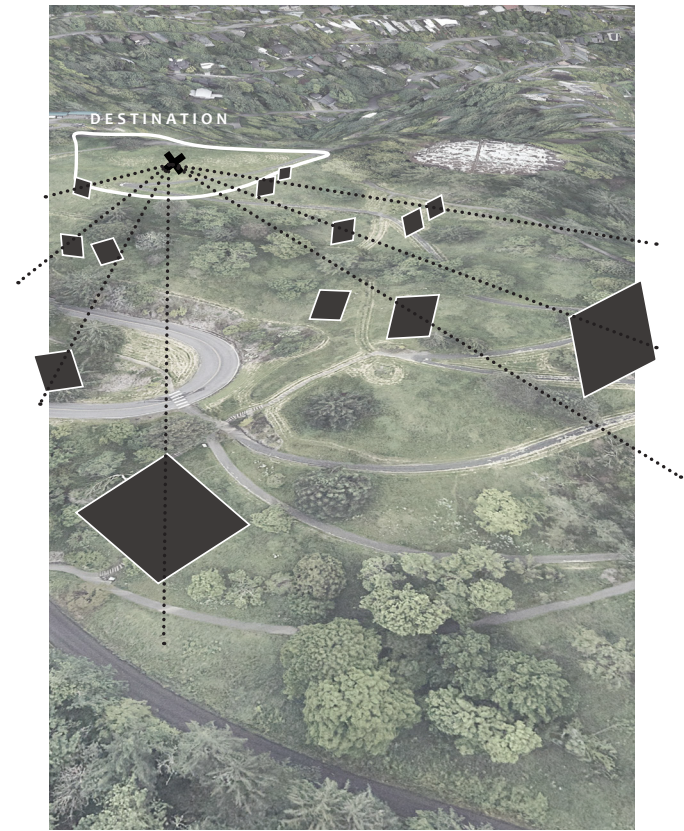
ALIGN 2ND BASIN CONTOUR



ALIGN 3RD BASIN CONTOUR



BASIN CORNER FACING TOP OF THE HILL ACROSS THE SITE

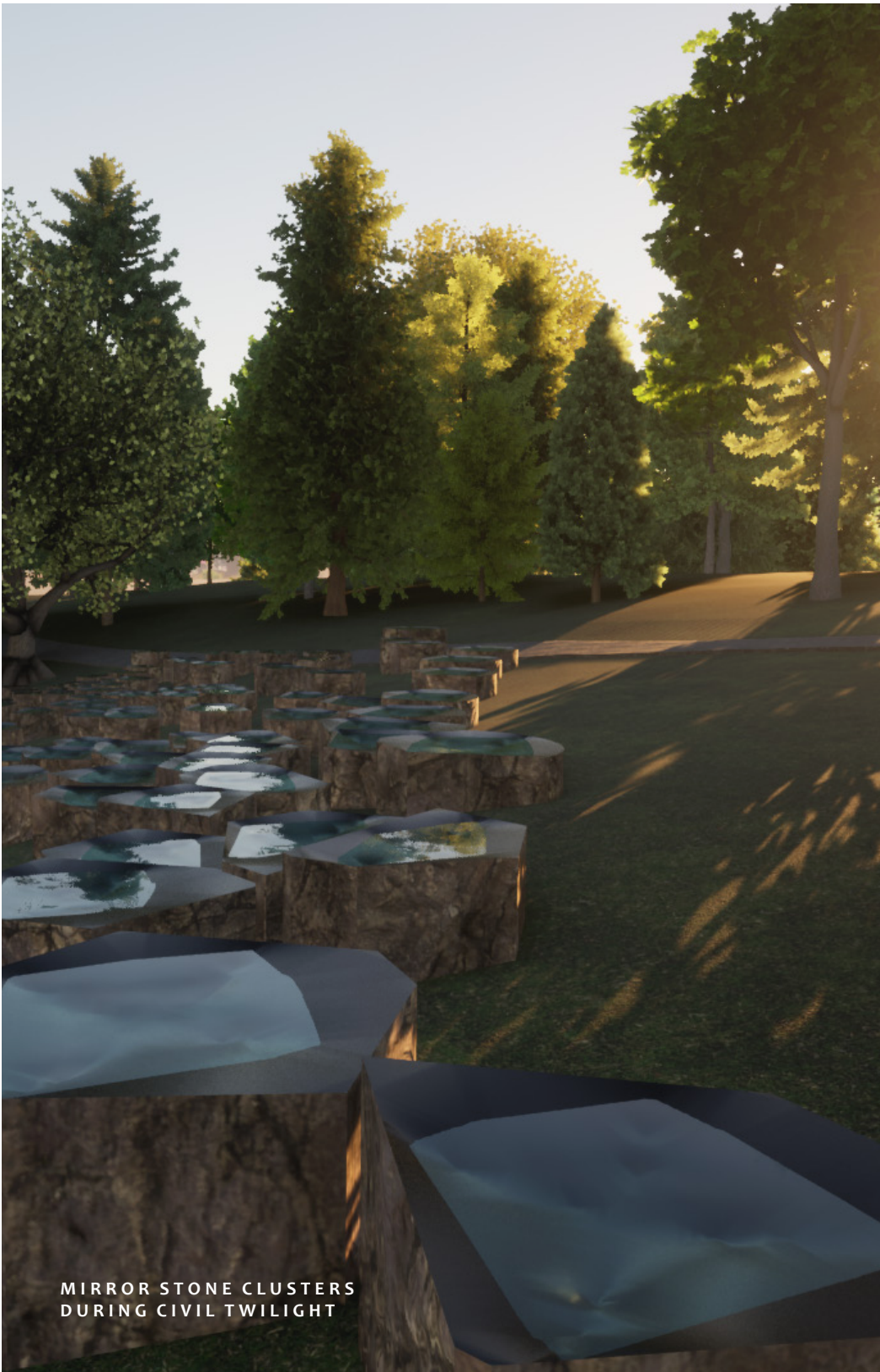


DESIRED OUTCOMES

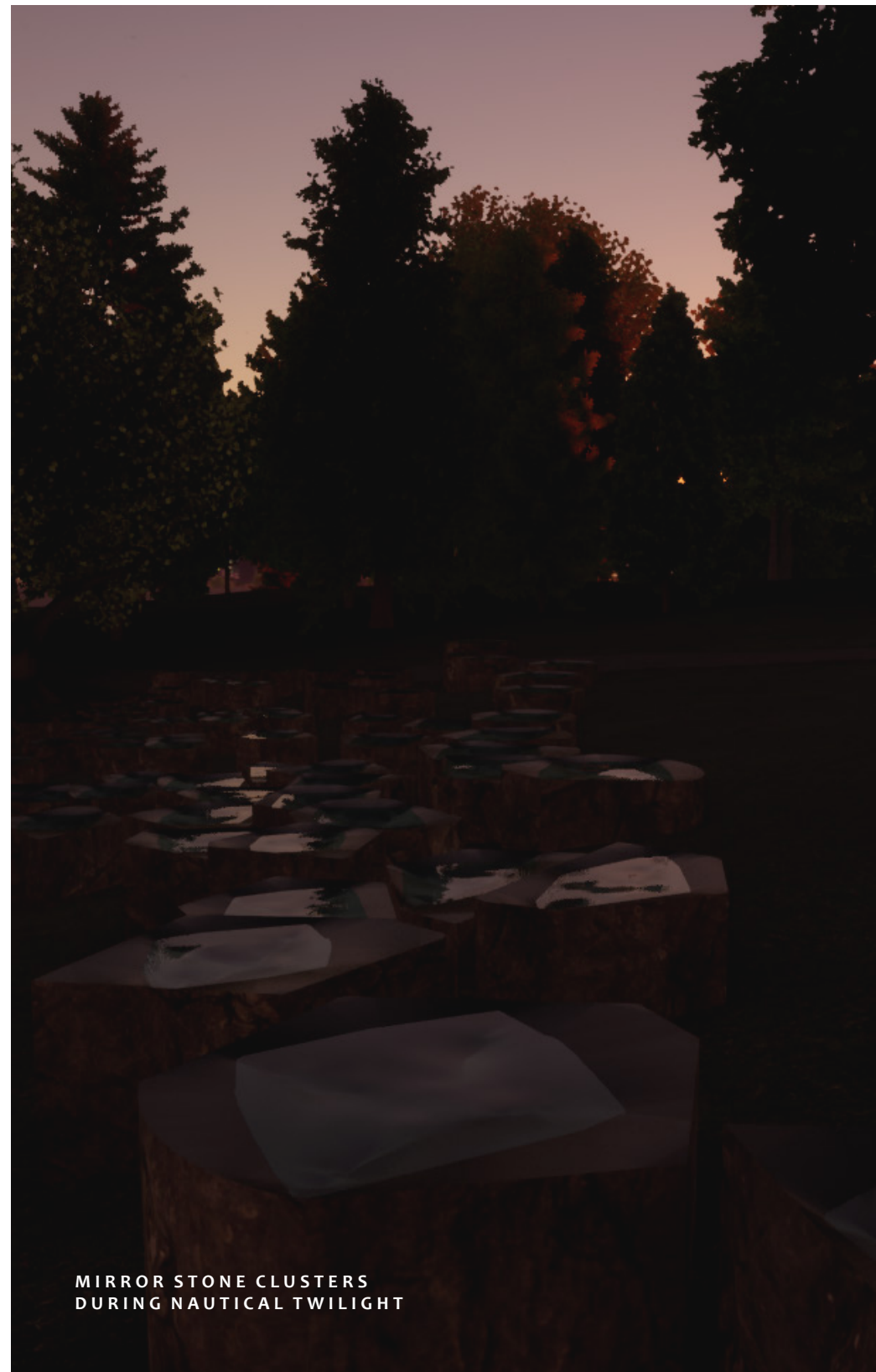
DESIGN PROCESS

RESULTING FORMATION

SITE EXPERIENCE



MIRROR STONE CLUSTERS
DURING CIVIL TWILIGHT

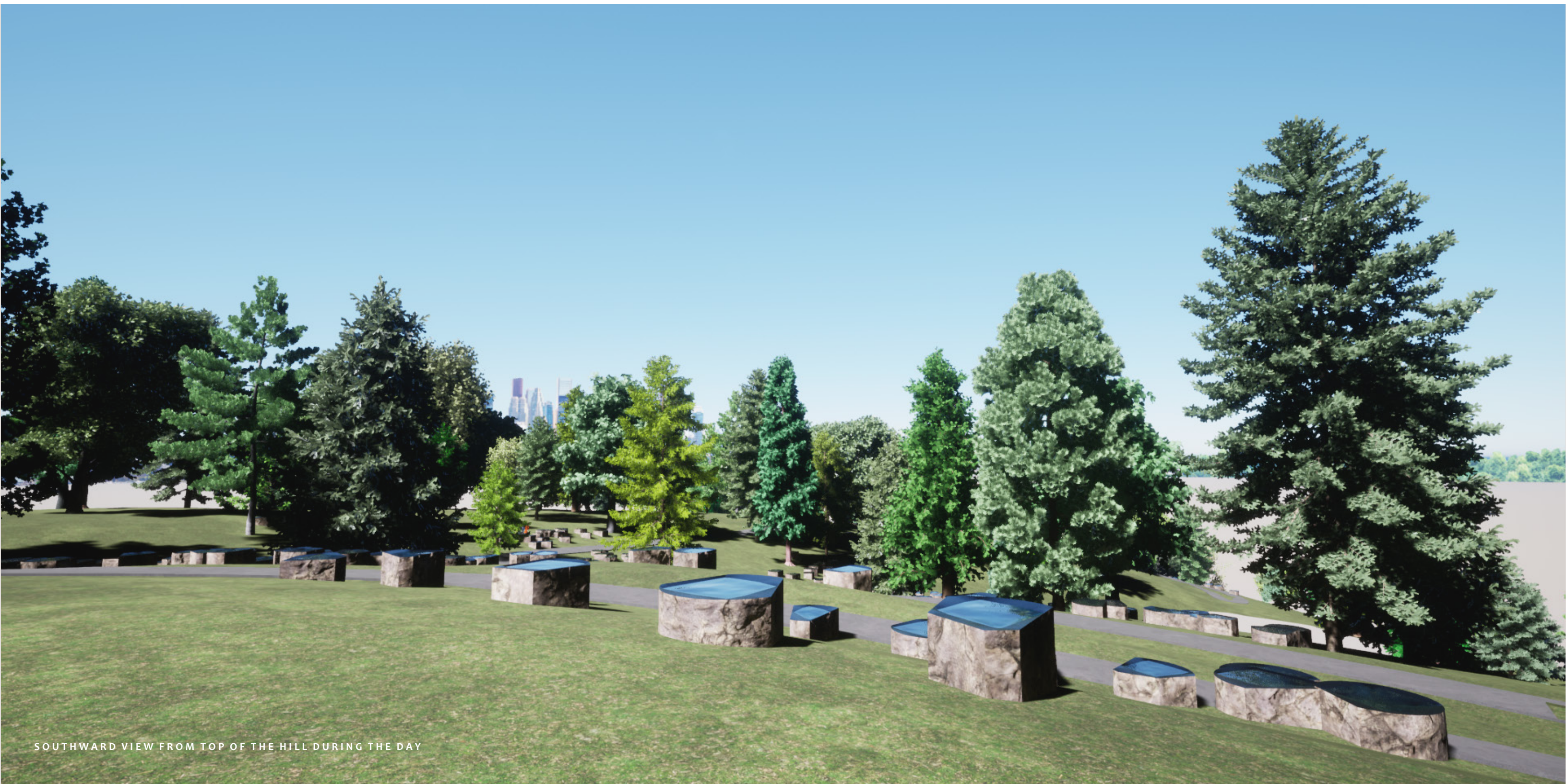


MIRROR STONE CLUSTERS
DURING NAUTICAL TWILIGHT



MIRROR STONE CLUSTERS
ON A MOONLIT NIGHT

SITE EXPERIENCE



SOUTHWARD VIEW FROM TOP OF THE HILL DURING THE DAY

SITE EXPERIENCE



SOUTHWARD VIEW FROM TOP OF THE HILL AT SUNSET

SITE EXPERIENCE



SOUTHWARD VIEW FROM TOP OF THE HILL ON A NIGHT OF FULL MOON

THE FUTURE

AS YOU CLOSE YOUR EYES AND BRACE FOR THE CRASH, YOU ARE MET WITH THE SOUND OF BLOWING WIND AND YOUR OWN HEARTBEATS. BUT NO IMPACT. OPENING YOUR EYES AGAIN, THE MOON AND STARS ARE HANGING RIGHT ABOVE, SO CLOSE THAT YOU CAN ALMOST TOUCH IT. THE LAND UNDERNEATH STRETCHES ALL THE WAY TO THE HORIZON, VEILED IN A GRADIENT OF DARKNESS WITH OCCASIONAL GLISTENING FROM WATERBODIES. THE SCENERY UNFOLDED IN FRONT OF YOU PROVOKED A SENSE OF FAMILIARITY, EVEN THOUGH YOU HAVE NEVER BEEN TO THIS PART OF THE WORLD BEFORE. YOU HAVE ARRIVED AT A PLACE YOU CAN CALL HOME.



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