ECOLOGICAL THRESHOLDS

Designing for Human-Nature Coexistence in a Post-Industrial Landscape

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Master's Thesis 2026
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THANK YOU !

Ilse and Oskar for continuous guidance, feedbacks and support throughout my thesis. Their assistance with data, expertise in the field and weekly discussions were key part to shaping analytical and design direction of this research.

Meta for encouragement and constructive feedbacks which has helped strengthen the research.

My family and friends for their continuous support, motivation and encouragement along this journey.

CHALMERS
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Master's Thesis 2026

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Abstract

Rapid urbanisation is resulting in fragmented ecological networks and growing disconnection between human and nature that challenges well-being in cities. Whereas post-industrial landscapes are identified as important socio-ecological systems with potential to support coexistence. A lot of conservation strategies are based on strict protection and human exclusion limiting opportunities for interaction and supporting spatial separation. This thesis explores the gap between ecological conservation and human engagement and how design can mediate this relationship. It looks at Limhamn kalkbrott in Malmö, a limestone quarry that is now a protected ecological hotspot but remains physically and socially inaccessible from the surrounding.

This thesis aims to explore how redesigning the edge of Limhamn kalkbrott as an ecological threshold can transform post-industrial landscapes into catalysts for ecological resilience and human well-being. The main research question asks ***How can post-industrial quarries such as Limhamn kalkbrott be redesigned to function as a shared habitat for both humans and nature in Malmö, Sweden ?*** A combined method approach of street network analysis to evaluate pedestrian movement and accessibility with habitat network analysis to model ecological connectivity for selected species : green toad, roe deer and eurasian eagle owl. These are overlapped to identify zones of protection, conflict, coexistence, and experiential. Two future scenarios - ecological priority and human access priority are developed and evaluated based on human and ecological systems.

The findings show that redesigning the quarry edge as a gradient rather than barrier can enhance ecological connectivity while allowing controlled human access. The concept of ecological threshold can allow spatial strategies to reduce habitat fragmentation, pedestrian flow and promote multispecies coexistence. The research contributes to landscape architecture by developing a threshold based design framework that transitions from analytical findings into threshold strategies. It focuses on the potential of post-industrial landscapes as shared habitat and proposes a transferable approach to improve ecological connectivity and human-nature relationship in urban contexts.

Keywords:
Post-industrial landscape, shared habitat, human-nature relationship, ecological connectivity , pedestrian movement.

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1 | Introduction

This chapter introduces the research background and objectives of this thesis. It starts outlining the broader challenges that relate to urban ecological fragmentation and the changing relationship between human and nature. In order to understand the emerging potential of post-industrial landscapes as socio-ecological opportunities, case study of limhamn kalkbrott is done to define the research gap, aim and research questions.

1.1 Background

Urban ecological crisis and the fragmentation of nature

Rapid urbanisation has changed ecosystems, which causes biodiversity loss, habitat fragmentation and growing gap between human and nature. Cities are largely planned by anthropocentric models that have prioritised industrial extraction and control over ecological relationships (Mostafavi,2010 ; Corner, 1999). According to UN-habitat, expansion of cities and redevelopment of land has contributed to decreased access and uneven distribution of urban green spaces minimising the ecological capacity within cities (UN-habitat, 2024). This fragmentation impacts on ecological resilience at the system level while also changing how humans experience and interact with nature in everyday urban life. A connected urban green network is becoming more important for maintaining ecosystem services like cooling, stormwater management, habitat continuity and climate adaptation (McPhearson et al.,2022). Outside ecological performance, even the decline of accessible and important urban nature has also weakened human-nature relationships.

Human-Nature relationships and urban well-being

Human well-being is basically linked to the health and functioning of the ecosystems. Research has shown that access to ecological rich environments positively contributes to physical health, mental restoration, emotional stability and long term environmental stewardship (Haines-Young &potschin, 2010). However in several urban contexts, nature is experienced either as highly managed recreational spaces or as strictly protected landscape which limits deeper forms of ecological engagement. Human-Nature Connectedness (HNC) research highlights that direct multisensory interaction with natural environment is key to develop environmental awareness, care and environmental behaviour (Lengieza et al.,2023; Kageyama et al.,2024) while this shows that urban landscapes should not only be preserved ecological value but also to create opportunities for humans to experience and develop an understanding of ecological processes that supports care and responsible action. This growing separation between human and ecological systems is not only social but also spatial reflects in how urban landscapes are structured and experienced.

Ecological voids, Rewilding and Post-Industrial landscapes s ecological opportunity

In response to ecological degradation and climate changes, rewilding and urban ecological restorations have emerged as an important approach to rethink several roles of nature in cities. In the past these sites were often seen as degraded or empty, but they have now increasingly become spaces of spontaneous ecological succession and habitat formation. This idea is very important in post-industrial urban contexts, where these ecological voids can function both as refugees for biodiversity. These approaches challenge the traditional division between urban and wild landscapes by identifying cities as hybrid socio-ecological systems which are shaped by both human and non-human processes (McPhearson et al.,2022). Former industrial landscapes are particularly important within this discussion as they are once associated with extractions and environmental degradation. Many post-industrial cities have become important for rare and adaptive species through abandonment and spontaneous succession (Hobbs et al., 2009). The concept of Third Landscape focuses on the ecological value of these neglected and unmanaged spaces and argues that these spaces can be biodiversity reservoirs in cities that control urban environments (Clément,2004). These perspectives reconceptualise ecological voids not as leftover spaces but as key socio-ecological systems able to transform human-nature relationships in cities.

Limhamn Kalkbrott as a Post-Industrial ecological hotspot

Limhamn kalkbrott in Malmö sets an example of an post-indutrial ecological landscape within a growing urban context. A former limestone quarry that has been shaped by mining and industrial production has slowly transformed into an ecological important landscape (Länsstyrelsen Skåne, 2023). The quarry is now an important habitat for protected species and ecological hotspot within the city. But its steep edges and protected status create a strong spatial barrier between quarry and surrounding neighbourhood. Therefore limhamn kalkbrott functions both as an ecological hotspot and an urban barrier raising questions about how such ecological voids can transition from isolated protected areas intoi integrated socio-ecological systems within urban fabric.

1.2 Problem description

Limhamn Kalkbrott's main challenge is to balance ecological protection with potential for human engagement. Current conservation methods depend on human exclusion to protect sensitive habitats and species. While this has supported ecological succession and biodiversity it also increases the quarry's role as a barrier within the urban landscape. This creates three key spatial challenges.

I. Conservation vs Connection
Current Ecological protection depends on limiting human access which reduces opportunities for ecological awareness and stewardship.

II. Edges as Barriers
The quarry's steep industrial edges restrict both species movement and human access between the basin and surrounding neighbourhood.

III.Visual access without engagement
Nearby residents can observe the quarry but cannot meaningfully interact with its ecological qualities.

1.3 Research Gap

Existing research has recognised quarries and post-industrial landscapes as novel ecosystems with significant ecological values (Hobbs et al.,2009). Research on human-nature connectedness also shows the importance of direct interaction with nature for environmental behaviour and well-being (Kageyama et al.,2024). However there remains a lack of design oriented research which translates ecological knowledge and human-nature interaction theory into spatial strategies for post-industrial landscapes. Particularly there is limited research on how quarry edges and ecological thresholds can be spatially designed to support coexistence between human access and ecological integrity. This thesis will focus on this gap by evaluating how the quarry edge can be reimagined not as a barrier but as a ecological threshold.

1.4 Aim

To address this research gap, this thesis aims to explore how redesigning the edge of Limhamn kalkbrott as an ecological threshold can transform post-industrial landscapes into catalysts for ecological resilience and human well-being.

1.5 Research Questions

The Main Question is -

How can post-industrial quarries such as Limhamn Kalkbrott be redesigned to function as a shared habitat for both humans and nature in Malmö, Sweden ?

This question is supported by two sub-question -

Q1. What are the possible impacts of changing the quarry's edge on human accessibility and habitat connectivity ?

Q2. What spatial design principles and strategies can be applied to redesign Limhamn kalkbrott for human-nature interaction ?

1.6 Delimitations

In order to answer these research questions the thesis explores how spatial design principles and stratergies can support both ecological connectivity and human-nature interaction within the specific context of limhamn kalkbrott.

The Thesis will focus on

I. Redesign of quarry edge and immediate threshold zones as socio-ecological intersection.
II. Spatial design stratergies supporting biodiversity resilience and selected species.
III. Spatial accessibility and landscape conditions influencing ecological connectivity and human-nature interaction.
IV. Scenario based exploration of future spatial evidence based strategies
V. The structural and conceptual possibilities of transforming post-industrial edge into shared habitats.

The thesis will not focus on

I. Masterplan for the wider city of Malmö
II. Detailed technical investigations on soil and water analysis.
III. Full ecological field surveys and long term species monitoring.
IV. Exact material specifications and maintenance planning.
V. Long term climate change impacts scenarios.

2 | Theory

This chapter introduces a theoretical basis that will guide the thesis in understanding Limhamn kalkbrott as a socio-ecological system and guide its transformation through spatial design. By reviewing key concepts related to Anthropocene and post-anthropocene thinking, human-nature relationships, ecology and human well-being. Instead of seeing these perspectives as separate discussion, they are used to form a structured framework which informs both analytical methods and design proposal to be developed in chapter 4 and 6.

2.1 Anthropocene And Post-Anthropocence

The Anthropocene is a time when most human activity has a big impact on ecological and geological systems. Landscapes such as quarries are examples of extraction, human control and ecological disruption.

Post-anthropocene authors argue that solving this current moment requires a reconfiguration of the relationship between humans and the more-than-human world. Donna Haraway's concept of "staying with trouble" *(Fig 1)* challenges designers to accept multispecies entanglements rather than wanting to return to an imagined pre-human nature. Bruno Latour's "politics with nature" also breaks down the division between society and ecology by stating that non-human species must be seen as an important actors in shaping shared environments. Timothy Morton's "ecology without nature" *(Fig 2)* questions the division between culture and ecology stating that ecology thinking must go beyond the concept of nature as a third party.

Fig 1 : Multispecies coexistece and entagglement between human and non-human actors (after Donna Haraway, Staying with trouble).

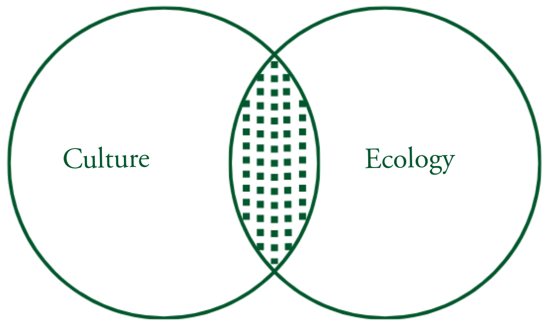


Fig 2 : Conceptual diagram showing ovelap between culture and ecology by defining nature as a seprate third party.

In design discussion these perspectives transform the role of landscape architecture from controlling nature to managing relationships between species, systems and processes. Hence post-industrial landscapes are not seen as weakened remnants but as active ecological systems supporting multispecies coexistence.

2.2 Human, Nature and Multispecies Relationship

2.2.1 Human-Nature Connectedness

Humans and nature are connected in more ways than just being close to each other physically. It involves mental, emotional, moral and sensory aspects. Environmental ethics define this relationship as an interaction between humans and non-humans based on long term well-being and moral responsibility (Saxena et al.,2018). Which means that humans are also part of ecological systems, rather than just who observe from outside.

Human-Nature Connectedness (HNC) framework *(Fig 3)* is used to understand this relationship through six dimensions: material, experiential, cognitive, emotional, philosophical and anthropocentric (Kageyama et al.,2024). Research shows that actual interaction rather than limited exposure is important for promoting ecological awareness and environmental behavior (Lengieza et al.,2023). Sensory interaction, emotional resonance and compassion are recognised as key pathways to strengthening HNC.

Multispecies perspectives improve the focus of design beyond human centered approaches by considering non-human species as active participants in shared environments. This changes the design approach from controlling nature to identifying ways of species with various needs and sensitivities to coexist.

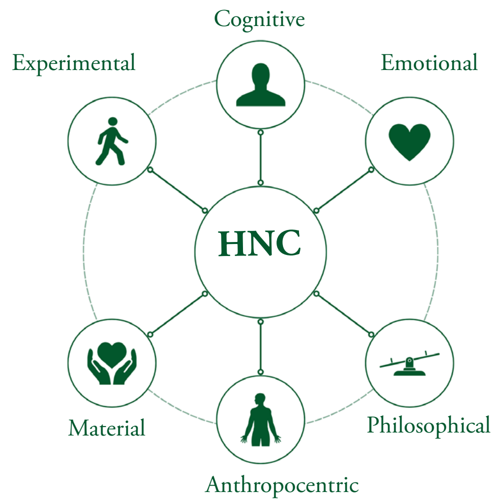


Fig 3 : Human-Nature Connectedness Framework illustrating six dimensions that inform design approaches aiming to strengthen relationship between human and non-human species in a shared environment.

2.2.2 Socio-Ecological systems

Urban environments are being increasingly recognised as socio-ecological systems that influence interactions between ecological processes, human activities and infrastructural systems. The Socio-Ecological-Technical Systems (SETS) framework shows how these components work to produce complex urban landscapes (McPhearson, 2022). Post-industrial landscapes are good examples for this hybrid environment as they are formed by past industrial activity and allow for ecological succession. These landscapes are neither entirely man-made or natural but represent changing systems influenced by human and non-human processes.

2.2.3 Conflict and Coexistence zones

Human - wildlife coexistence theory looks into how humans and non-humans species share space in varying levels of interaction, conflict and separation (Cater & Linnell, 2016 ; Nyhus, 2016). Disturbance ecology defines species responses to human presence through tolerance thresholds. As some species can adapt to human activity while others are very sensitive especially during breeding or nesting.
Rise in spatial conflicts when human activities are overlapped with critical habitats while coexistence occurs where disturbance remains at the minimum threshold. These interactions can be interpreted into spatial categories like protected zone, conflict zone, coexistence zone and opportunity zones, which are used in this thesis as threshold strategies.
Species movement and habitat required to study urban ecological systems.Different species respond to spatial conditions like habitat fragmentation, human disturbance and accessibility in different ways. Therefore amphibians, mammals and birds need specific habitat conditions and connective patterns which must be considered for spatial design to support ecological functionality (Kindvall et al., 2024; Nyhus,2016).

2.3 Ecology, Biodiversity and Habitat connectivity

2.3.1 Habitat Connectivity

Urban biodiversity is based on structure and connectivity of habitats over fragmented landscapes. As habitat fragmentation reduces movement of species, limits gene flow and endangers ecological resilience.
Habitat Network Theory offers a spatial and ecological foundation to understand how species move through fragmented urban landscapes. While using Habitat Network Analysis tool (HNAT) to model Habitat functionality, species movement and ecological corridors. This is relevant for species like amphibians, birds and mammals that rely on semi connected or continuous habitats (Kindvall et al., 2024).
This perspective is particularly related for species with different movement capacities *(Fig 4)* such as amphibians, mammals and birds which forms the basis for evaluating ecological performance within this thesis.

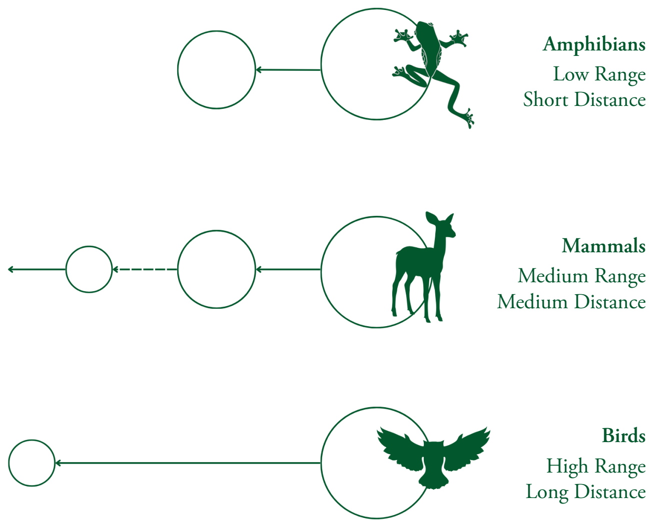


Fig 4 : Diagram illustration of speceis movement with varying range and conncetivity needs with fragmented landscapes.

2.3.2 Thresholds and edges

Edges are the transitional zones between ecological systems that offer high biodiversity and interaction. These zones act as areas of exchange but are too sensitive to disturbance *(Fig 5)*.
Threshold theory continues this concept describing points where ecological systems transiting due to external pressure (Walker & Meyers, 2004). In spatial terms these thresholds can be studied as zones where ecological and human processes interact, conflict or coexist.
Instead of treating these edges as rigid boundaries, they can be redesigned as gradients which connect between protection and access. This idea is central to this thesis where the quarry's edge is reimagined as an ecological threshold rather than barrier.

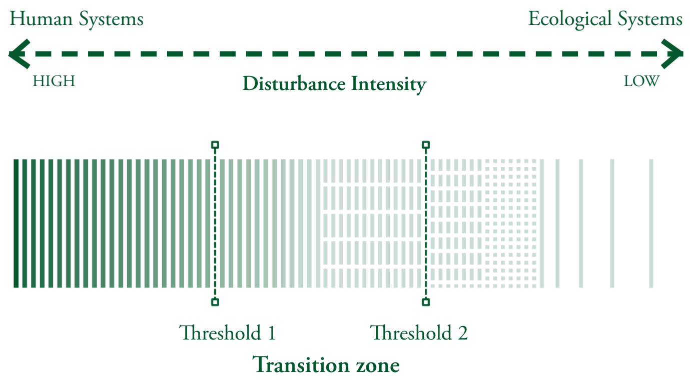


Fig 5 : Conceptual diagram of thresholds showing disturbance intensity between human and ecological systems with transition zone pointng the interaction and change.

2.4 Human well-being, movement and landscape

2.4.1 Human well-being

The health of people is closely linked to how the ecosystem works and benefits provided. Ecosystem services like climate regulation, stormwater management and recreation are directly linked to improved physical and mental health. Research shows that interaction with nature can enhance stress recovery, memory retention and emotional stability (Haines-Young & Potschin, 2010). In urban environments access to such ecological rich landscapes has shown to support stress reduction and emotional well-being.
As discussed in 2.2 human-nature connectedness shows the importance of direct interactions with ecological environments for promoting environmental awareness and environmental behaviour (Kageyama et al., 2024). However in many cities nature is not controlled or protected, limiting opportunities for such interaction.
This indicates an important design challenge how to allow human interaction with ecological systems while preserving their functionality. Therefore within this thesis well-being is understood not only as an outcome of ecological performance but also as an important consideration for spatial design.

2.4.2 Human movement and Network connectivity

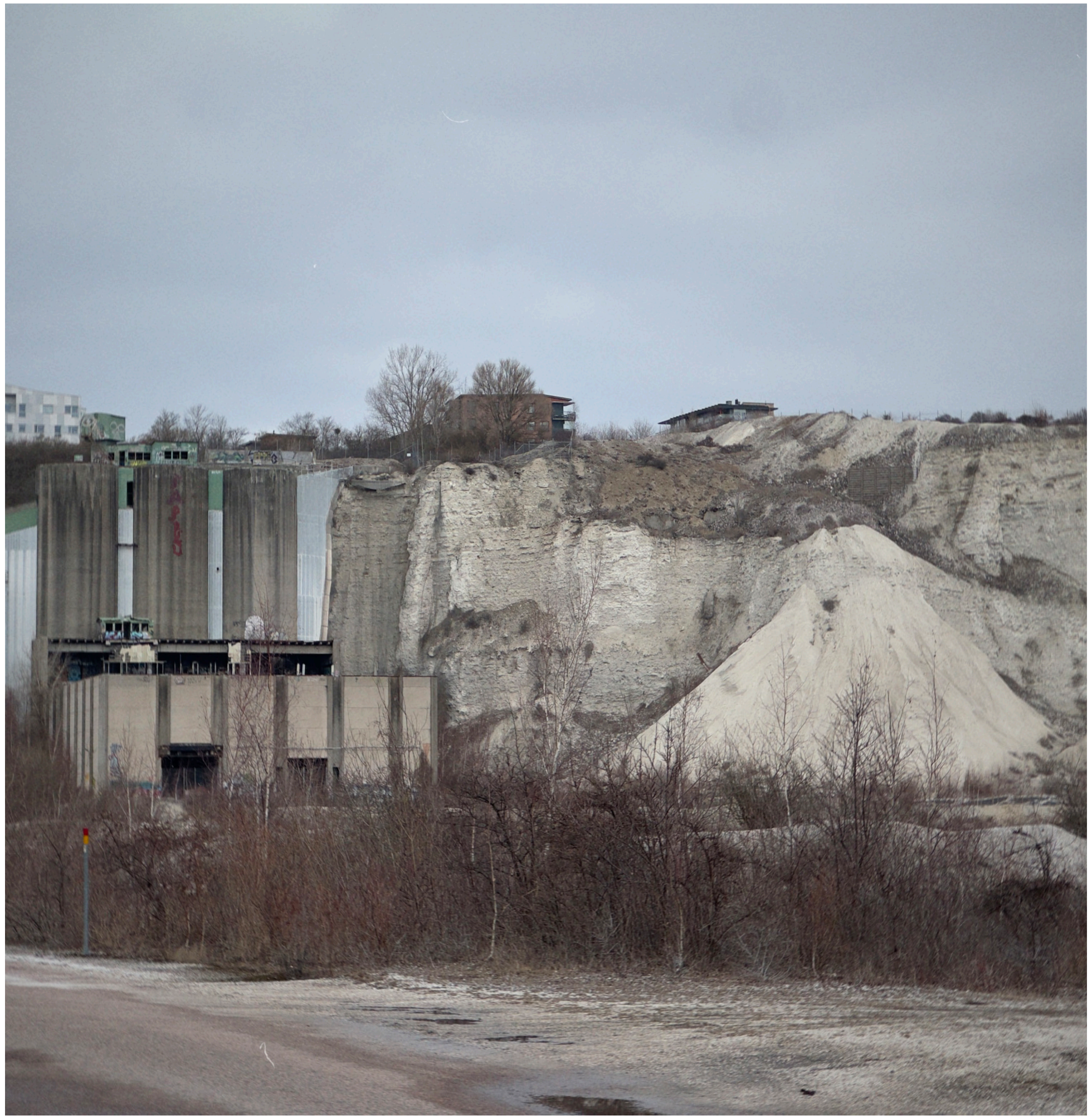
The movement of pedestrians in urban areas is influenced by spatial organisation and connectivity of the street network and not by physical distance (Hiller, 1996). According to the space syntax theory the greater the connectivity and integration of the street attracts greater the movement and accessibility in cities (Hiller & lida, 2005). Some of the indicators used to measure accessibility, movement corridors and spatial barriers in urban networks are angular integration and angular betweenness (Stavroulaki et al.,2023).
Disturbed pedestrian connectivity and spatial barriers between ecological landscape and urban area are due to disconnected edges and industrial infrastructure (Corner, 1999). Therefore spatial connectivity is important to understand movement patterns, accessibility and human interactions with urban landscapes.

2.4.3 Landscape as infrastructure and Spatial organisation

Contemporary Landscape architecture sees landscape more as evolving systems than rigid forms. Landscape is described as infrastructure shaped by ecological processes, flows and temporal changes (Corner,1999). This view changes design from aesthetics criteria to evidence-based approach based on ecological data, spatial analysis and environmental processes.
Spatial organisations shape human movement, perception and interaction within landscape.instead of relying on separation between humans and ecological systems, design can guide behaviour through controlled access, visibility and spatial sequencing (Corner, 1999; McPhearson et al.,2022).
Strategies like elevated pathways, buffers and viewpoints allow human interaction with minimum, this allows for ecological protection and human experience to coexist (Kageyama et al.,2024).

Conclusion

Concepts discussed in this chapter form a design framework that redefines the edge of limhamn kalkbrott as an ecological threshold. This framework will inform the methodological approach of this thesis including accessibility analysis and habitat modelling which in turn guides the development of spatial strategies for design implementation.



3 | Context

In this chapter introduction to ecological and historical context of the study area locating Limhamn Kalkbrott within the wider urban context of Malmö. Will outline the quarry's transformation from an industrial extraction landscape to a protected post-industrial ecological landscape. Further examining the relationship between quarry and surrounding urban fabric. This contextual understanding presents a basis for street network and ecological analysis and develops design scenarios in chapter 4.

3.1 Project Site

3.1.1 Malmö : Urban and Ecological context

Malmö is situated in the south of Skåne region. Historically an industrial port city that is rapidly growing and ongoing transformation from heavy industry to sustainable urban development. Ecologically the city is flat coastal landscape where the region shows agricultural plains, coastal meadows and fragmented habitats supporting various flora and fauna. As the city is densifying, planning strategies focus on integrating waterfront developments, blue and green infrastructures focusing on parks , coastal landscape, wetlands, nature reserves, green roof and streetscapes in dense neighbourhoods (Malmö stad).

3.1.2 Limhamn Kalkbrott : The Limestone Quarry

A large quarry in Limhamn district is an industrial limestone quarry which was used for cement production began in 1866 and continued for a century until it was shut down in 1994 (Malmö stad, 2023). At this time all blasting techniques created stepped terraces and vertical cliffs over the continuous extraction phase. Currently the quarry approximately measures 1,300m length, 800m width and about 65m depth (Länsstyrelsen Skåne, 2023). Due to the quarry's pattern unique landscape environment, steep limestone walls, terraces and water basins create different climate conditions compared to surrounding urban landscapes. Since the quarry lies below sea level regular pumping out of groundwater is required to prevent flooding and harming the habitats in the bottom of the quarry (Malmö stad, 2023).

3.1.3 NATURA 2000 and Biodiversity

The site was allocated as a municipal nature reserve in 2010 and Natura 2000 site (SE0430157) under the EU habitats directive considering its ecological importance (European Environment Agency, 2020) where its a network of protected areas across Europe to safeguard habitats and species considered important. The quarry's condition support a wide range of ecosystems more than 2000+ species of plants, mammals, birds and fungi have been recorded *(appendix 1)* . Conservation importance with some of the rare and red listed key species, for example the European green toad (Bufotes viridis) and Sisymbrium supinum (limestone mustard). Temporary ponds and water bodies within quarry impacts habitats like amphibians and aquatic insects, while the cliffs and open areas attract birds. Conservation efforts are done to maintain the diverse habitats and ecological conditions of the quarry where management looks after visitors, ponds and wetland maintenance with implementing restoration project SemiAquaticLife project (2016-2021) that improves habitats for amphibians and semi aquatic species (Länsstyrelsen Skåne, 2021).

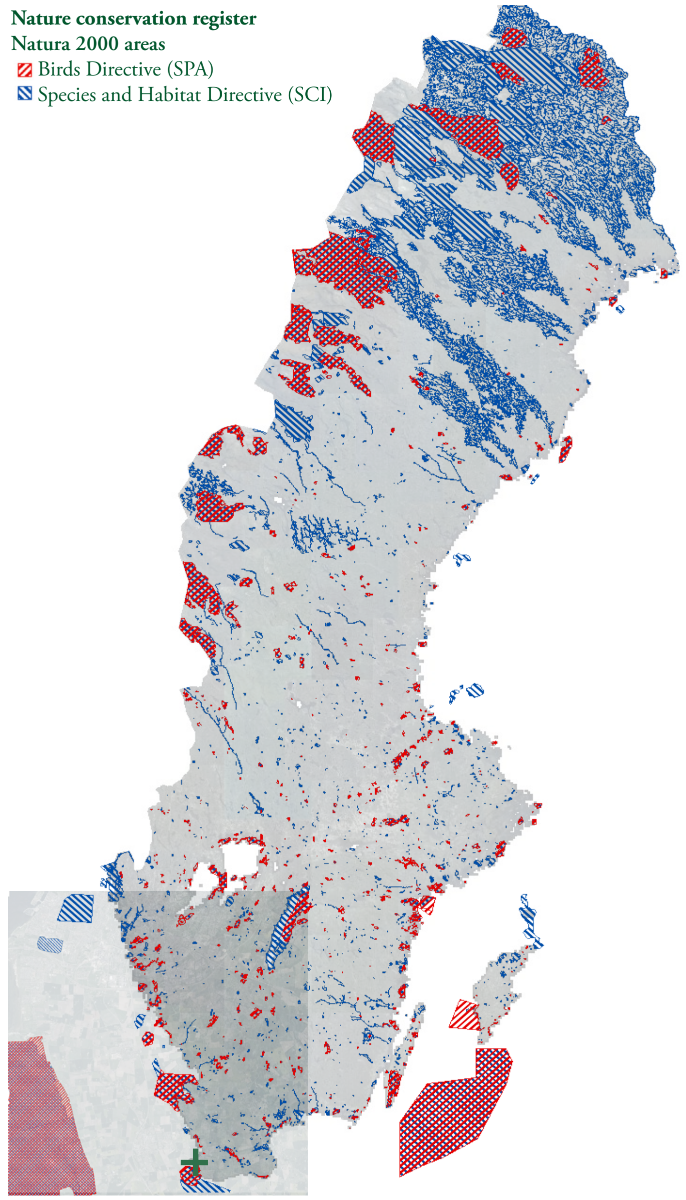


Fig 6 : Natura 2000 sites_Sweden[1:6358569]

3.2 Timeline of Quarry

The history of limhamn kalbrott shows how industrial change and ecological adaptation have always been linked. The site has changed a lot over the years. In the 1600s it was a small-scale limestone extraction and in the 20th century it was used for large-scale industrial quarrying.

When extraction was paused an unexpected ecological succession was seen turning the industrial void into a microclimate incubator for rare species. The timeline is based on historical reports of the quarry by Malmö stad (2023) and Länsstyrelsen Skåne (2021:2025).

Industrial Transformation

Ecological/Species Evalution

Spatial Narratives

1600 - 1850

Small-scale limestone extraction for agriculture and construction around Limhamn.

Sparse flora (coastal grassland and heath vegetation) on calcareous soil.

Human–nature coexistence - early modification of landscape without large-scale disruption.

1866 - 1940

Anthropocene phase

Habitat collapse most flora/fauna disappear (except weeds, pioneer grasses, crows, gulls).

Limhamn Cement Works opens (Skånska Cement AB) extensive quarrying, transport networks built.

1950 - 1980

Massive extraction pits, conveyor systems; artificial plateaus

Cliff species adapt (peregrine falcon, kestrels nest) on quarry edges.
Dust tolerant lichens emerge.

Edge ecologies forms (nature begins adapting to industrial geometries).

1990 - 1994

Beginning of spontaneous ecology succession in ruins of industry.

Insects, amphibians, and grasses recolonize unused zones.
Green toad (Bufo viridis) appears.

Extraction ceases, Closure of quarry. Last major blasting

1998 - 2010

Extraction ceases; groundwater and rain begin forming lakes; access restricted.

Over 1,000+ species emerge: orchids, birches, dragonflies, toads, butterflies.

Ecological resilience, quarry becomes a microclimatic "incubator"

2011 - 2025

Ecological succession

2,000+ species recorded: peregrine falcons, grass snakes, bats, rare butterflies, amphibians, orchids.

Declared a protected site (2011); management by Malmö stad.

2026 - 2100

Thesis focus

What might happen?

3.3 Quarry observation and spatial conditions

*Fig 7 : Observed site conditions_*

The site visit helped to understand existing habitats, restricted access conditions, circulation routes within limhamn kalkbrott. Observation of cliff edges, industrial remnants, wetlands systems, spontaneous vegetation informed the design process by defining areas of ecological sensitivity, potential human access points and certain threshold conditions used to develop zoning and edge strategies.

- edge park circulation
- viewpoints
- ponds
- vegetation succession
- shrubland
- wetlands

*Fig 8 : Industrial remains and Extraction Infrastructure_*

Fig 11: Water retention pond

Fig 9 : Traces of Industrial activity_repainted and maintained

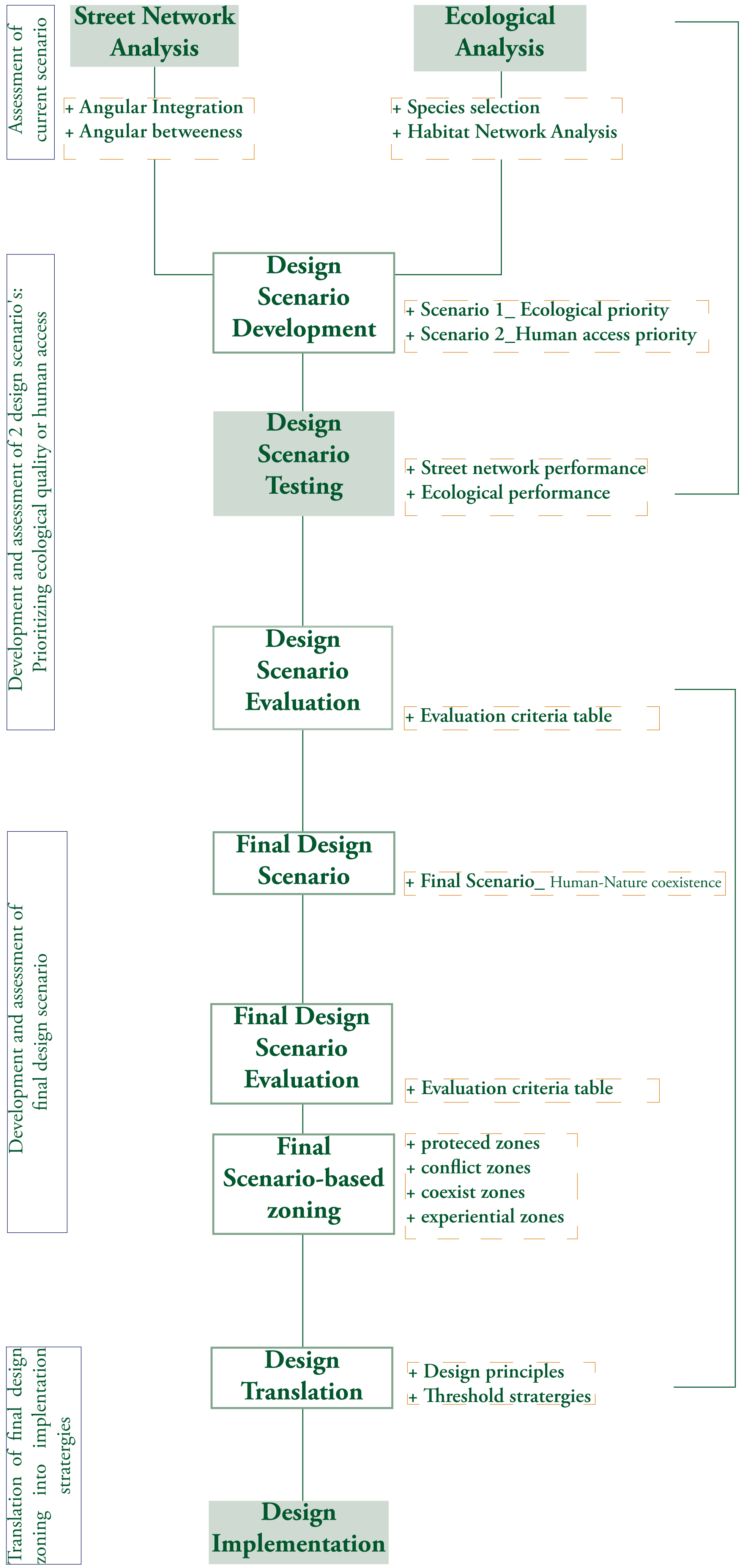
Fig 12 : protected quarry edge and restricted access

Fig 10 : Water pumb pipe and vegetation along cliff edges

Fig 13 : Habitat diversity within quarry basin

4 | Method

This chapter will focus on the methodological framework used to redesigning the edge of Limhamn Kalkbrott would impact ecological connectivity and human-nature interaction. The method combines street network analysis, habitat connectivity analysis and design scenario testings and evaluation. It is approached by combining two analytical tools, street network analysis with PST tool and Habitat connectivity analysis with HNAT.



Q1. What are the possible impacts of changing the quarry's edge on human accessibility and habitat connectivity?

Q2. What spatial design principles and stratergies can be applied to redesign Limhamn kalkbrott for human-nature interaction?

4.1 Street network analysis

The analysis begins with understanding how spatial configurations of the street network around limhamn kalkbrott can influence accessibility, movement patterns and mainly the potential interaction between humans and quarry landscape. The main focus is to examine how spatial changes within the quarry threshold could change the way people access and experience the site.

Through Space syntax quantitative assessments of centrality and integration are used to measure how different segments of the street network (non_motorised) relate in terms of distance, connectivity and route choice. This approach can identify areas where quarry is currently acting as spatial barrier and possible new locations to improve accessibility. The detailed PST analysis settings is provided in *appendix 2*.

4.1.1 Angular Integration

Measures accessibility of each street segment within the network to all other segments with least angular change. This approach is based on space syntax theory where movement is considered to follow paths that minimise directional change rather than pure metric distance (Hiller, 1996).

The analysis is conducted at 1 km and 2 km radii is used to evaluate pedestrian scale accessibility within the urban context. These radii are commonly used in urban analysis to reflect local and neighbourhood patterns (Starvoulaki et al.,2023). The network is weighted by segment length to reflect the impact of longer street segments within pedestrian patterns.

In relation to Limhamn kalkbrott this analysis is used to identify accessible areas around the quarry edge, street network discontinuities in which the quarry cuts off the network and potential points to improve connections for pedestrian access.

4.1.2 Angular Betweenness

Measures the degree to which a street segment is part of the shortest angular paths allowing movement through the network (Hiller & lida, 2005).

The analysis is conducted at 1 km and 2 km radii is used to evaluate pedestrian movement patterns at both local and neighbourhood scales. High betweenness values shows that segments are key connectors or movement corridors in the network. Low values identify segments with limited movement through or peripheral roles.

In relation to limhamn kalkbrott this analysis is used to identity primary pedestrian movement corridor around the quarry, understand the pattern of flow in relation to the quarry edge and strategic points where new connections could affect movement pattern.

4.2 Ecological analysis

This study applies a species specific approach to understand the ecological complexity of the quarry's landscape. Where the analysis focuses on how selected species move through the quarry, what habitat conditions do they require in order to survive, reproduce and maintain connectivity. Initial qualitative research led to identifying relevant ecological data with species information since the quarry has developed into a significant ecological habitat, encouraging a different variety of species which is necessary to evaluate movement patterns along and around its edges.

Fig 14 : Green Toad (Bufotes viridis)

Fig 15 : Roe Deer (Capreolus capreolus)

Fig 16 : Eurasian Eagle Owl (Bubo bubo)

4.2.1 Species Selection

However to represent this ecological complexity of Limhamn kalkbrott and the surrounding landscape, three representative species groups are selected, each consisting of different habitat requirements and movement capacities. The Green toad is selected due to its rare and conservation importance, Roe deer represents common terrestrial mammals and Eurasian eagle owl for quarry specific cliff and nesting habitat.

1.Amphibians are very sensitive to habitat fragmentation as well as changes in aquatic conditions which makes them key indicators of habitat connectivity. In the quarry population of rare species like green toad (Bufotes viridis) and other semi aquatic fauna present in quarry are related to wetland habitats (Malmö stad, 2024) these movements between dispersed aquatic areas show permeability and quality of landscape which guides to analyse aquatic terrestrial linkages and pond networks for breeding (Länsstyrelsen Skåne, 2025).

2.Mammals such as roe deer (Capreolus capreolus), hare (Lepus spp.), fox (Vulpes vulpes) and several bat species use the quarry mosaic of open ground and edge habitats. While these mammals move in different scales in the quarries, slopes give a better idea of how territorial connectivity works inside and outside quarries threshold (Malmö stad, 2024).

3.Nesting birds depending on nesting sites or vegetation structures show different types of habitat connected across vertical and horizontal gradients of the quarry. As limhamn kalkbrott supports variety of nesting birds that include western mash harrier (Circus aeruginosus), peregrine falcon (Falco peregrinus), Eurasian eagle owl (Bubo bubo) and other waders connected with reed beds, broken rock faces and water margins (Länsstyrelsen Skåne, 2021;Malmö stad, 2024). Their flight patterns and habitat use show how different environments in quarries like aquatic, grassland and vertical cliff edge areas are connected to help understand how serial and terrestrial networks work together in conservation landscapes .

4.2.2 Biotopes of Malmö

For a better understanding of the ecological patterns at limhamn kalkbrott it is necessary to examine spatial distribution of biotopes within the Malmö region. By looking at the species observation we can assume that recorded species are usually found in biotopes or habitat patches that suit them. To represent the biotope information for Malmö data were obtained using raster datasets from Swedish land cover map (NMD), each pixel value matches the biotope code which indicates exact habitat type at the location.

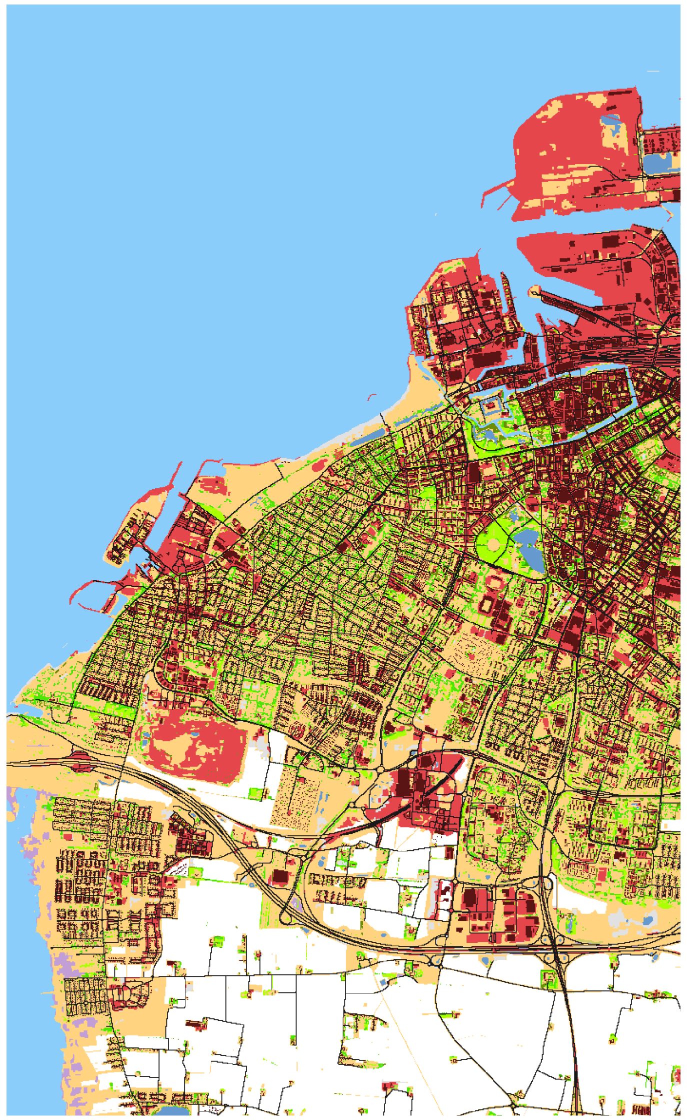


Fig 17: Unprocessed biotope map_ 1:100000_National Land Cover Database

4.2.3 Preparation of ecological data inputs

To run the Habitat Network Analysis using HNAT tool certain input data are prepared in two main parts: a biotope map and a parameter table where these datasets form the foundation for modelling habitat functionality and species movement.

1. Biotope map Study shows predictability of species habitat functionality and dispersal in the network model is sensitive to habitat type representation in biotope map (Kindvall et al., 2024). Hence these biotopes were categorized reflecting on the habitat conditions present in and around Limhamn kalkbrott where the base land cover dataset was refined identifying biotopes that are applicable to the selected species. The biotope map was received from O. Kindvall (personal communication, February 2026), and was originally based on Naturvårdsverket. (2020). The base map was enriched with elevation data (Lantmäteriet., n.d.) and ponds (City of Malmo, 2026). The non-motorized street network was retrieved from OSM (OpenStreetMap contributors, 2026) as shown in *(Fig 18)*

2. Parameter table Biotope map will then be linked to a parameter table in the form of a spreadsheet where the tables are allocated ecological parameters to each biotope code (raster dataset). These parameters will define how species interact with specific habitat types. Each of these parameters differs for the selected species group as shown in *(Fig 19)*. The parameter values were from previous research on selected species by Oskar Kindvall and Ilse Ellenbroek.

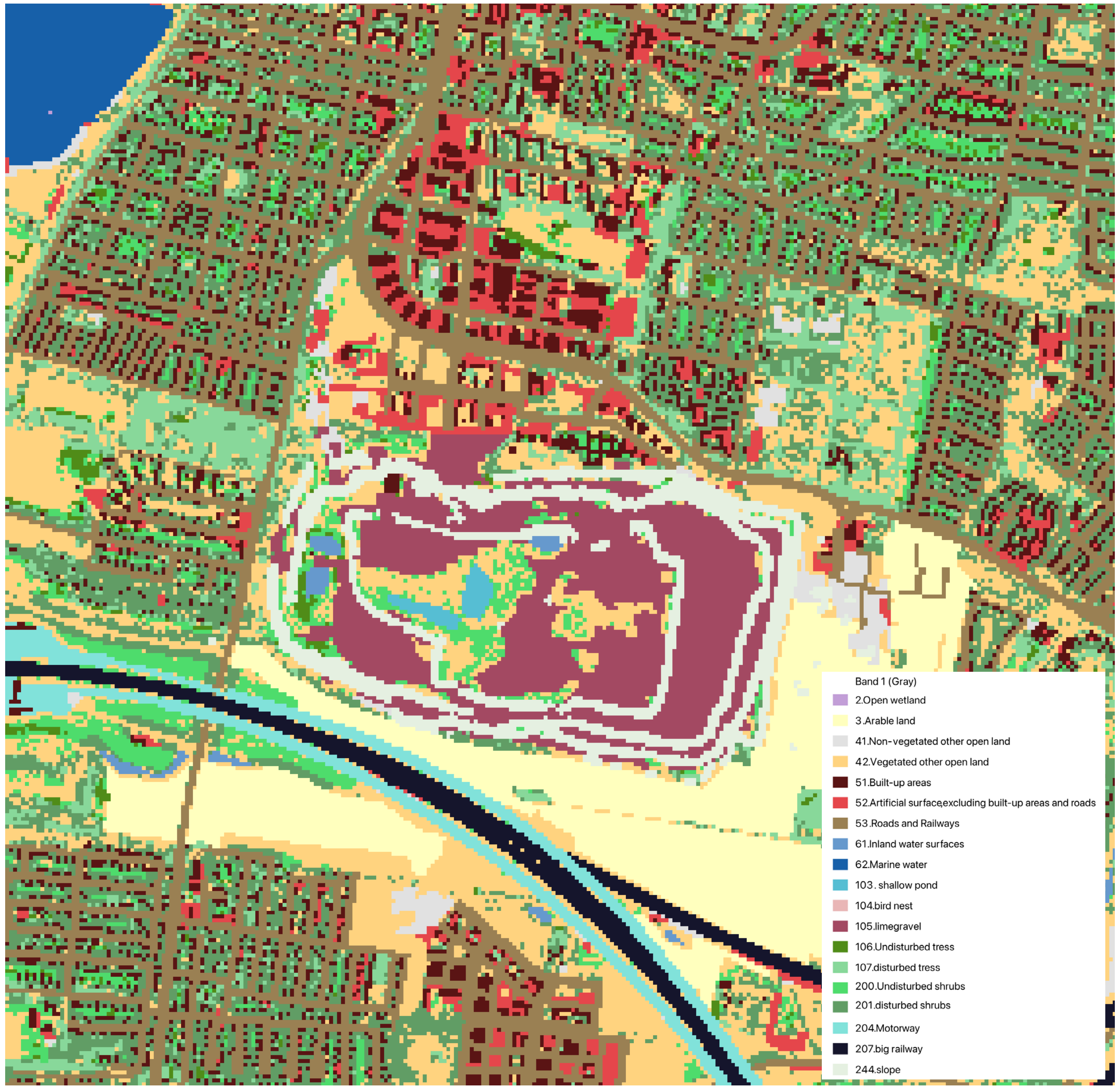


Fig 18 : Biotope map_ Malmö

				Network name	GreenToad			RoeDeer			EagleOwl		
				Average dispersal distance (metres)	600	Alpha	0.00166667	250	Alpha	0.004	300	Alpha	0.00333333
				Network threshold	0.01	Max	2763.10211	0.01	Max	1151.29255	0.01	Max	1381.55106
Origin	BiotopeType	BiotopeName	Estimate	BiotopeCode	Quality	Reproduction	Friction	Quality	Reproduction	Friction	Quality	Reproduction	Friction
NMD - Swedis	1.1. Skog ej på	1.1.1. undisturbed tress		106	8	0	1	8	1	1	10	0	1
NMD - Swedis	1.1. Skog ej på	1.1.2. disturbed tress		107	8	0	1	8	0	1	10	0	1
NMD - Swedis	4. Övrig öppe	4.1. Non-vegetated other open land		41	5	0	1	1	0	1	2	0	1
NMD - Swedis	4. Övrig öppe	4.2. vegetated other open land		42	10	0	1	8	0	1	10	0	1
NMD - Swedis	NMD Object he	undisturbed shrubland		200	7	0	1	9	1	1	10	0	1
NMD - Swedish	land cover ras	disturbed shrubland		201	7	0	1	8	0	1	10	0	1
NMD - Swedis	3. Jordbruksm	3. Arable land		3	2	0	2	8	0	3	5	0	1
NMD - Swedis	5. Exploatera	5,1. Built-up areas		51	0	0	1000	0	0	1000	0	0	1
NMD - Swedis	5. Exploatera	5.2. Artificial surface, excluding built-up areas and roads		52	0	0	2	0	0	5	0	0	1
Trafikverket i l	5. Exploatera	5.3. Roads and railways		53	0	0	3	0	0	3	0	0	1
Trafikverket	Väg	Motorway		204	0	0	100	0	0	100	0	0	1
NMD - Swedis	Järnväg	Big railway		207	0	0	10	0	0	1	0	0	1
NMD - Swedis	6. Vatten/ Wa	6.1. Inland water surfaces		61	10	0	1	5	0	50	1	0	1
NMD - Swedis	6. Vatten/ Wa	6.2. Marine water		62	0	0	100	0	0	100	0	0	1
	2. Öppen våtr	2. Open wetland		2	10	0	1	6	0	3	10	0	1
		shallowponds		103	10	1	1	5	0	1	0	0	1
		slope		244	5	0	100	0	0	100	0	0	1
		limegravel		105	5	0	1	1	0	1	5	0	1
		birdnest		104	5	0	100	0	0	100	5	1	1

Fig 19 : Parameter table

4.2.4 Ecological output maps

The Habitat Network Analysis tool (HNAT) results in six raster outputs used for analysing species movement and habitat connectivity. In this thesis habitat quality, dispersal probability and functionality maps are primarily used in design scenario evaluation.

The Quality map shows areas with suitable habitat conditions according to species-specific needs such as shelter, food availability and breeding capacity. The output is used to evaluate habitat quality in and around the quarry landscape.

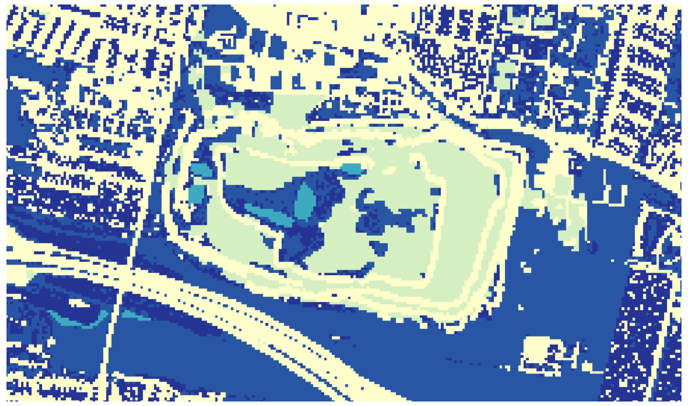


Fig 20 : Current Scenario_Habitat quality map

The Dispersal map shows the potential of species movement across the landscape using movement resistance and cost-distance analysis. This output can be used to identify ecological corridors and evaluate the corridor strength between habitat areas.

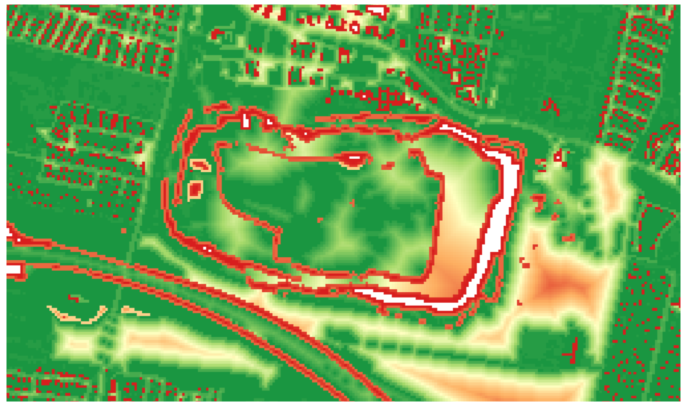


Fig 21 : Current Scenario_Dispersal probability map

The Functionality map combines habitat functionality and dispersal probability to identify areas that are highly interconnected and ecologically functional. This output is used to evaluate ecological connectivity and recognise habitat areas.

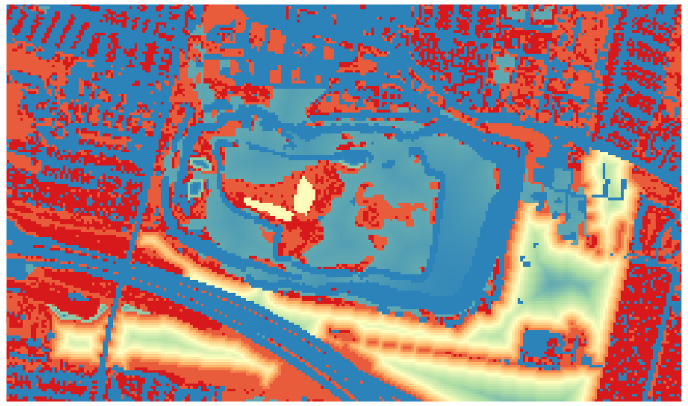


Fig 22 : Current Scenario_Habitat functionality map

4.3 Design Scenario Development

Developing on the combined street network connectivity and habitat network connectivity, two future scenarios are developed to explore how different edge conditions could influence human-nature relationship. The scenarios explore how different quarry transformations impact the relationship between human movement and ecological connectivity.

Scenario 1_ Ecological priority

In this scenario ecological connectivity is prioritised by extending quarry habitats into urban landscapes. Existing slope, limegravel and disturbed surfaces inside the quarry are transformed into vegetated slopes, wetland patches and continuous green corridors. New undisturbed shrubs and tree zones are introduced on sensitive edges to help species dispersal and reduce fragmentation. Removal of human accesses in and around the quarry edge. Wetland edges are restored to strengthen amphibian and bird habitats and buffer vegetation along transport infrastructures to reduce disturbance. The scenario explores the potential of the quarry to function as an urban habitat reserve improving biodiversity and ecological resilience.

Scenario 2_ Humans access priority

This scenario prefers human accessibility into the quarry landscape. New entrances, terraced pathways and continuous circulation routes are introduced to connect all sides of the quarry. In contrast to ecological priority scenario, the pathway is intended to cut through habitat zones maximising accessibility and visibility. Existing limegrave surfaces are transformed to recreational landscapes including walking trails, viewing platforms and resting areas the quarry edge becomes an active urban interface. This scenario explores the possibility of human access redefining the quarry as a socially integrated landscape, increasing fragmentation and pressure on habitat networks.

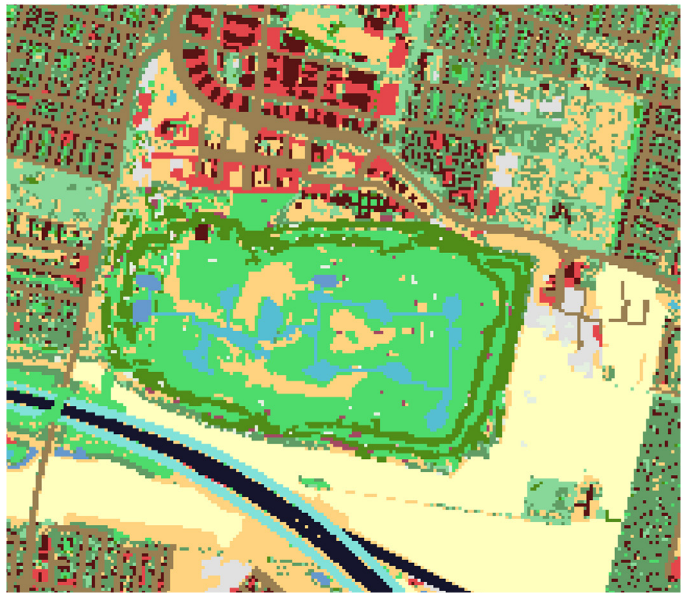


Fig 23 : Scenario-1_Biotope map

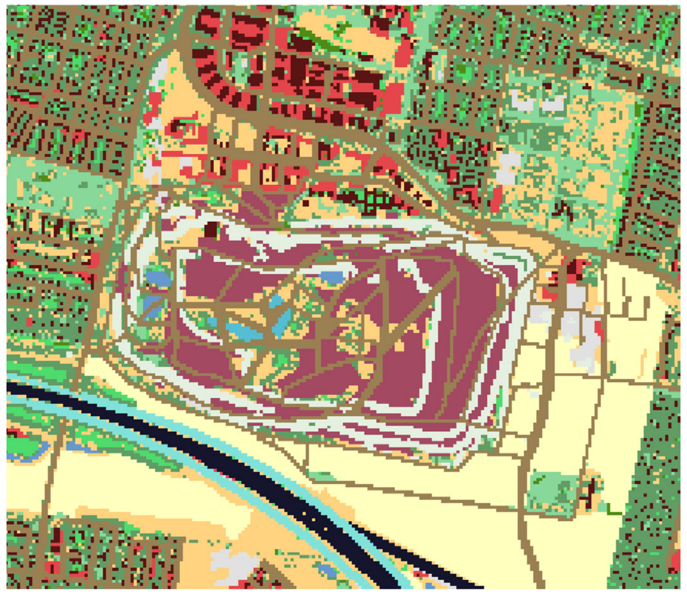


Fig 24 : Scenario-2_Biotope map

4.4 Design Scenario Testing and Evaluation

To test how scenario 1 and 2 perform within the quarry landscape and surroundings, both scenarios are analysed through street network and ecological performance testings. The testing will show how each scenario affects human accessibility and ecological connectivity using angular betweenness 2km and multispecies habit functionality map.

Then evaluation of the two design scenarios based on the human and ecological system.

The scenarios are evaluated using a colour scale from dark green (high improvement) to red (high reduction). Therefore the evaluation reflects the degree to which each scenario supports human accessibility and ecological performance.

Evaluation Scale	Impact level	System Condition
	High improvement	System is fully functional and dominant
	Low improvement	System is working but not optimal
	Current condition	No change from base scenaio-0
	Low reduction	System is in conflict
	High reduction	System is highly degraded

Fig 25 : System evaluation scale

The following indicators are evaluated for each scenario using the colour scale defined above

System	Evaluation criteria	Indicators	Current Scenario	Scenario - 1	Scenario - 2
Human System	Accessibility	Angular Integration 2km			
	Movement pattern	Angular Betweenness 2km			
Ecological System	Habitat Quality	Quality map			
	Corridor strength	Dispersal map			
	Ecological connectivity	Functionality map			

Fig 26 : Scenario evaluation table

4.5 Final Design Scenario

From the evaluation of scenario 1 and scenario 2 shows that neither ecological priority or human access priority alone can support long term coexistence within Limhamn kalbrott. Scenario 1 ecological continuity strengthens but accessibility and movement remains disconnected while scenario 2 increases accessibility and movement but habitat fragmentation and ecological disturbances also increases. The final design scenario develops a balanced human-nature relationship by combining ecological protection with controlled human accessibility.

The final design scenario is then tested using the same procedure applied in scenario 1 and 2 street network performance and ecological performance testings. The final scenario is then evaluated using the same criteria table *Fig 17* and compared with current scenario, scenario 1 and scenario 2 to understand how the proposed coexistence approach can balance ecological protection with controlled human accessibility.

Final Scenario_ Human-Nature Coexistence

In this final design scenario high functional habitats such as breeding shallow ponds, nesting cliffs and undisturbed shrub zones are protected as ecological cores by dense shrub vegetation and restricted seasonal human access. Existing circulation routes are reorganised to reduce fragmentation of the ecological system by maintaining selected access into the quarry landscape. Limestone gravel terraces and disturbed surfaces are transformed into a vegetated landscape and meadow planting along the trails.

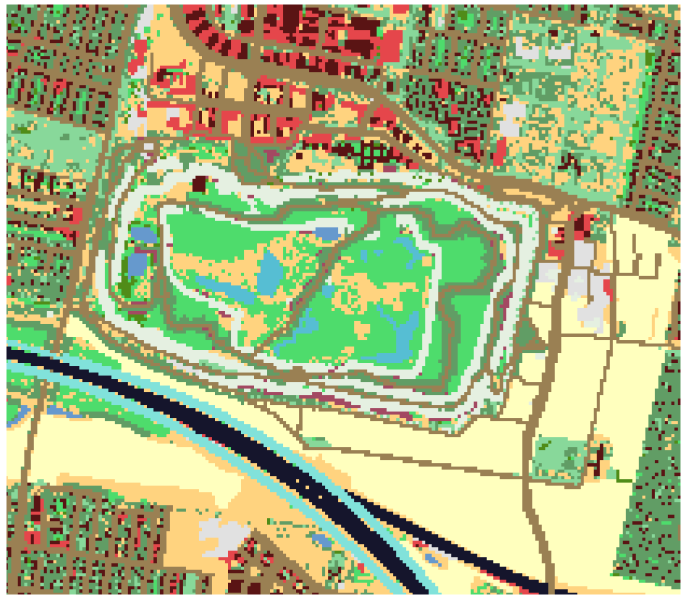


Fig 27 : Final Design Scenario_Biotope map

4.6 Scenario-based zoning

To understand the relationship between the human and ecological systems results from the analysis are integrated with ecological outputs to overlay in order to identify human movement, access points and spatial thresholds intersecting with habitat networks and functionality.

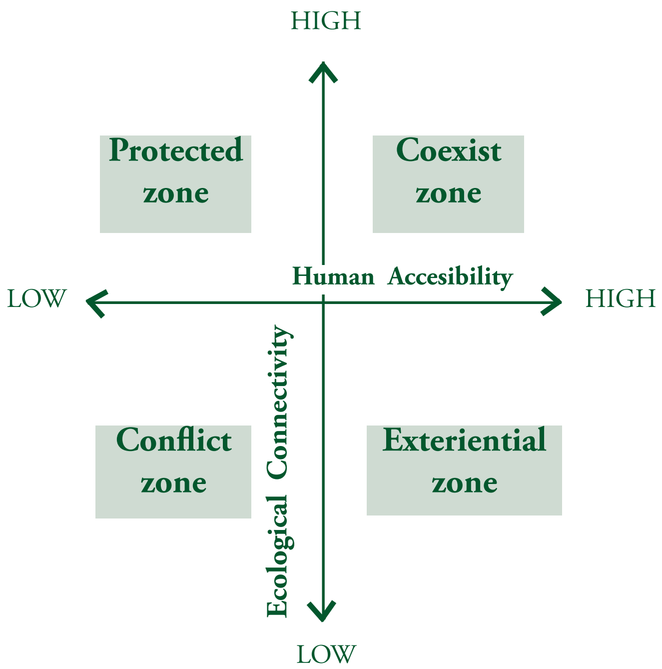


Fig 28 : Zoning criteria

Protection zone
Areas with high ecological value and sensitivity, where habitat functionality is important for species to survive (eg. breeding grounds, shallow ponds/ wetlands, nesting cliffs) these zones need strict limitation of human access to avoid disturbance and maintain ecological processes.

Conflict zone
Areas where human accessibility overlaps with ecological sensitive habitats, which shows some potential disturbance and fragmentation. So these zones zoom into spatial tension between human movement and species requirements.

Coexistence zone
Areas with ecological systems and human presence can overlap with minimal disturbance. This zone has less sensitive habitats and areas where species have high tolerance to human presence.

Experiential zone
Transitional area with potentials for spatial intervention, area with weak connectivity or accessibility into the quarry. Key area for both human experience and ecological connectivity.

These analytical zones help to develop into design translation.

4.7 Design Translation

The final step of this methodological framework is translation of the analysis results of scenario evaluation and final zoning into design principles and threshold strategies that will guide human-nature interaction within the quarry landscape.

4.7.1 Zones into Design principles

Each zones relates to a specific design response within the quarry edge condition

Zone	Design approach
Protection zone	Preserve and restrict access
Conflict zone	Buffer and redirect access
Coexistence zone	Allow controlled interaction
Experiential zone	Introducing new connections and interventions

4.7.2 Threshold strategies and Transitions

From the identified zones translation into threshold conditions where the quarry edges act as gradient instead as fixed boundary. Different threshold strategies arrange ecological protection, buffering, controlled access and interaction.

These threshold strategies are further developed in chapter 6 through threshold transitions and design implementation.

5 | Analysis & Results

This chapter presents outcomes of spatial and ecological analysis to understand the relationship between human accessibility and habitat connectivity in and around limhamn kalkbrott. Results from street network analysis and habitat network modelling are analysed separately and then combined to identify patterns of ecological functionality, movement potential and spatial thresholds that affect human-nature interaction. By combining these analysis layers conflict zones, coexistence zones are identified and forms a basis for evaluation of future scenarios for redesigning the quarry edge.

5.1 Street network analysis Results

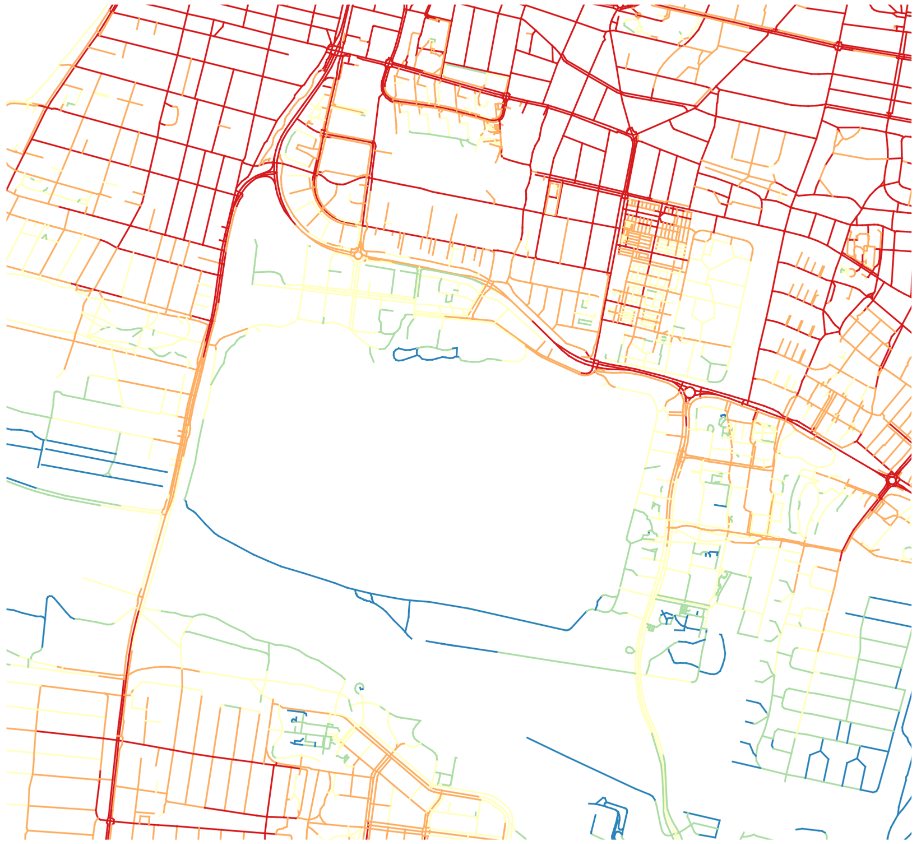


Fig 29 : Angular Integration_1km

At 1km scale streets around quarry has low to medium integration which feels more isolated compared to denser networks in the north residential areas.

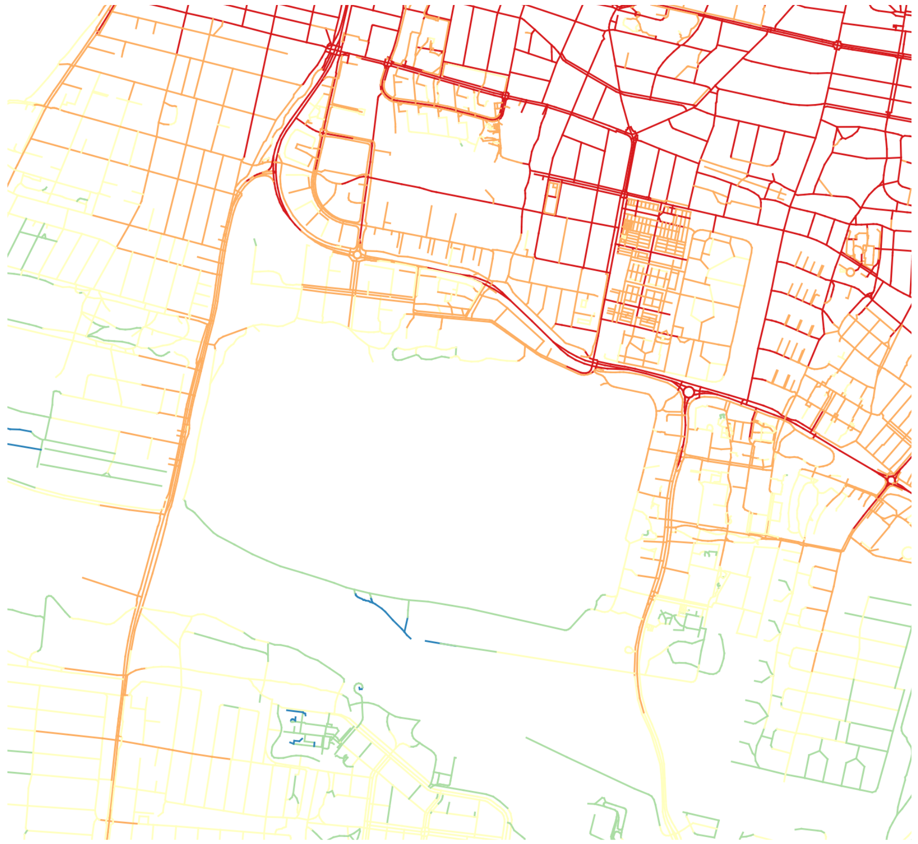


Fig 30 : Angular Integration_2km

At 2km integration increases across city, more stronger in the north residential areas but quarry breaks network from continuous integration across edges. Shows northern sides being better integrated compared to the southern side.

This shows quarry as gap in network, by improving pedestrian network around and through the quarry can spread integration evenly, more accessible and better connected.

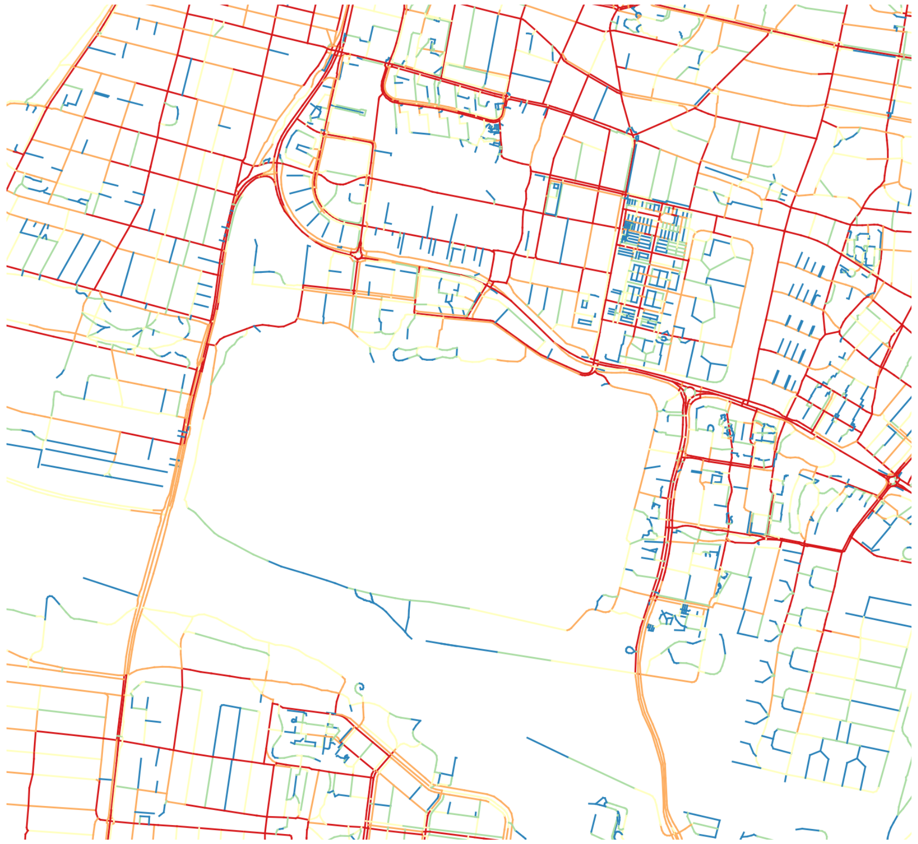


Fig 31 : Angular Betweenness_1km

At 1km scale the area around quarry is poorly connected, many streets end at edges limiting access points. So pedestrian network is weak along southern and western side.

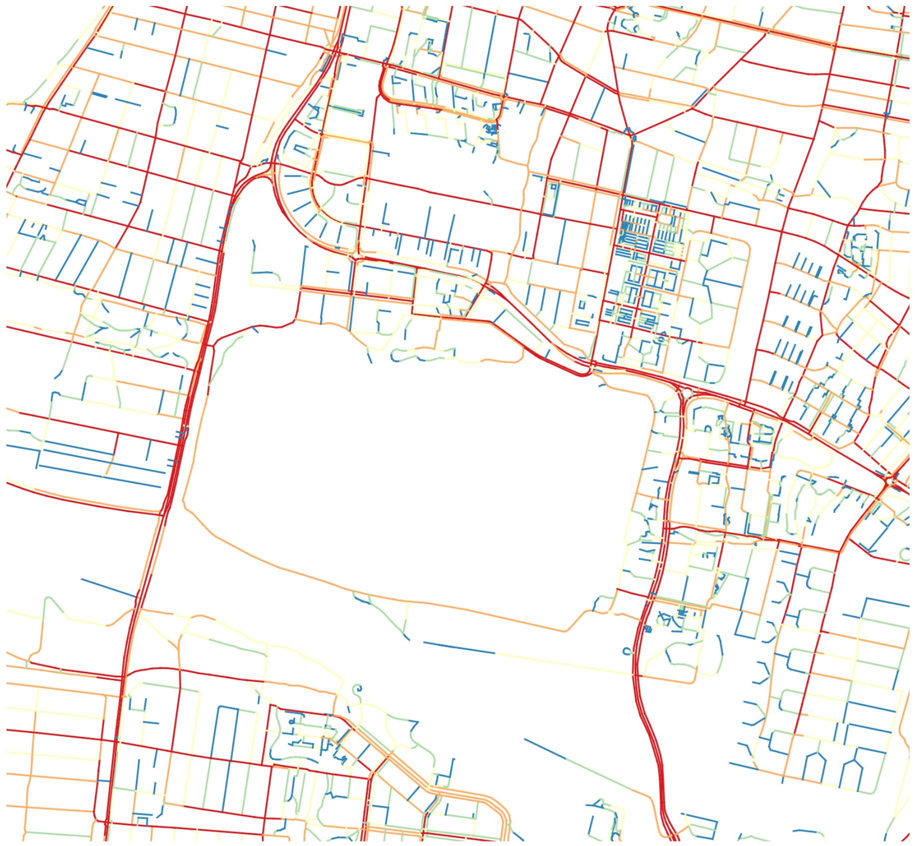


Fig 32 : Angular Betweenness_2km

At 2km scale pedestrian network improves around quarry with good connectivity on southern and western edges while northern and eastern still remains weak.

Design takeaway -
By adding new connections can improve pedestrian network through and around quarry which changes quarry from void/barrier into spatial link between different sides of the quarry.

5.2 Habitat network analysis Results

Dispersal probability

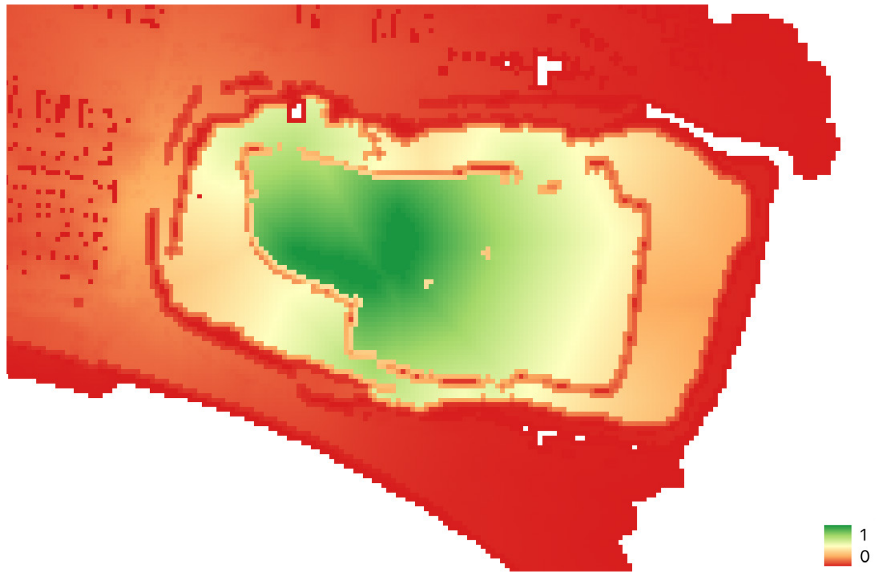


Fig 33 : GreenToad_Dispersal probability map

Dispersal shows movement limited to quarry itself. Very low spread into the surrounding areas. Movement is restricted outside quarry where Built environment and the highway/railways acts as strong barrier. Hence quarry act as critical habitat core for toads, for safer movement inside quarry creating connections to nearby wetland is important.

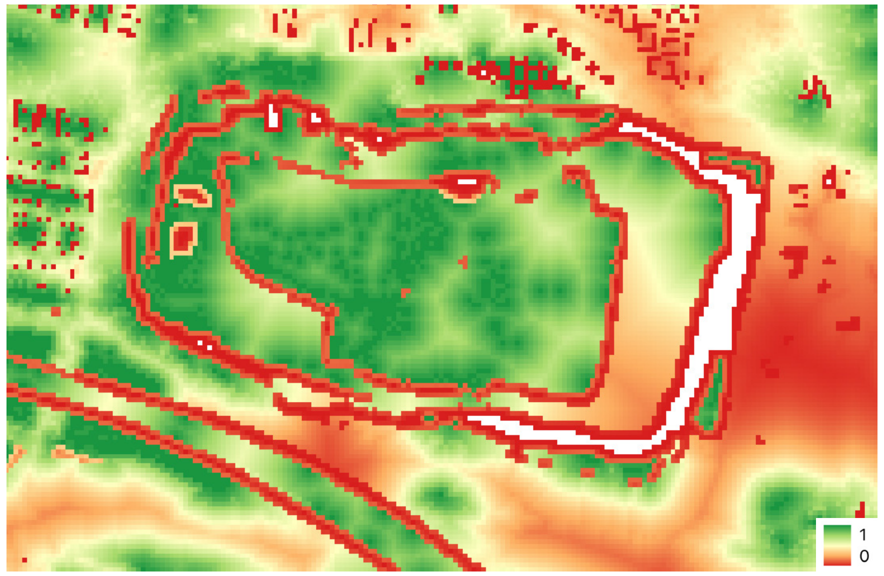


Fig 34 : RoeDeer_Dispersal probability map

Dispersal map clearly shows movement spread (ability to move through larger area) but major barrier is seen around the quarry cliff, highways and built-up areas. Therefore quarry and surrounding landscape areas already support roe deer with large network connection.

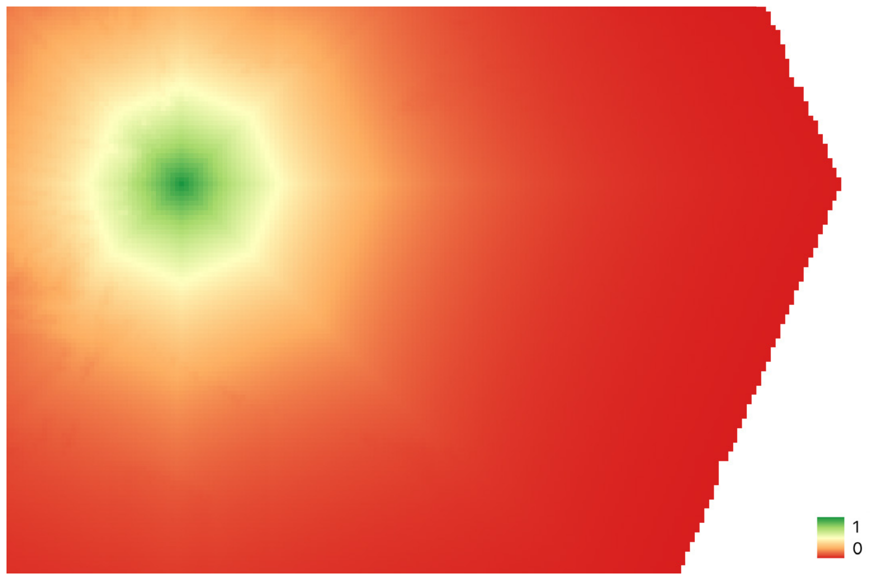


Fig 35 : EurasianEagleOwl_Dispersal probability map

Dispersal movement is strong within quarry and its immediate surroundings, but decreases in surrounding neighbourhood. Which means protecting this area is important. For design interventions while human access the quarry its good for vegetated buffers around this area for less disturbance.

Habitat funtionality

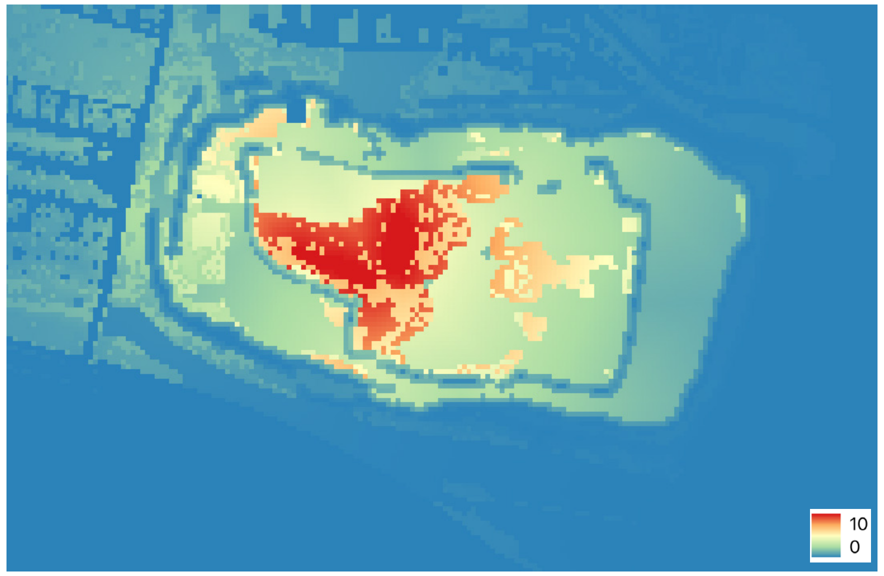


Fig 36 : GreenToad_Habitat Functionality map

Functionality is highest inside quarry, mainly around the shallow ponds, while surrounding quarry edges area is low, here the quarry cliff acts as barrier for Green toad.

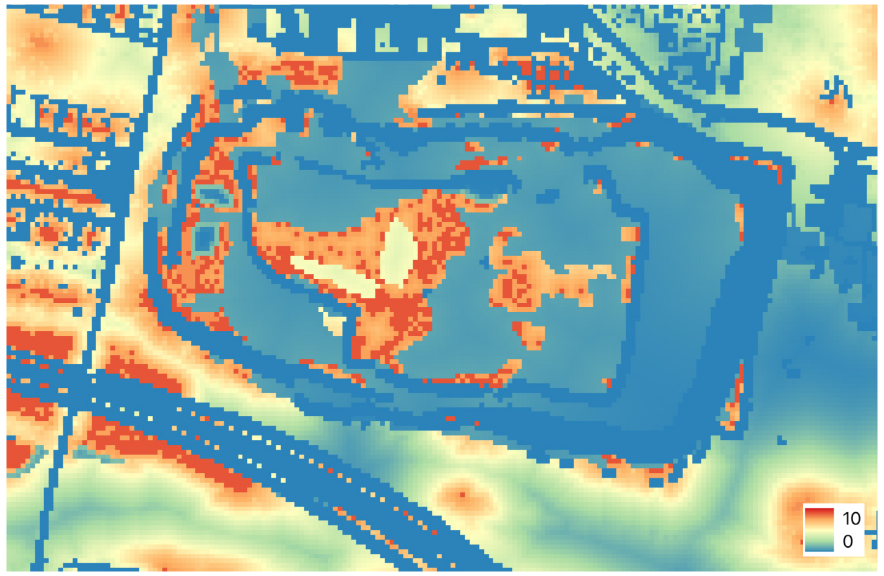


Fig 37 : RoeDeer_Habitat Functionality map

Functionality map shows quarry and surrounding neighborhood provides suitable conditions for roes deer in green spaces (undisturbed shrubs).

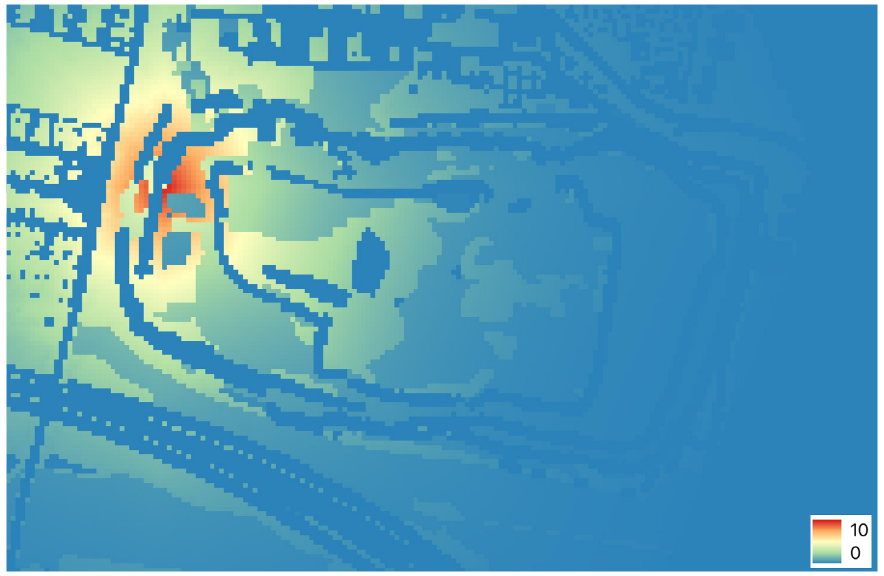


Fig 38 : EurasianEagleOwl_Habitat Functionality map

The quarry area clearly shows that it currently acts as the main habitat area for the Eurasian eagle owls. Functionality is highest within the quarry (nesting zone on the cliff), while surrounding area is low suitable which shows quarry provides key habitat conditions needed for the owl.

Design takeaway -
The analysis highlights important habitat cores to be preserved while carefully managing buffering disturbance along quarry edges.

5.3 Design Scenario Testing Results

STREET NETWORK PERFORMANCE

CURRENT SCENARIO

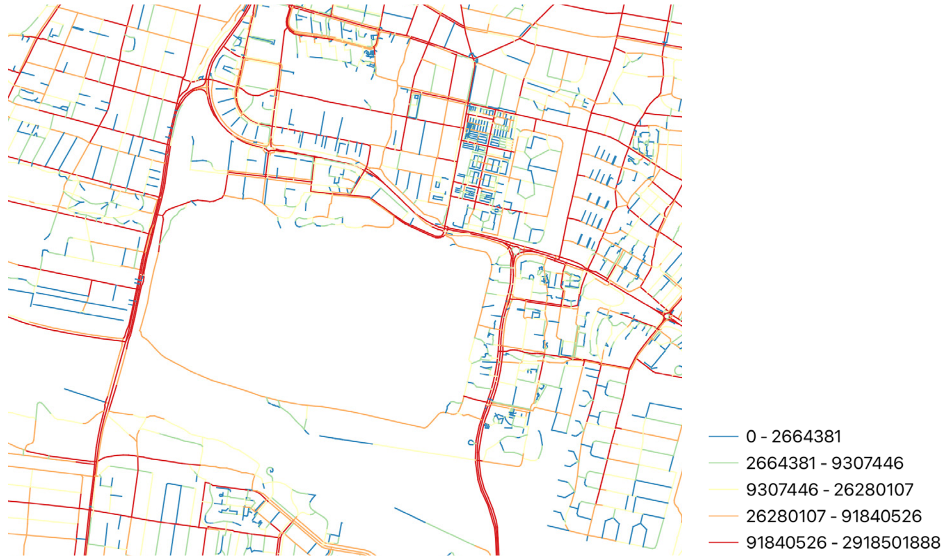


Fig 39 : Angular Betweenness_2km

SCENARIO - 1

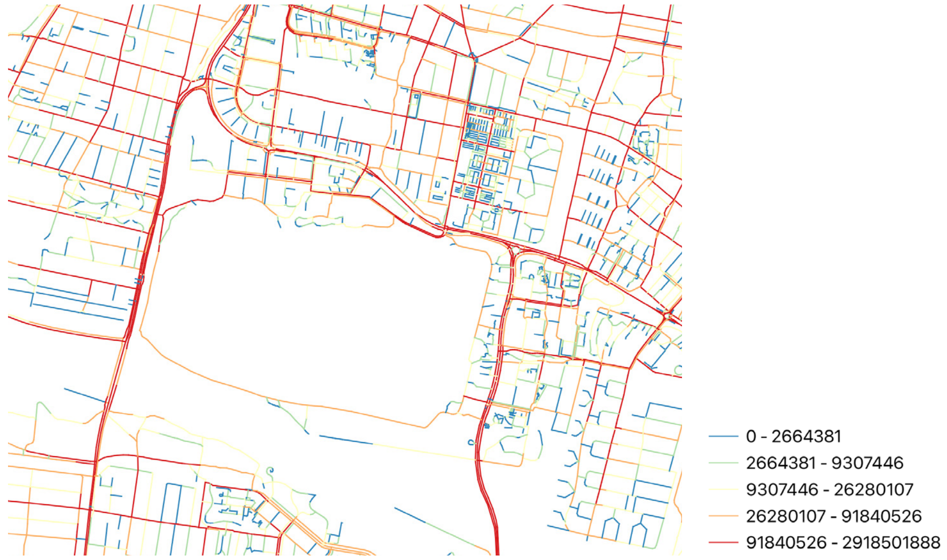


Fig 40 : Angular Betweenness_2km

SCENARIO - 2

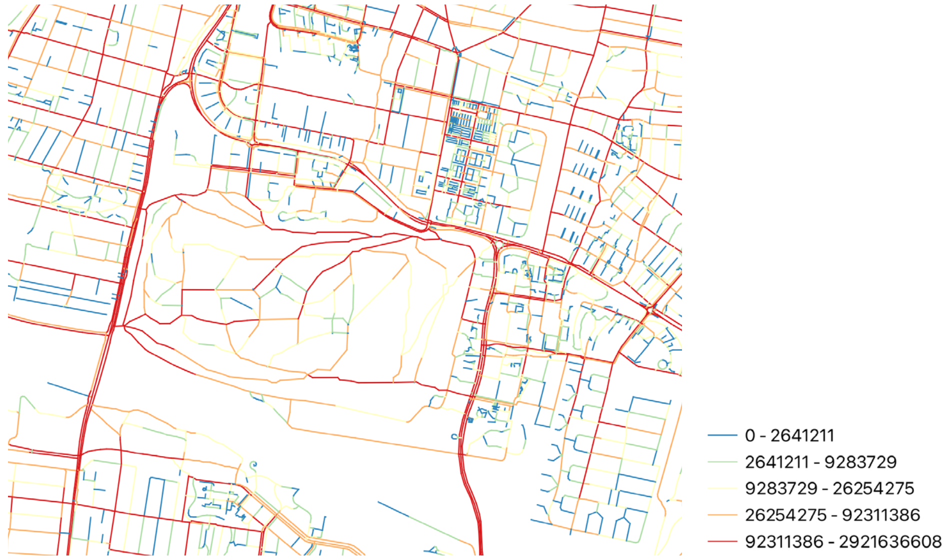


*Fig 41 : Angular Betweenness_2km_*

ECOLOGICAL PERFORMANCE

CURRENT SCENARIO

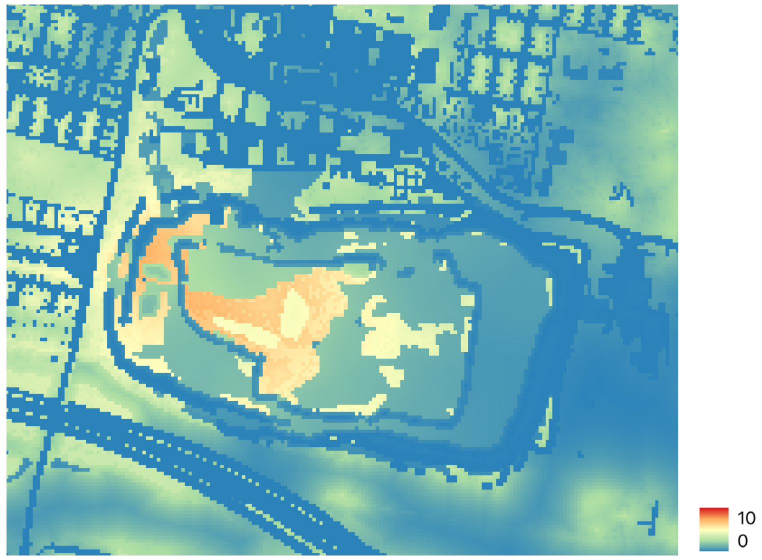


Fig 42 : Multispecies_Habitat Functionality map_1:20000

The current scenario shows limited integration between human and ecological systems, as the quarry remains completely disconnected from the surrounding urban network (non motorised) with movements only concentrating along the quarry edge. The quarry basin supports habitat functionality mainly within isolated patches but still remains fragmented and lacks connections.

SCENARIO - 1

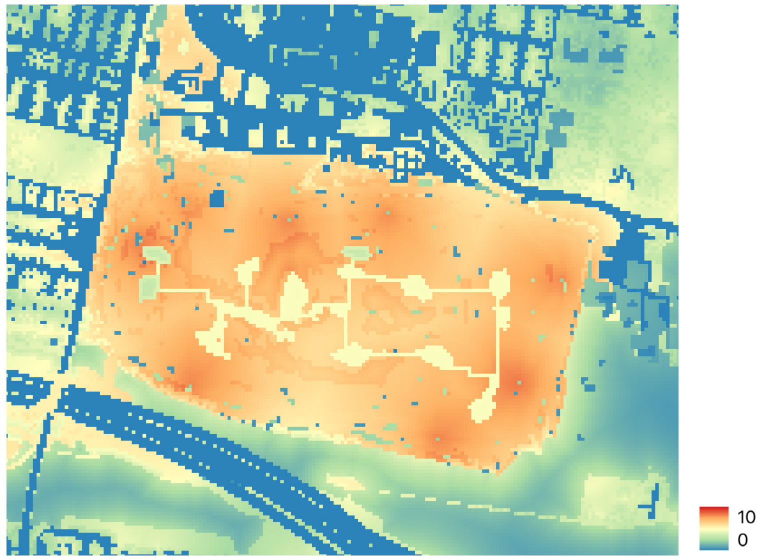


Fig 43 : Multispecies_Habitat Functionality map_1:20000

In this scenario, keeping the human movement only along the edge and increasing habitat continuity shows notable increase in ecological functionality. Hence the quarry becomes a continuous habitat core with connections extending into the surrounding green areas.

SCENARIO - 2

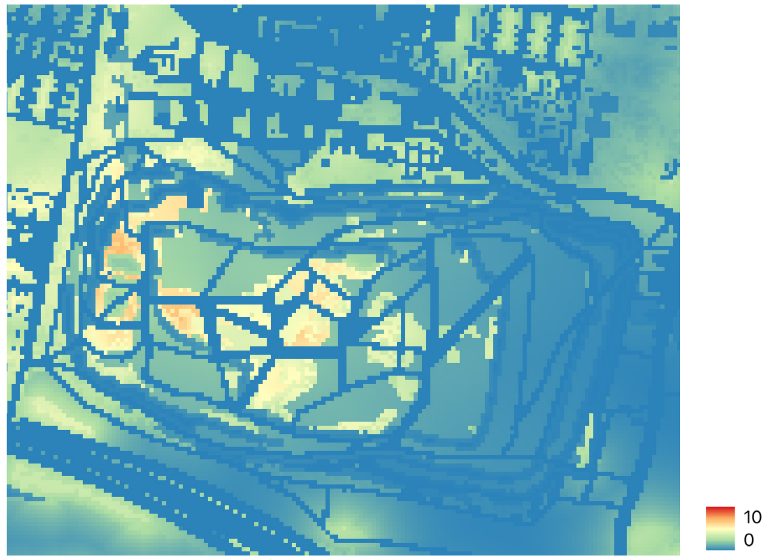


Fig 44 : Multispecies_Habitat Functionality map_1:20000

Alternatively in this scenario human movement is prioritised by introducing a dense internal network of paths and cross connections to quarry edges. The street network analysis clearly shows an increase in accessibility which connects the quarry interior to the urban system.

However the increased accessibility inside the quarry results in habitat fragmentation zones which will reduce the functionality of the habitats. Therefore ecological cores turn into isolated patches and reduce species movement.

5.4 Design Scenario Evaluation

System	Evaluation criteria	Indicators	Current Scenario	Scenario - 1	Scenario - 2
Human System	Accessibility	Angular Integration 2km	current condition	Low reduction	High improvement
	Movement pattern	Angular Betweenness 2km	current condition	Low improvement	Low improvement
Ecological System	Habitat Quality	Quality map	current condition	High improvement	Low reduction
	Corridor strength	Dispersal map	current condition	High improvement	High reduction
	Ecological connectivity	Functionality map	current condition	High improvement	Low reduction

Fig 45 : Scenario evaluation table

High improvement · *Low improvement* · *current condition* · *Low reduction* · *High reduction*

Evaluation conclusion

Scenario 1 improves habitat connectivity and ecological functionality limiting human accessibility , while Scenario 2 improves human accessibility and movement but causes fragmentation and disturbance within the ecological systems.

The above comparison shows the conflict between the two systems and shows the need for a balanced spatial approach that will support coexistence instead of choosing one system over another.

5.4 Final Design Scenario Testing And Evaluation

STREET NETWORK PERFORMANCE

FINAL DESIGN SCENARIO

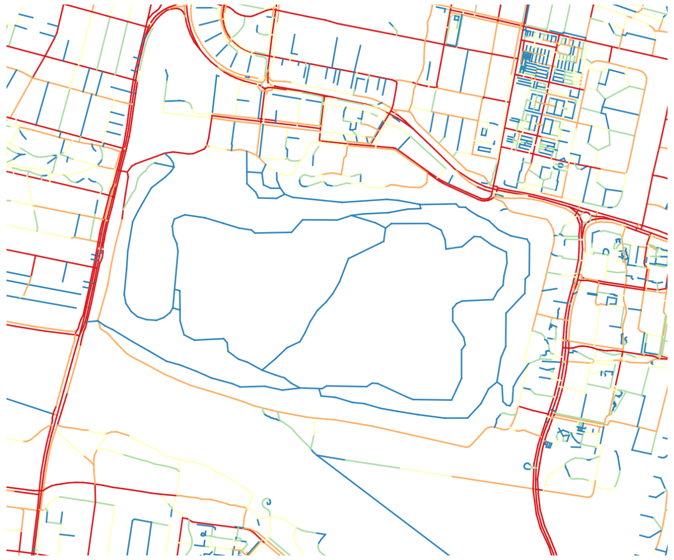


Fig 46 : Angular Betweenness_2km

ECOLOGICAL PERFORMANCE

FINAL DESIGN SCENARIO

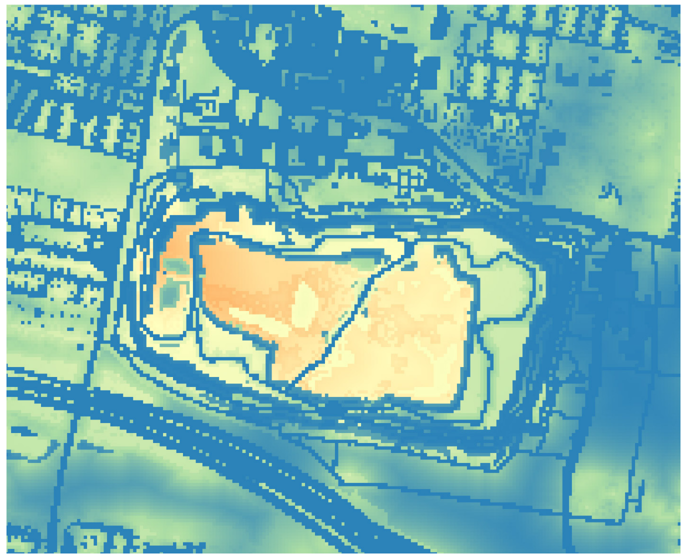


Fig 47 : Multispecies_Habitat Functionality map_1:20000

In this final scenario both controlled human movement and ecological cores show a balanced increase in accessibility and ecological functionality. Human movement is organised along the selected pathways while sensitive habitats such as shallow ponds, nesting cliffs and shrubland zones remain protected from disturbance.

Hence the quarry functions as a connected coexistence landscape where ecological continuity is maintained by allowing controlled interaction and access into the quarry.

System	Evaluation criteria	Indicators	Current Scenario	Scenario - 1	Scenario - 2	Final Scenario
Human System	Accessibility	Angular Integration 2km				
	Movement pattern	Angular Betweenness 2km				
Ecological System	Habitat Quality	Quality map				
	Corridor strength	Dispersal map				
	Ecological connectivity	Functionality map				

Fig 48 : Scenario evaluation table

High improvement *Low improvement* *current condition* *Low reduction* *High reduction*

Final evaluation conclusion

The final scenario shows a balanced coexistence condition where both human and ecological systems are integrated. Compared to scenario 1 and 2 the final design scenario reduces spatial conflicts by organising movement along less sensitive quarry edges and maintaining habitat functionality within protected ecological core.

5.5 Scenario-based zoning Results

Fig 49 : Current Scenario_zoning map

Current Scenario - Existing condition
The existing condition shows zone distribution with protected areas concentrated within the quarry basin and near the west cliff, conflict zones along the edges. Coexistence and experiential zones are discontinuous and limited. This indicates spatial integration between human accessibility and ecological connectivity is a bit weak.

Fig 50 : Scenario 1_zoning map

Scenario 1 - Ecological priority
This scenario clearly dominates the protected zone transitioning into high ecological connectivity and low accessibility (Fig.). Conflict zones are along the edge of the quarry while coexistence and experiential zones are not seen, thus resulting in spatially focusing on ecological preservation.

Fig 51 : Scenario 2_zoning map

Scenario 2 - Human access priority
In this scenario coexistence and experiential zones expand by increasing the accessibility across the quarry. But protected areas become fragmented and conflict zones increase compared to the existing condition, hence reducing the ecological connectivity.

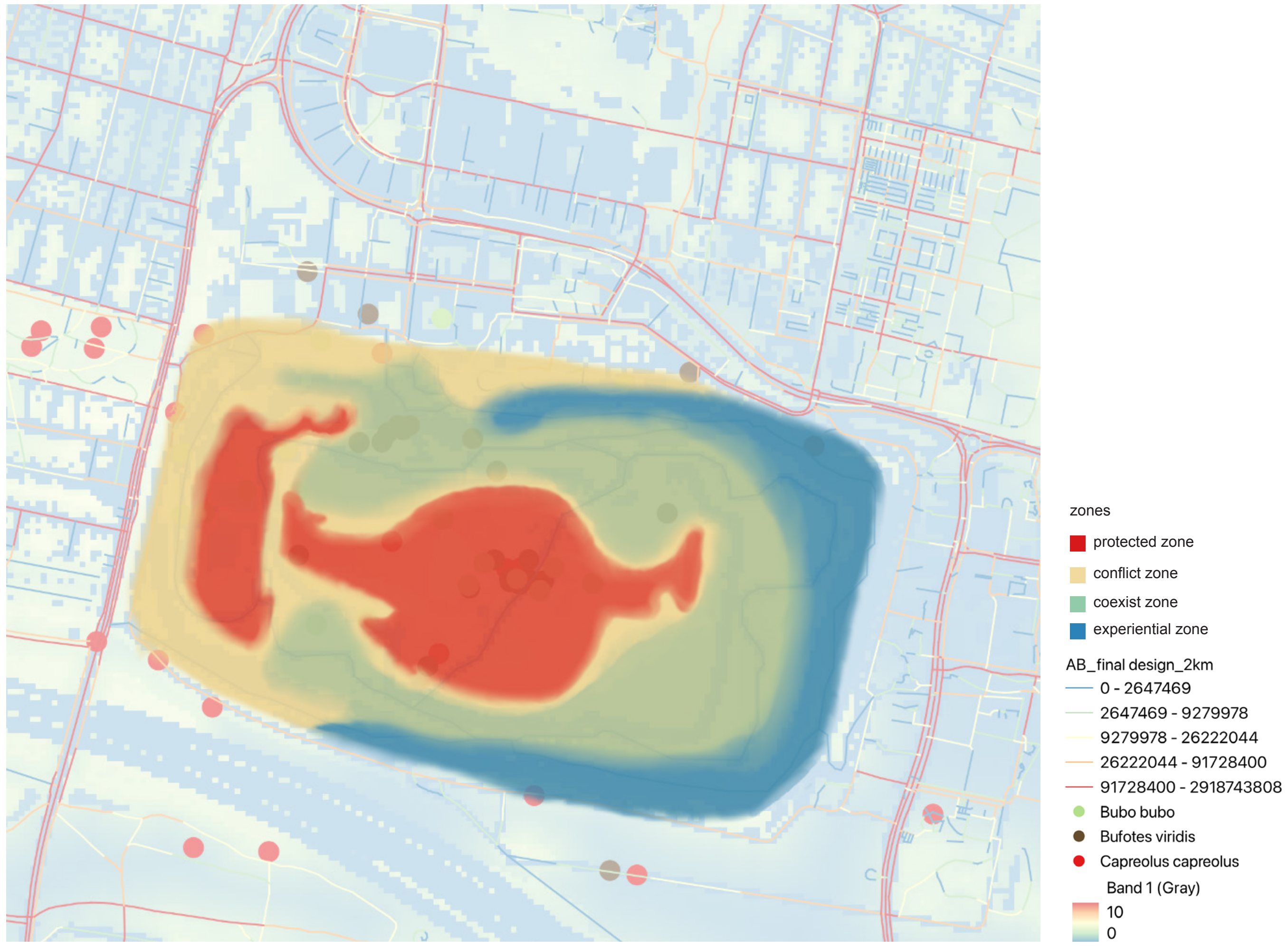


Fig 52 : Final Scenario_zoning map

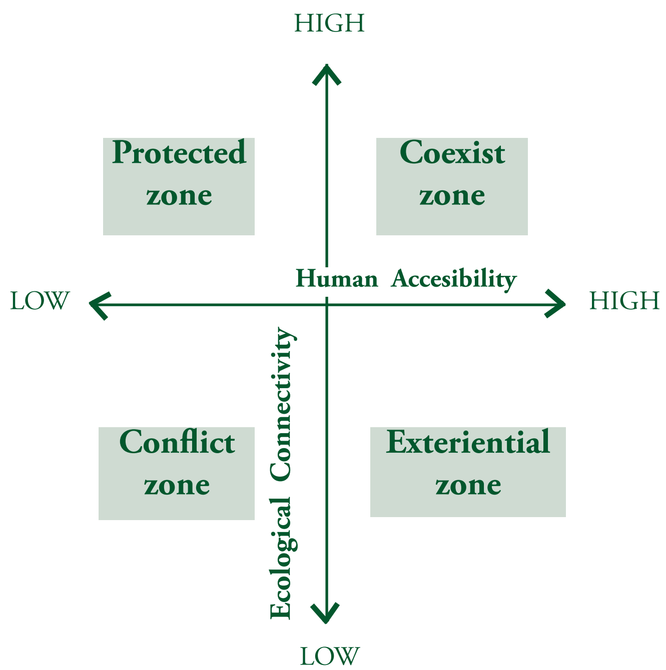
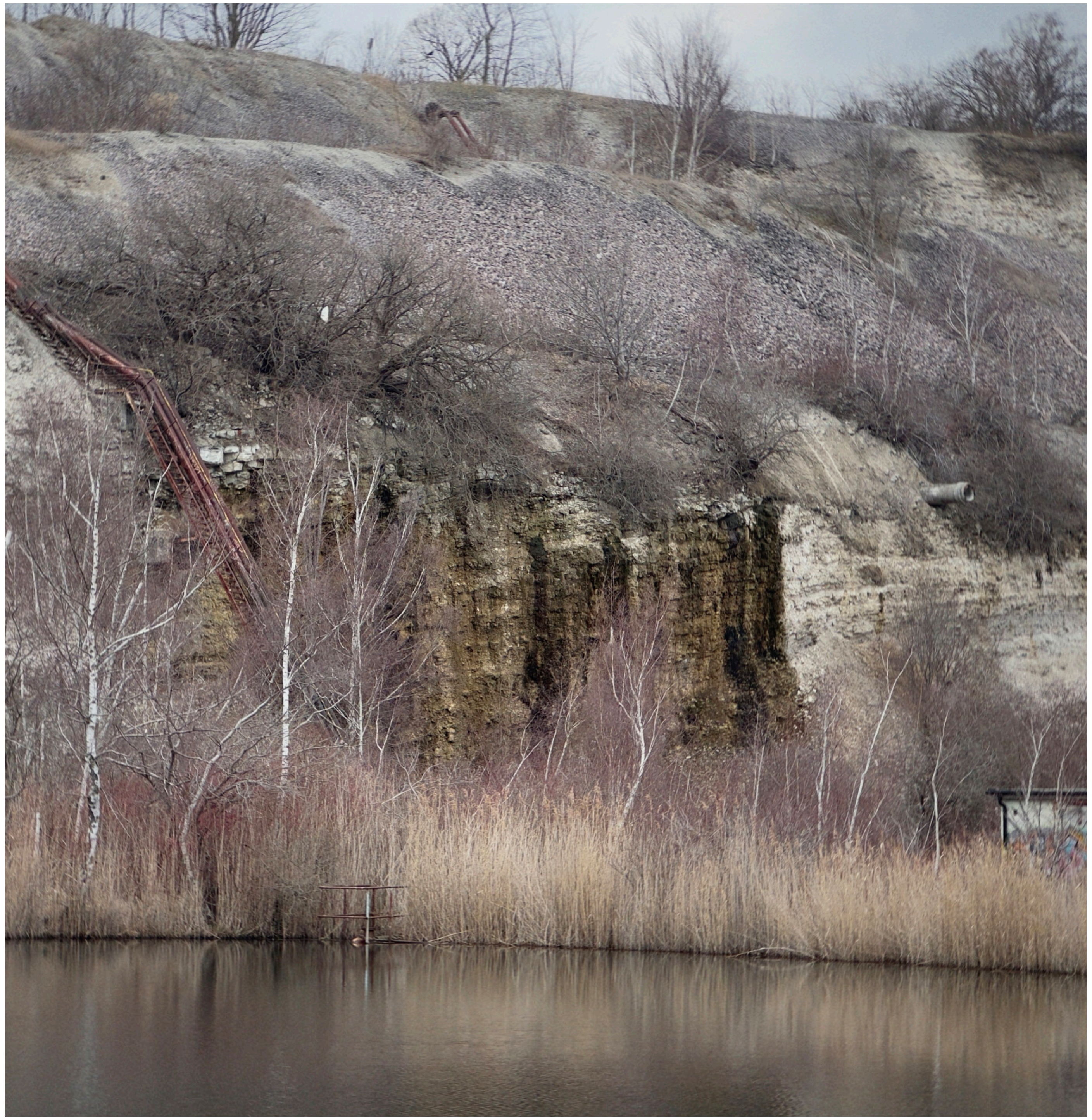


Fig 53 : Zoning criteria

Final Scenario - Human-Nature coexitence
The final scenario balances human accessibility and ecological connectivity. Protected zone remains concentrated within habitat core, coexistence and experiential zone are organised along less sensitive quarry edges and movement paths. Compared to scenario 1 and 2 the final zoning reduces fragmentation while maintaining the ecological connectivity.

Design translation conclusion
The final zoning guides the design principles and threshold strategies developed in the following design chapter.

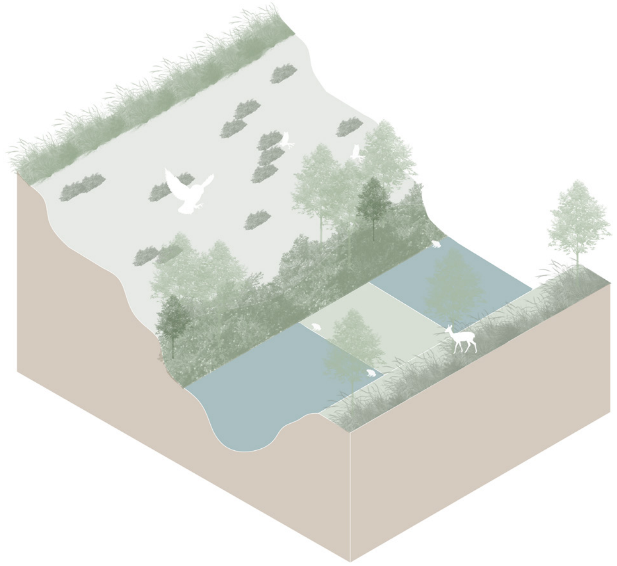


6 | Design

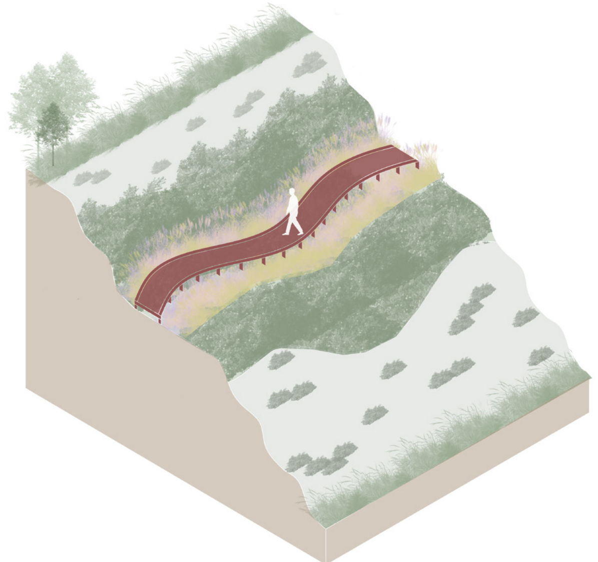
The design chapter translates analytical findings, scenario evaluation and zoning into threshold strategies for redesigning the edge of Limhamns kalkbrott as ecological threshold. The identified zones of protection, conflict, coexistence and experiential are translated into spatial edge conditions and threshold strategies that guide the final landscape design implementation.

6.1 Design Principles

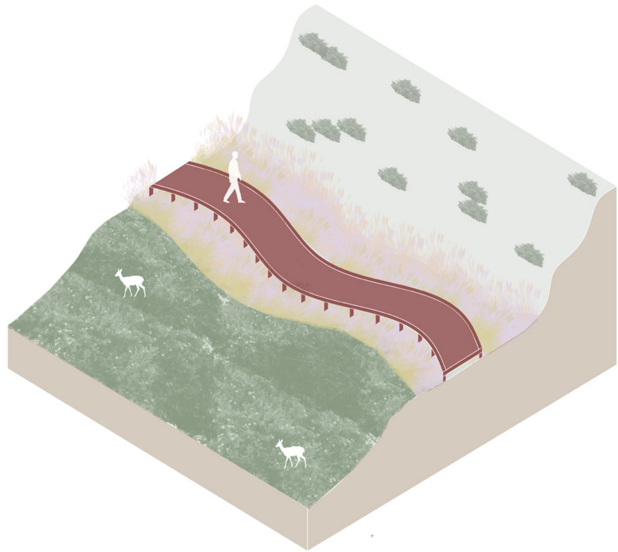
The following principles set a framework for converting analytical findings into spatial changes (*(appendix 3)*.



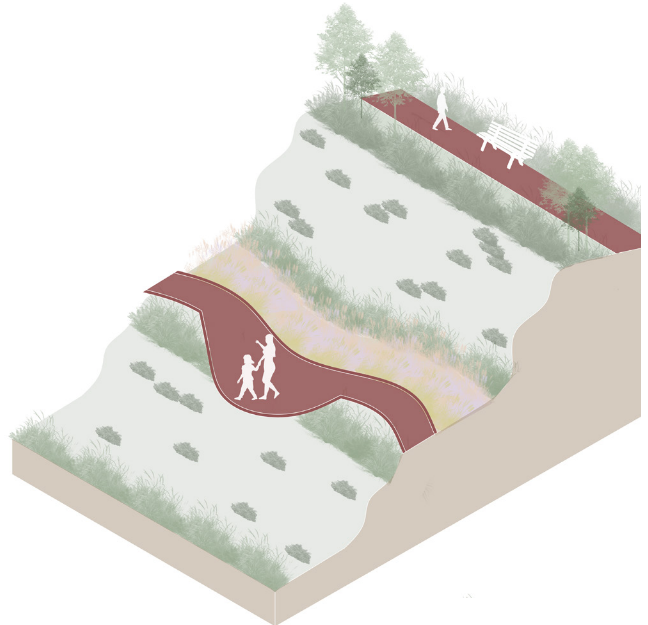
Protected Zone
Protect high functionality habitats identified through Hnat analysis by restricting human access and maintaining core zones.



Conflict Zone
Buffering conflict zones where sensitive ecological zones are overlapped with human movement, spatial separation to reduce disturbance.



Coexistence Zone
Human movement in low sensitive zones identified in coexistence mapping, to use elevated pathways, controlled entry points.



Experiential Zone
Transforming barrier conditions into gradients identified experiential zones that are limiting ecological movement and human interaction. Redesigned through terracing and vegetated slopes.

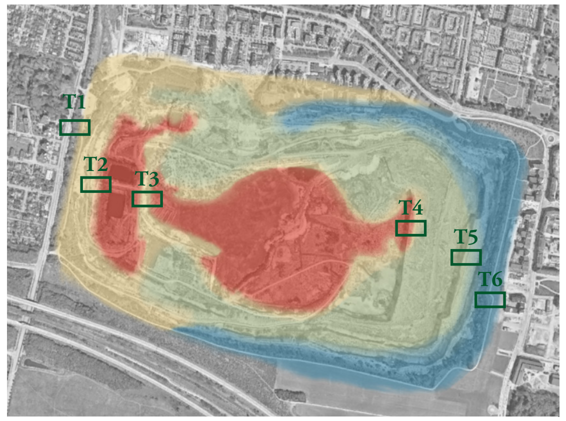
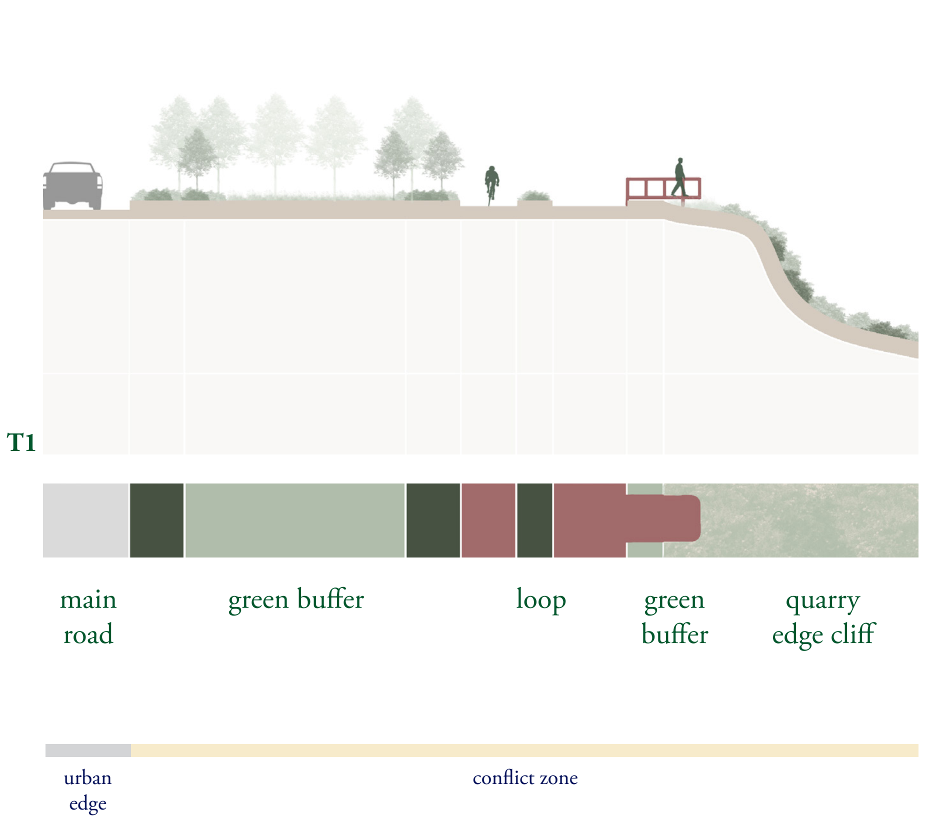
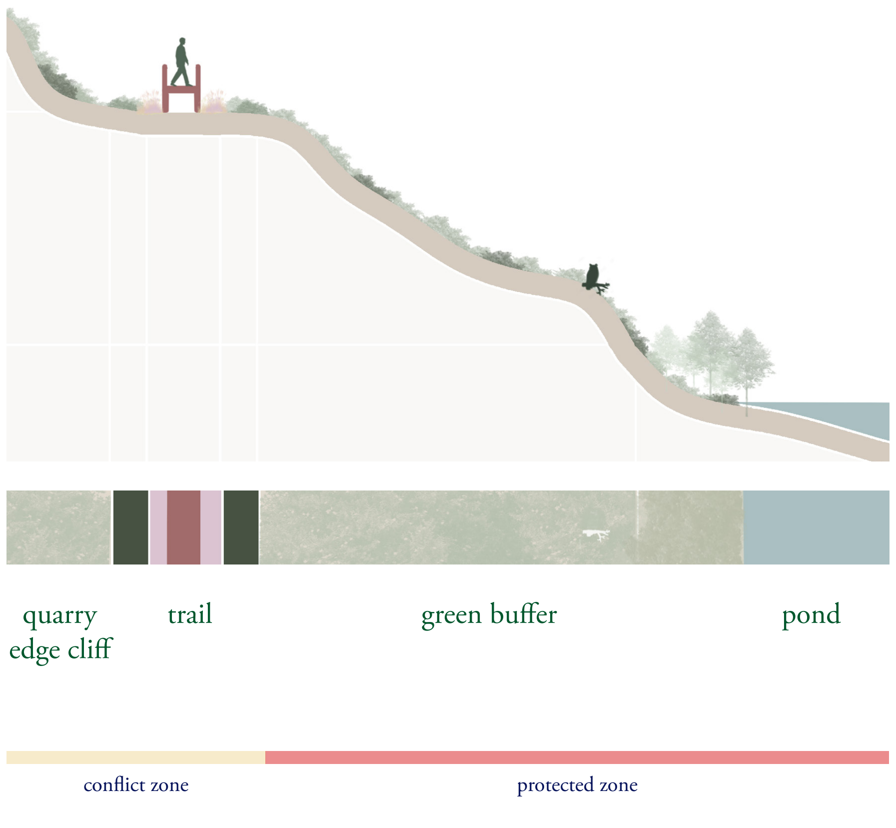


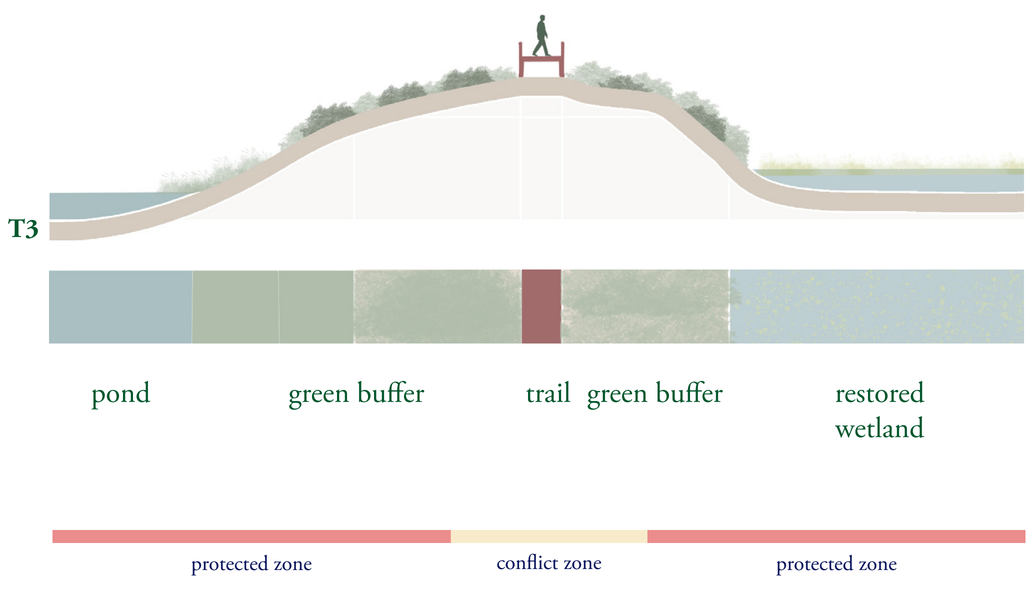
Fig 54 : Threshold transition locations

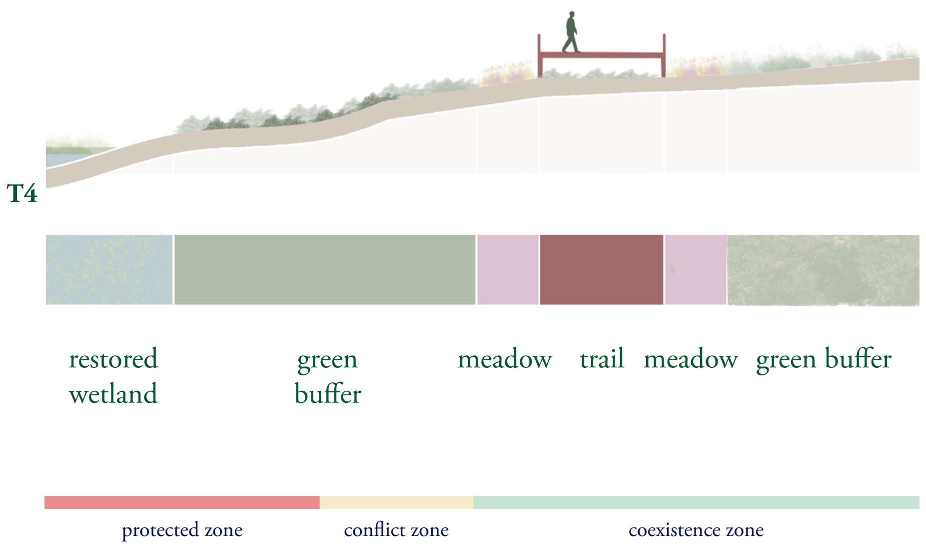
6.2 Threshold Stratergies

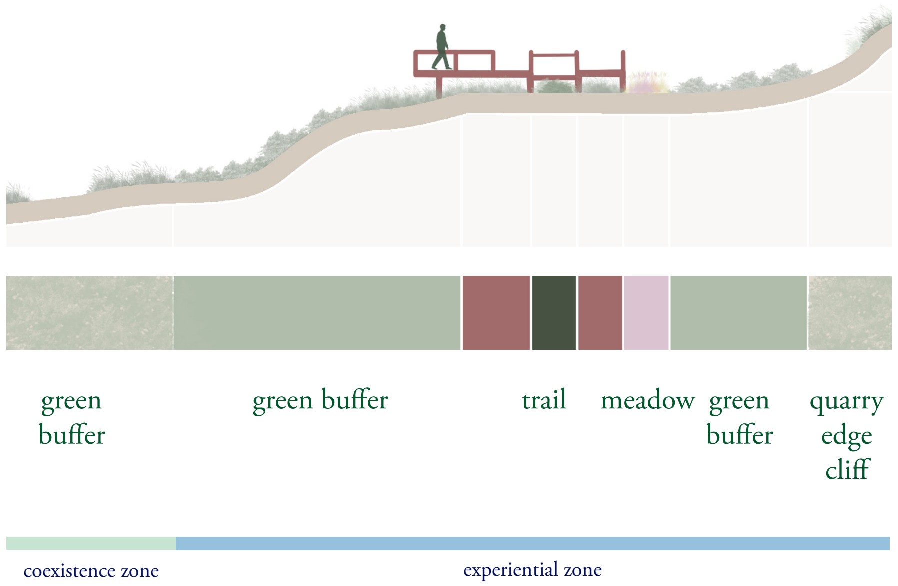
The strategies translate the identified zoning and design principles into threshold transitions across the quarry landscape. Each transition addressed to specific threshold conditions manages ecological protection, human accessibility and interaction.

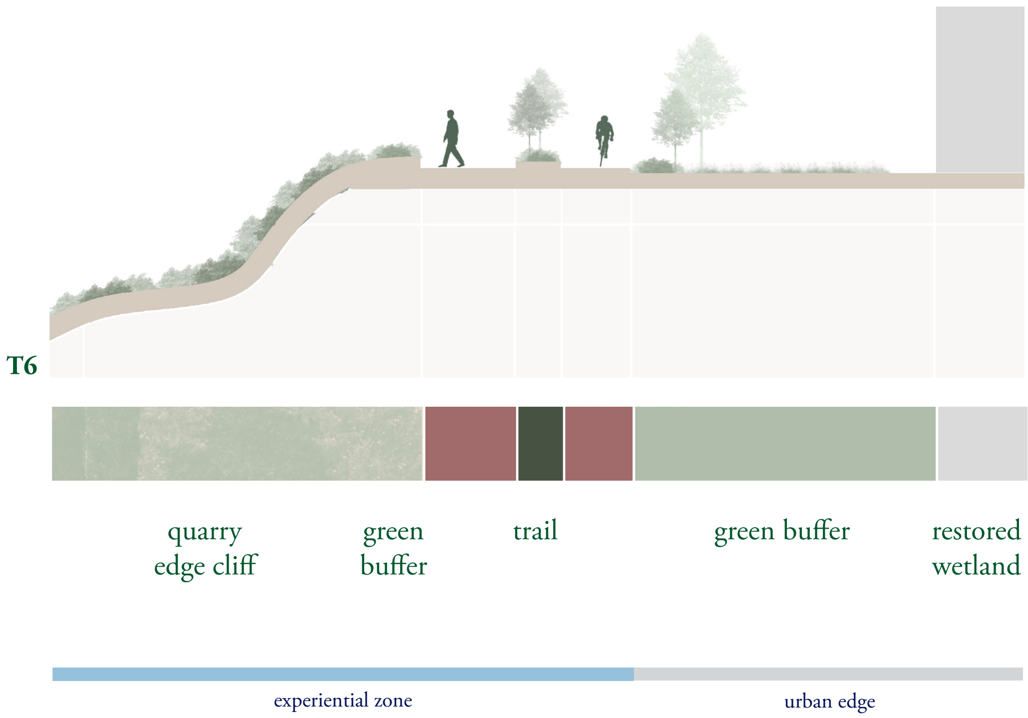












6.3 Design Implentation

The landscape plan arranges movement through a hierarchy of urban loops, main trails and secondary trails connected with viewing and pause area. The central quarry zone remains ecologically protected, containing shallow ponds, shrubland, wetland restoration areas and breeding habitats.

1 Entrance / Exit
2 Urban loop
3 Main trail
4 Secondary trail
5 Viewpoints
6 Shrubs
7 Meadows
8 Wetland
9 Ponds
10 Limestone cliffs
11 Eagle owl nesting area
12 Green toad breeding area
13 Roe deer resting area

Fig 55 : Threshold based LANDSCAPE PLAN_1:50

Fig 56: Urban edge to protected habitat perspective_ 1:10

The landscape transitions from urban edge into protected ecological zone through seasonal access trails, vegetated buffers and habitat zones that support eurasian eagle owl and roedeer.

Access decrease as ecological sensitivity increases

Controlled human access and ecological buffering transforming the quarry into a multispecies landscape.

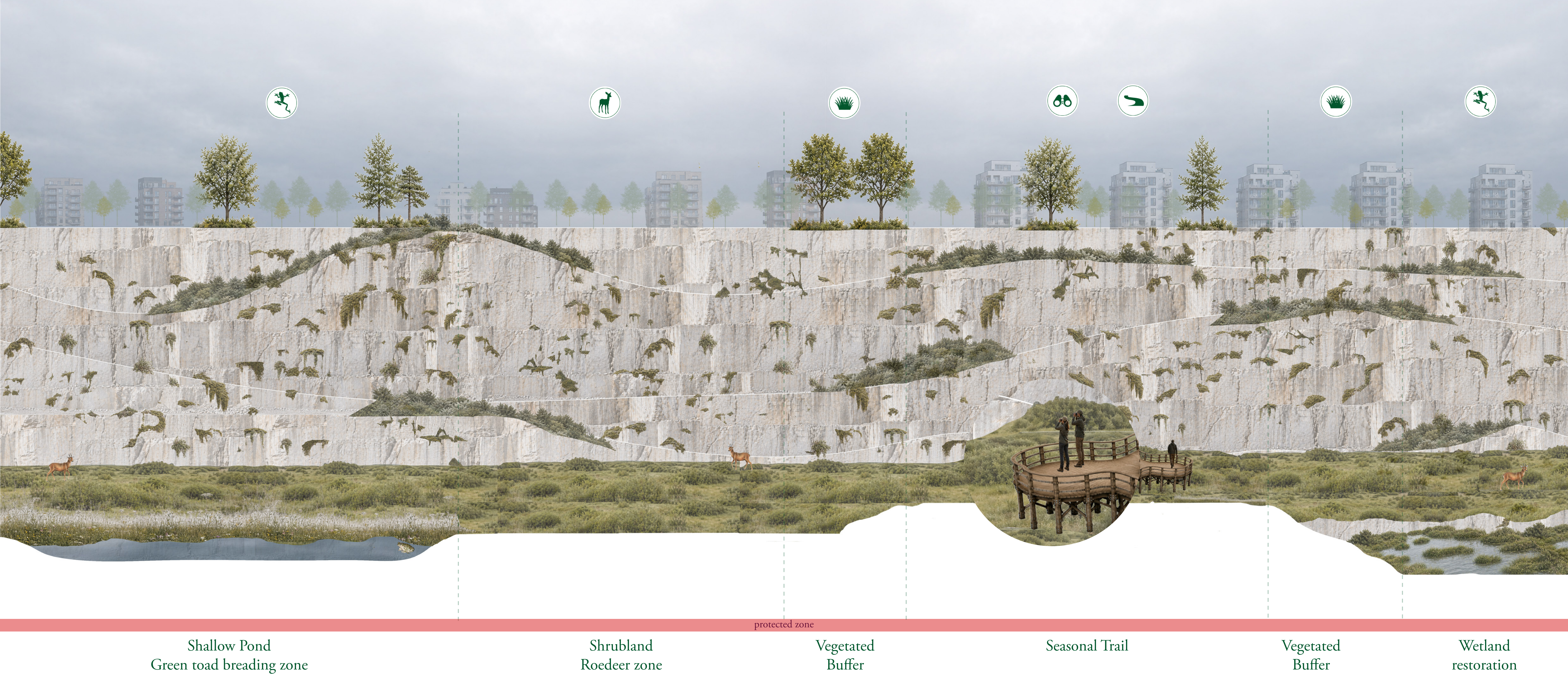


Fig 57: Habitat protection and Wetland restoration perspective_ 1:10

Seasonal trails and vegetated buffers in the protected zone provide a low impact trail corridor that can support roedeer habitat and green toad breeding while restoring and expanding wetlands.

Restoration of wetlands strengthen habitat connectivity and increase ecological resilience

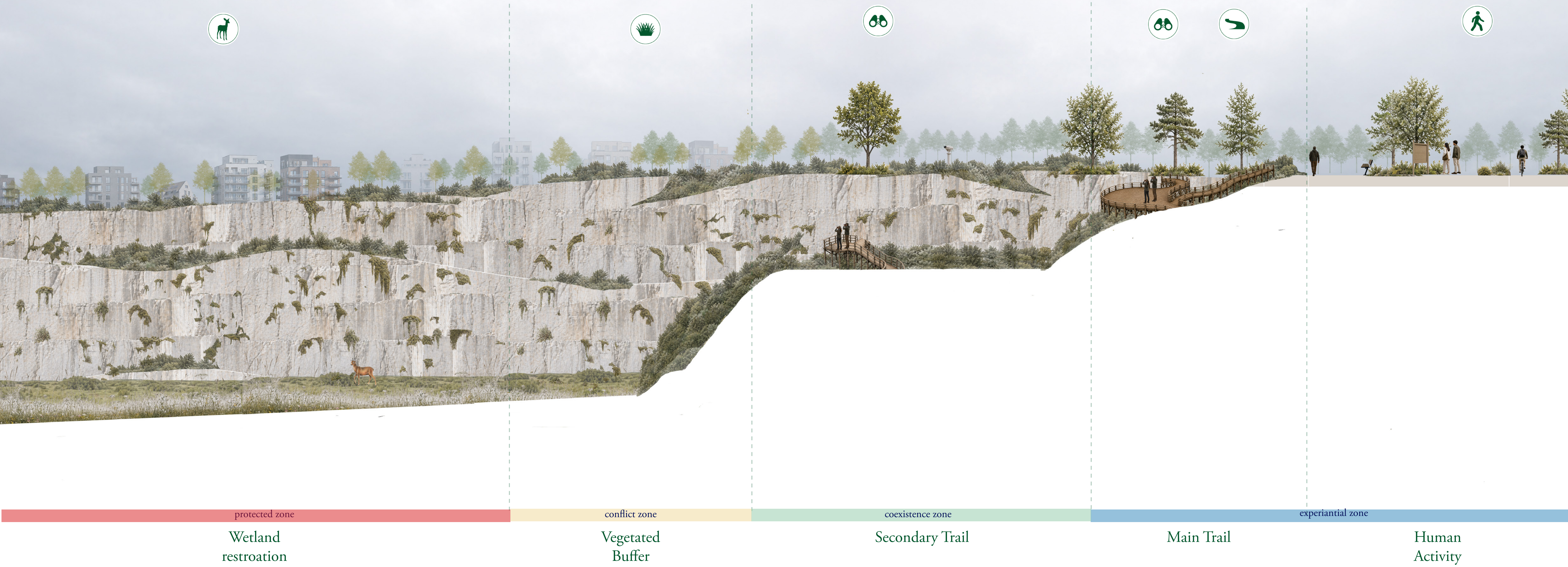


Fig 58: Human-nature coexistence perspective _ 1:10

Controlled coexistence landscape in which trails and viewpoints allow access between ecological protected and restored wetland and urban activities.

Human access increases gradually toward the urban edge

Conclusion & Discussions

This thesis explored how the edge of Limhamn kalkbrott can be redesigned to function as shared habitat for both humans and nature in the urban context of Malmö. By combining spatial analysis, habitat network modelling and scenario-based evaluation and design the research shows how the quarry edge can be planned for interaction between human and ecological processes.

Q1. What are the possible impacts of changing the quarry's edge on human accessibility and habitat connectivity?

The analysis shows that transformation of the quarry edge has a direct impact on both human and ecological systems.

From an ecological perspective, transforming the steep and rigid edges into terraced slopes, vegetated buffers and habitat corridors significantly improves the connectivity between the quarry and the surrounding. These interventions help species (green toad, roe deer and eurasian eagle owl) to move, reduce fragmentation and increase the functional range of the quarry as a habitat core. In terms of humans, increase in accessibility and interaction with the quarry landscape by introducing controlled access points, pathways and visual connection. However scenario testing and evaluation show that increased accessibility can lead to ecological disturbances and habitat fragmentation when not controlled carefully.

Q2. What spatial design principles and threshold strategies can be applied to redesign Limhamn kalkbrott for human-nature interaction?

The research develops a set of design principles and threshold strategies to balance this conflict based on the scenario evaluation and combined analysis.

The main approach is to design the quarry edge as a gradient of conditions and not a fixed boundary. These gradients zones forms into different levels of access and ecological sensitivity which includes protected ecological zone with restricted seasonal access, buffer zones that reduce disturbance, coexistence zones allowing controlling interactions, experiential zone focusing on human activity. All these threshold strategies translate the analytical findings into spatial interventions such as vegetated buffers, elevated walkways, terraced slopes and viewing platforms. When combined as a design implementation they allow for a controlled interaction of human and ecological systems.

Together these two sub-questions result in the answering the main research question

How can post-industrial quarries such as Limhamn Kalkbrott be redesigned to function as a shared habitat for both humans and nature in Malmö ?

The final design shows that limhamn kalkbrott can be redesigned as a shared habitat by transforming from a conflict into a planned coexistence.

Instead of maintaining the quarry as a separate ecological reserve or having just guided tours, the research proposes using a threshold based design approach where human-nature interaction is controlled by spatial conditions. By organising the quarry edge as zones and gradients of protection, buffering, coexistence and engagement the design allows ecological process to continue in sensitive areas, support species movement across the quarry landscape, humans to experience and access the quarry in controlled form. The thesis research combines street network analysis and habitat modelling, scenario-based evaluation and zoning to identify spatial conflicts and coexistence potentials between human accessibility and ecological systems.
The methodology develops protected, conflict, coexistence and experiential zones through analysis of accessibility, movement and habitat functionality with the translation into threshold based strategies. Thus the quarry is transformed from a spatial barrier into a socio-ecological connection that supports both ecological resilience and human well-being. This can be a transferable framework for the redesigning post-industrial quarry landscape

The research presents a threshold based approach which can be a transferable framework for rethinking urban edges as space for coexistence.

Methodological Limitations

The biotope data modelled and parameter table defined for habitat network analysis is based on existing research, but they do not cover the real time processes of ecology, seasonal variations or species adaptation over time. The analysis is only performed for the selected species from each group which reduces the ecological complexity of limhamn kalkbrott. Since other species groups are not taken into consideration can influence the overall habitat functionality.
The quarry landscape is an evolving system sensitive to temporal ecological processes and human activity.

Design limitations and critique

The proposed design though has some limitations, introduces a threshold based approach for balancing ecological protection and human access. The design suggests that spatial organisation only can control human behaviour, mainly through controlled pathways and zoning. But sometimes human uses of spaces can be unpredictable and informal movement may still occur in restricted areas.
Moreover the design proposal reduces the level of difficulty of implementing and managing especially in protected natura 2000 sites. Regulation challenges, maintenance requirements and long term governance have not been addressed.

Increasing human access and new planting strategies may also create accidental ecological consequences like disturbance to habitats, growth of invasive species and impact on sensitive breeding environments. Even with controlled movement and seasonal access through zoning , long term monitoring and management would still be needed in order to keep the habitat resilient over time.

Future research improvements

Some aspects of this study could not be developed further, if more time was available the ecological analysis could have been expanded to include a wider range of species and seasonal changes that would result in deeper understanding of habitat network analysis. With respect to design , the proposal could have focused on phased implementation scenarios mainly considering the sites conservation framework and natura 2000 regulations.

Findings from this thesis research sees possibilities to rethink post-industrial landscapes like quarries in urban landscapes. Throughout Europe there are former extraction sites similar to limhamn kalkbrott that have gradually started to develop into an ecologically valued habitat yet spatially disconnected from the urban areas with similar conditions existing in other limestone quarries where restricted access and spontaneous ecological succession have rare biodiversity.

While the approach developed in this thesis has combined habitat network modelling with spatial design strategies therefore could be applied to other quarry landscapes having the same conditions as limhamn kalkbrott by designing the quarry edge as ecological threshold and considering the different geological and ecological conditions of the quarry. The methodological framework presented in this thesis research can also be modified and implemented for spatial accessibility, ecological connectivity and conservation regulation post-industrial environments.

The thesis therefore sees post-industrial quarries as potential socio-ecologicla infraastuceure that can support biodiversity, ecological resilience ans human-nature interaction within expanding urban environments.

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Appendix

Appendix 1 : Species Listed

1. Bearded Tit
2. Ringed Plover
3. Common Shelduck
4. Black Redstart
5. Sand Martin
6. White throated Dipper
7. Kingfisher


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8. Peregrine Falcon
9. Raven
10. Grey Heron
11. Eurasian Eagle-Owl
12. Western marsh harrier


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13. Southern Damselfly
14. Green Toad
15. Hares
16. Badgers
17. Roe Deer
18. Fox


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19. Hawkweed
20. Clematis
21. Globe Flower
22. Hypericum Perforatum
23. Limestone Fern
24. Limestone Pennycress
25. Salix Myrsinifolia


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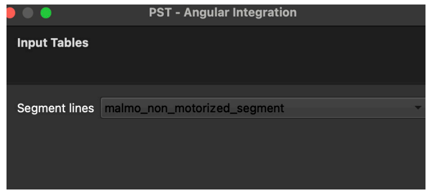
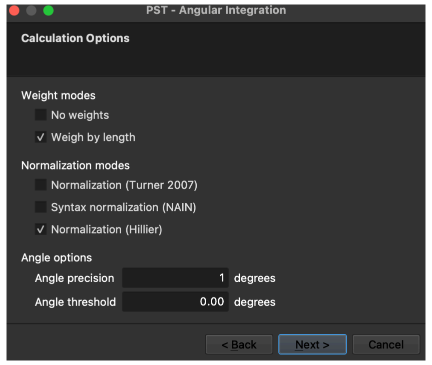
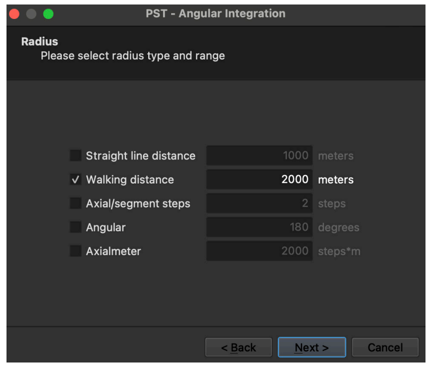
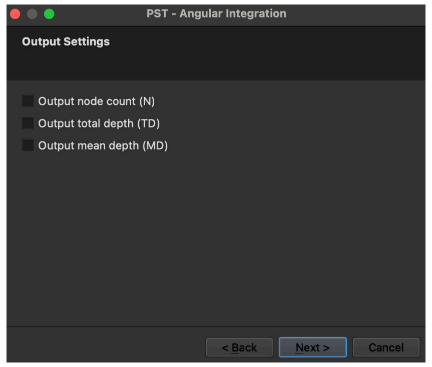
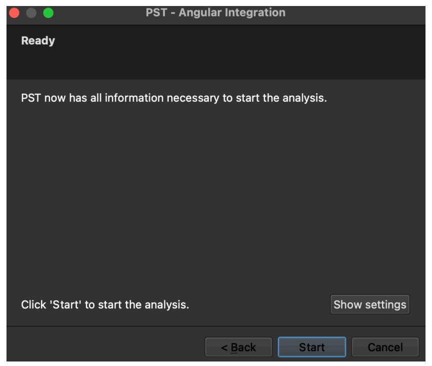
Appendix 2 : Qgis PST analysis settings



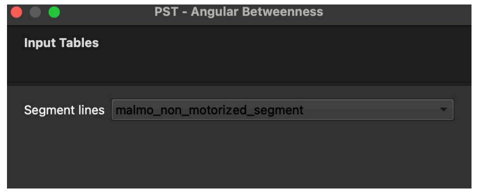


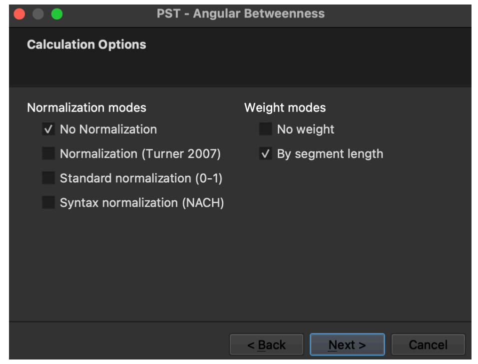


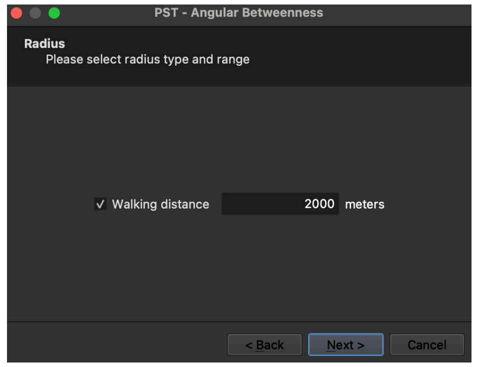


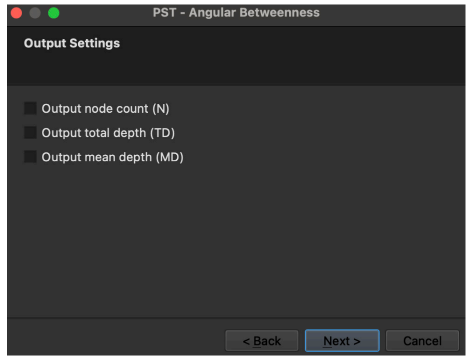


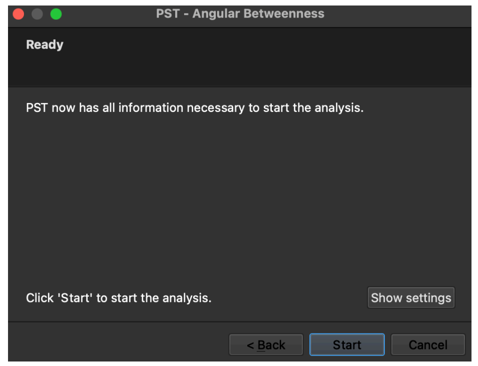
Angular Integration_2km











Angular Betweenness_2km

Appendix 3 : Threshold Design Guidelines

Zone type	Design principle	Threhold Stratergies	Ecological performance	Human interaction
1. PROTECTED ZONE	Protect core habitats and during breeding seasons	- no access signage - dense calcareous shrubland buffer (5-10m) - cliff vegetation (rocky substrate + spare pioneer plants) - elevated seasonal trail (2m) - open grassland and wetland restoration	- protect during breeding cycle - undisturbed nesting	- no direct access - seasonal restrictions - visual awareness
2. CONFLICT ZONE	Reduces human disturbance to maintain ecological connectivity	- elevated path (2m) - vegetated buffer (15-30m) - soft edge transition meadow (2m) + low shrubs (4m) + dense shrubs (6m)	- movement corridor for roe deer - greentoad connectivity between habitats	- controlled visual access (framed view into quarry)
3. COEXISTENCE ZONE	Allow controlled interactions in low sensitive zones	- elevated pathways (2-4m) - defined routes - pause nodes - open grassland + low shrubs + meadow (8 -12m)	- edge movement for roedeer - maintain ecological connectivity	- structures and guided access - controlled experience
4. EXPERIENTIAL ZONE	Allow human activities and engagement	- entry plaza - viewing platforms - seating - signages - hard surface + vegetation (low planting +spare trees)	- avoid core habitats - redirect roedeer to low impact areas	- gathering and pause nodes - educational nodes

Appendix 4 : Artificial Intelligence

Ai tools (chatgpt and midjourney) were used for text refinement and generation of conceptual visual images and textures such as limestone, elevated pathways, meadows, shrubs ,trees and water for the perspective renders.