1

音场：
印度西高止山脉热带雨林地区的生态声学基础设施
SOUNDFIELD IN WESTERN GHATS, INDIA

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摘要

音场项目将声音作为理解和观察印度西高止山脉热带雨林的主要方式。通过记录和分析具体声音的强度和范围，项目希望使用一种新的方法重新理解人类开发建设对生物迁徙廊道的影响。大象迁徙廊道是研究的重点，由于热带雨林植被茂密、能见度低的空间特点，居住其中的大象们主要依靠听觉和震动来感知周边环境。但当地人类开发建设对其造成的影响不在于空间上，而在于听觉上的干扰。基于此，本项目着力于设计出不同的音场范围，进而引导象群的行进方向。这些音场被定义为森林中的生态基础设施，在大象及其他野生动物与当地居民间创造出一种新的生态平衡。

关键词

音场；声音生态基础设施；大象廊道；西高止山脉热带雨林；缓冲区；十字路口

ABSTRACT

Soundfield envisions sound as the lens through which to view the landscape of the Western Ghats. By gaging the intensity and location of specific sounds within the landscape, Soundfield seeks to realign human and wildlife transit within the Western Ghats. Focusing on elephant corridor which is based on ecologies of sound, Soundfield defines divergent areas of elephant and human traverse. By generating types of sounds that attract, or dissuade these distinct groups, Soundfield proposes the infrastructure to mitigate navigation between humans, elephants and other wildlife through the Ghats.

KEY WORDS

Soundfield; Acoustic Ecological Infrastructure; Elephant Corridor; Western Ghats; Buffer Zone; Cross

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场地环境

西高止山脉位于印度的西部沿海区域，是一条横跨整个印度南北的热带雨林气候山脉，同时也是联合国教科文组织认证的世界遗产区域以及生态热点区 。整条山脉长近1 600km，覆盖面积约16万平方公里，平均海拔约1 190m。这里是世界上最大的亚洲象栖息地，约有25 000头亚洲象以及其他珍稀物种生活其中[①]。

支离破碎的大象廊道

大象在印度宗教以及世俗文化里均占有很崇高的地位。西高止山脉是整个印度大象活动最为频繁的区域之一，然而近年来，随着人口的增加以及人类活动的扩张，大象的生存区域在不断缩小——在当地一个近4.7km^{2}的区域里，每年有30头大象以及数百人死于人象抗争之中。铁路、公路等基础设施的建设对整个热带雨林地区的生态环境造成了剧烈影响，包括一项长期以来被忽视的关键性生态要素——声音。

声音是一种震动，这种震动经由不同媒介的传播后被生物的大脑所读取。而所听到声音的不同取决于其震动频率的不同。震动频率越高，声音越尖锐，传播的距离越短；频率越低，声音越低沉，传播的距离越长。每个物种都有其独特的声音频率接收范围。大象是生物界中非常罕见的能够发出、接收到低频声音的物种——在普通热带雨林环境里，大象大约能够听到2.5km之外发出的低频声音。而对于生活在西高止山脉里的大象来说，身处热带雨林特殊的空间环境中，声音是比视觉图像更为重要的环境判断因素。人类聚居地中有很多低频噪音源，而疾驰的火车、高速运转的马达，以及速度达到80km/h以上的汽车是产生低频噪音的主要来源。由于低频声音传播距离远的特性，其覆盖范围已对当地象群造成了极其巨大的干扰。大象会下意识地回避这些发出低频声音干扰的区域。西高止山脉区域内一共有88条大象廊道，大部分都是南北走向。而由于绝大部分铁路与高速公路都是东西向穿越西高止山脉，这些交通基础设施便成为了一道道音场隔断带，将88条大象廊道“切”成无数碎片。

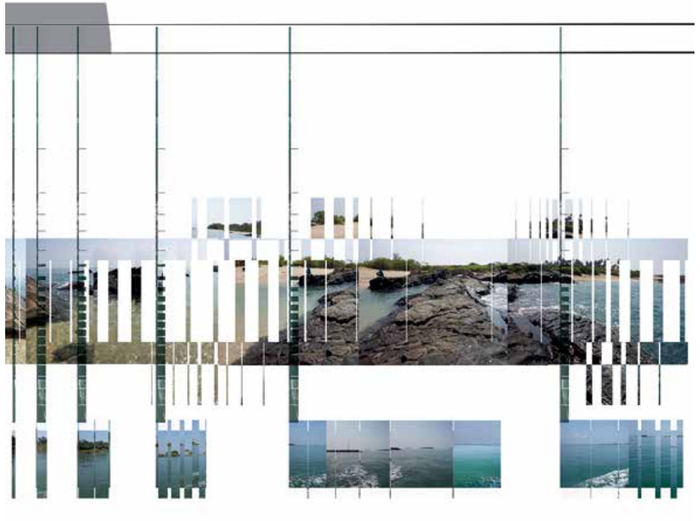
音场

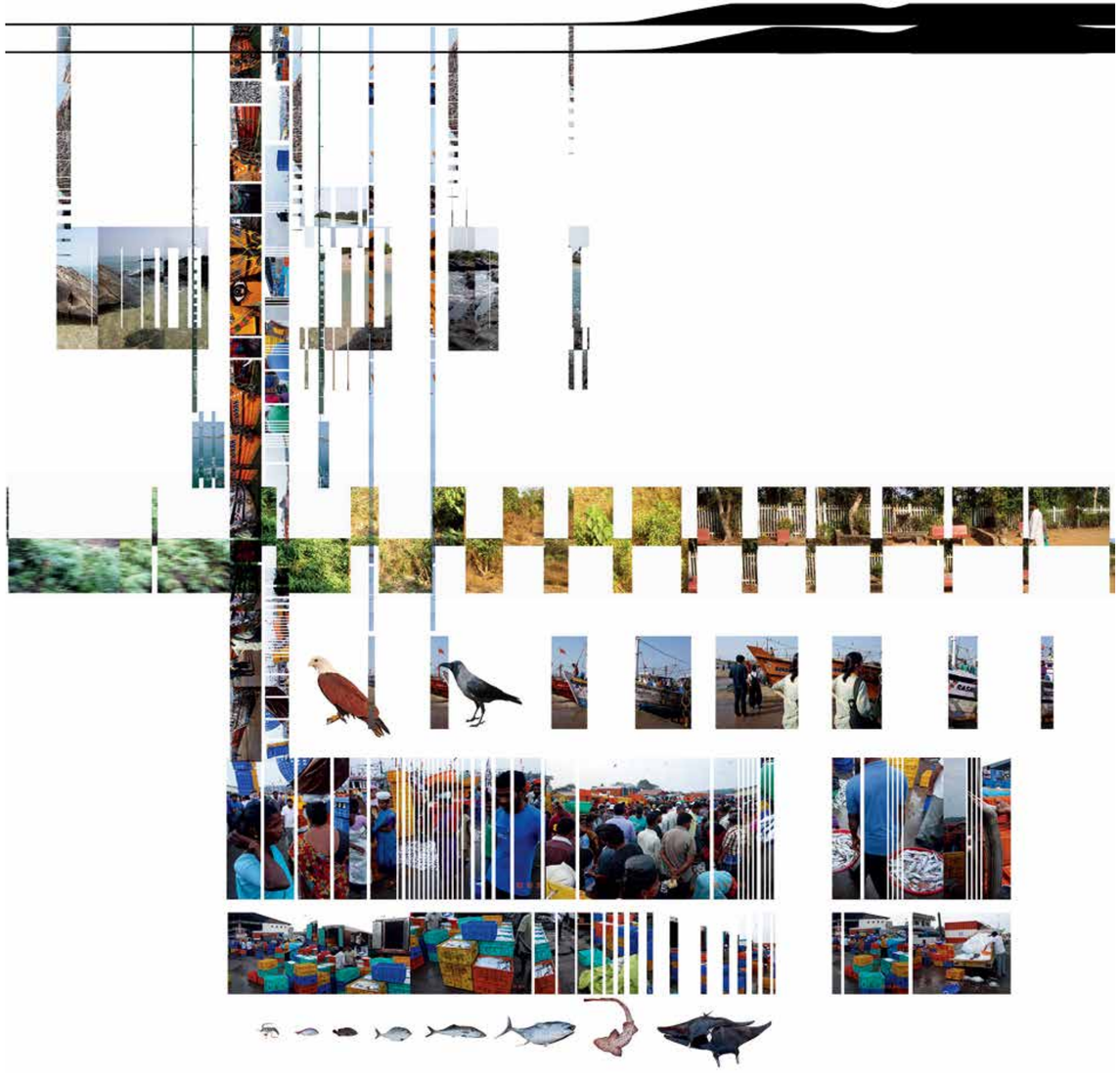
音场项目希望以声音为切入点，通过设计策略以及空间设计改变音场环境，从而修

① 更多信息请参见：http://www.sanctuaryasia.com/magazines/cover-story/6830-right-of-passage-elephant-corridors-of-india.html。

1. 本项目着力于设计出不同的音场范围来引导象群的行进方向，进而在大象及其他野生动物与当地居民间创造出一种新的生态平衡。

1. By generating types of sounds that attract, or dissuade elephant groups, Soundfield proposes the infrastructure to mitigate navigation between humans, elephants and other wildlife through the Ghats.





项目地址：
印度西高止山脉热带雨林地区
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设计时间：
2015年

LOCATION:
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CHIEF DESIGNER:
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PROJECT LEADER:
Anuradha Mathur
DESIGN PERIOD:
2015

2. 作者在西高止热带雨林记录的音场环境部分片段。

2. A part of the Soundfiled transect of the Western Ghats.

复大象廊道。

穿越西高止山脉的高速公路势必会有一段上山与下山路，而其中有部分路段采用Z字形山路，以应对极端陡峭的地形变化。车辆在这些路段会降低行驶速度，而低速行驶的汽车并不会制造大量低频声音；与此同时，地形高差的变化也为项目设计创造了机遇。这些天然优势让Z字形山路成为音场隔离带的潜在突破口。

我选择了65号公路阿贡比以南段的Z字形山路作为具体的设计场地。首先，我对场地进行了细致的调研，并尝试使用序列剖面图将其视觉化。序列剖面图不是以地理位置为逻辑依据，而是根据我们在道路上如何“听”到场地而绘制。道路处于剖面的中心，也是该剖面的基点位置，地形根据这个基点向剖面两侧延伸。如图5所示，我们可以清楚地看到地形与植被对声音扩散或阻隔的影响。靠山体一端的声音会被阻隔，而靠崖一端的声音较易传播。

方案将Z字形山路分为两个区域：1）缓冲区：车辆减速抵达的Z字形山路前段，以及车辆开始加速离去的后段；2）十字路口：车辆缓慢行驶的Z字形山路中段。

缓冲区

我将Z字形山路前段和后段定义为大象廊道与机动车廊道的“缓冲区”，建议添置新的频率高但传播距离短的声音源，并且保持密度较高的植被环境，以将大象引导至山路中段。

已有的关于大象用听觉分辨捕食者的实验证明，对于猎豹的低吼声，大象表现出疑

2

惑和紧张的态度；而令人惊讶的是，对于人类的咆哮声和老虎的低吼声，大象并没有表现出惧怕和规避。最有趣的是，18群通过测试地点的大象均对蜜蜂的嗡嗡声表现出很强烈的反应——立刻转移行进方向或者跑开。蜜蜂的嗡嗡声属于一种高频声音，传播距离短但强度很大。基于大象对蜜蜂嗡鸣声的本能回避反应，方案在盘山路上下两端各设置了数个蜜蜂农场。在具有经济效益的同时，这些农场成为了在车辆抵达Z字形山路开端开始减速的路段和驶离Z字形山路开始加速的路段中一道针对大象的有效声音屏障，进而将接近场地的迁徙象群引导到Z字形山路的中段通过。

十字路口

Z字形山路中段被定义为大象廊道与机动车廊道的“十字路口”。在该段行驶的车辆速度相对较慢，并且司机精神最为集中。方案建议设置一个覆盖Z字形山路中段的音场监测系统，以及与之相连的道路交通灯系统。当系统监测到有大象活动时，交通灯变成红色或者黄色闪烁，以阻止或警示司机减速行驶；同时项目还进行了道路加宽、通过地形重塑减缓道路两旁的坡度变化，以及移除部分植被等改造。这些举措有利于司机与大象拥有更好的视野和更宽阔的缓冲范围，以应对可能的突发状况，从而创造一个机动车与大象共享的十字路口区域。设计还建议在此处设立一个生态声学监测研究中心，以便对“十字路口”这个生态声学基础设施的作用进行长期监测与评估。

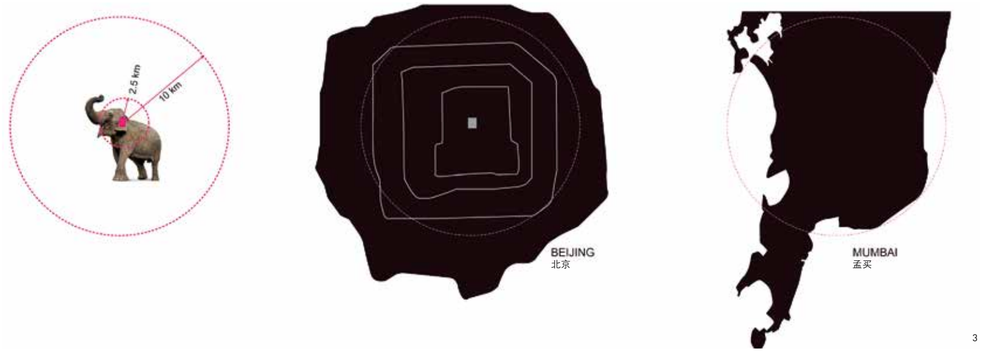
音场数据网

音场监测系统除了警示司机外，还有一个更为深远的意义——其不间断地记录着一个生态热点的所有音频数据。我们设想，如果将十字路口视为一种被设置在西高止山脉所有的Z字形山路处的交通基础设施，那么其就可编织出一张覆盖整个山脉的实时更新的声音数据网。热带雨林中的声音蕴含着巨量的信息。西高止山脉的声音数据库将会成为一个宝贵的原始数据库存，为不同的生态学家和不同的研究课题提供颇具价值的原始数据支持。

结语

音场项目将声音作为最主要的感官途径来理解设计场地——印度西高止山脉区域，发现导致当地居民与大象矛盾背后的重要原因，并基于对声音环境的改造来修复被高速公路切断的大象廊道，同时为西高止山脉热带雨林地区提供一种独特的生态监测手段。

我们可以从三个角度来评估音场项目的意义：1）从本地村庄角度来说，过往车辆能够拥有一个更加安全的行驶环境，而当地居民则可以通过养殖蜜蜂与果树获得额外收入及工作机会；2）从生态价值角度来说，一个十字路口能修复一条长度50km以上的大象廊道；3）而从对未来的贡献角度来讲，每一个十字路口都是一个可以覆盖微型生态热点区域中所有声音数据的资料库，当我们拥有了10个、100个，乃至成千上万个这样的十字路口时，声音数据网将为我们提供一种全新的理解西高止山脉，甚至全球热带雨林生态规律的切入视角。**LAF**



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3. 在普通热带雨林环境里，大象大约能够听到2.5km以外发出的低频声音。在一个周边环境干扰较小的区域中，同时满足昼夜温差较大以及无云的夜晚时分，大象的低频声音接收距离能达到10km，即约300km^{2}的面积范围。

3. An elephant could hear a low frequency sound from 2.5 km away in normal tropical forest environment. Within a cloudless quiet night, the range could possibly extend to 10 km, which covers 300 km^2 area.

① For more information please visit http://www.sanctuaryasia.com/magazines/cover-story/6830-right-of-passage-elephant-corridors-of-india.html.

Site Brief

Western Ghats, located along the western coast of India, is a range of hills covered with monsoon forest, a UNESCO world heritage site and a biodiversity hotspot. The whole range runs approximately 990 miles through the states of Maharashtra, Goa, Karnataka, Kerala and Tamil Nadu, ending at Kanyakumari, at the southern tip of India. These hills cover 62,000 square miles and the average elevation is around 3,900 feet. It is also a corridor that works as the vital lifeline for more than 25,000 Asian elephants①. It also provides a safe passage to a number of other rare species.

Breaking the Elephant Corridor

Elephants are an iconic species that are highly respectful in India's culture. However, urban expansion and human activities have threatened elephant habitats in Western Ghats. Only in Hassan, a 1.8 square mile village, hundreds of people and 30 elephants die in conflict each year. The development of transportation infrastructure, such as highways and railroads, brings a huge impact on the local ecological system. One of the significant aspects that has always been ignored is Acoustic Disturbance.

Sound is a vibration that propagates as a typically audible mechanical wave of pressure and displacement, through a medium such as air or water and being received by brains. Different sounds act with different frequencies. Higher frequency sound, like a "sizzle," has a relatively short transmission distance. Lower frequency sound, like "rumble," has a relatively long transmission distance. Different species have their unique sound reception frequency range. Elephants are a species that has one of the lowest frequency receive ranges. An elephant could hear a low frequency sound from 2.5 km away in a normal tropical forest environment. Therefore, auditory perception is much more important than visual to the elephants in Western Ghats.

Moving cars, especially at speeds higher than 50 miles / hour, are the main low frequency noise generators. Although transportation infrastructure does not occupy a large place spatially, each highway passes through the Western Ghats creates a thick linear acoustic noise zone to the forest. Elephants hear the noise and get confused. There are 88 elephant corridors in the Western Ghats and most of them are in the north-south directions. Meanwhile highways are mostly east-west directions in order to pass through the mountains. These highways literally divide elephant corridors into pieces.

Soundfield

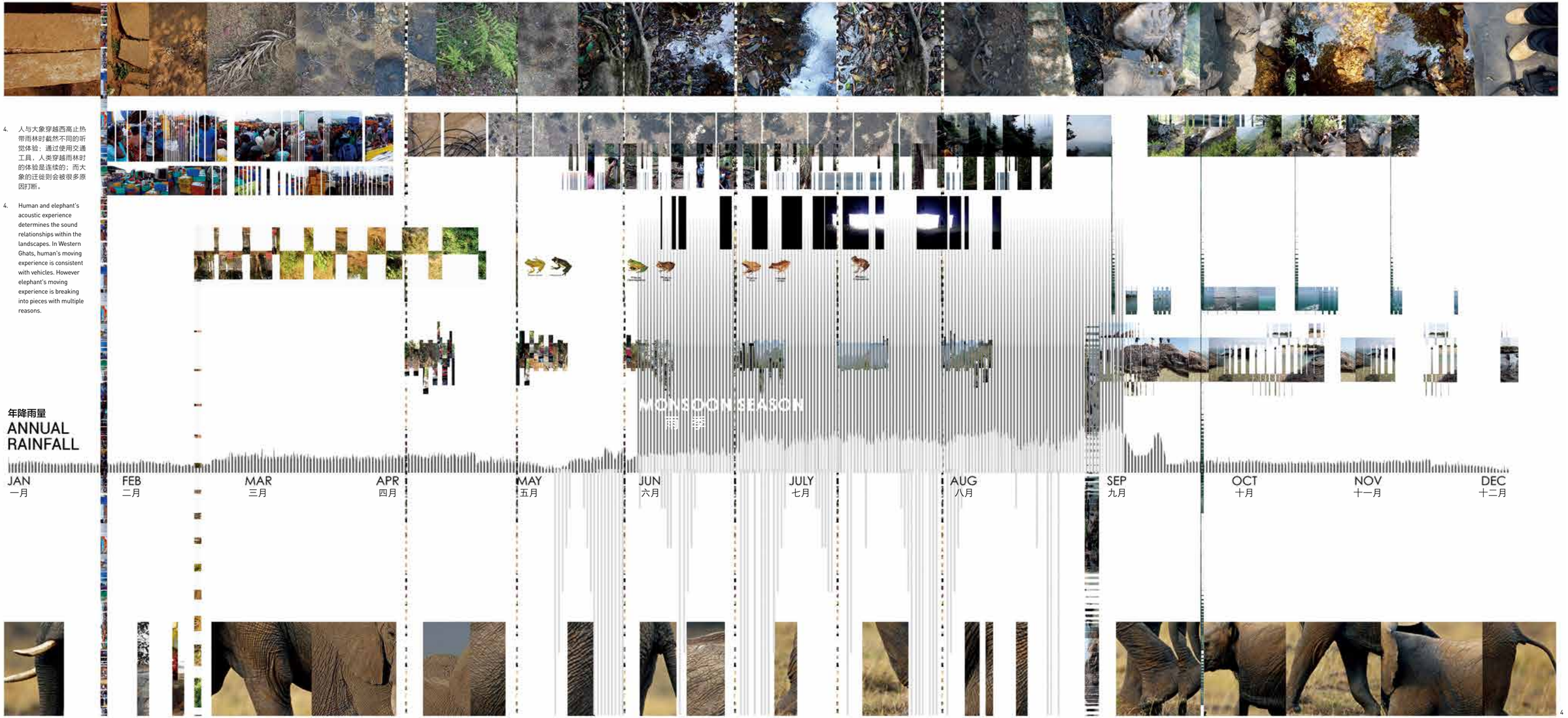
The Soundfield project considers Sound as a main design lens, repairing the elephant corridor by providing an intervention to the acoustic condition of the site.

Most of highways in the mountains have steep elevation changes, some parts of them are extremely steep, and a zigzag mountain road type is necessary. In these spots drivers always are more focused and the driving speed is slow, generating less low frequency sound in general. These aspects make the zigzag mountain road a potential site type to reconnect the elephant corridor.

The site I chose is an intersection between an elephant corridor and No. 65 downhill mountain road. First, I mapped out the site through a sound experience. The frame of site's sequential section was not based on geological directions, but based on how we "hear" the site. In the sequential section, roads are always at the middle. Every bend of the zigzag downhill road becomes the reference point to align the whole section system. As shown in the section diagrams, it is easy to understand the acoustic environment shaped by landscape.

4. 人与大象穿越西高止热带雨林时截然不同的听觉体验：通过使用交通工具，人类穿越雨林时的体验是连续的；而大象的迁徙则会被很多原因打断。

4. Human and elephant's acoustic experience determines the sound relationships within the landscapes. In Western Ghats, human's moving experience is consistent with vehicles. However elephant's moving experience is breaking into pieces with multiple reasons.



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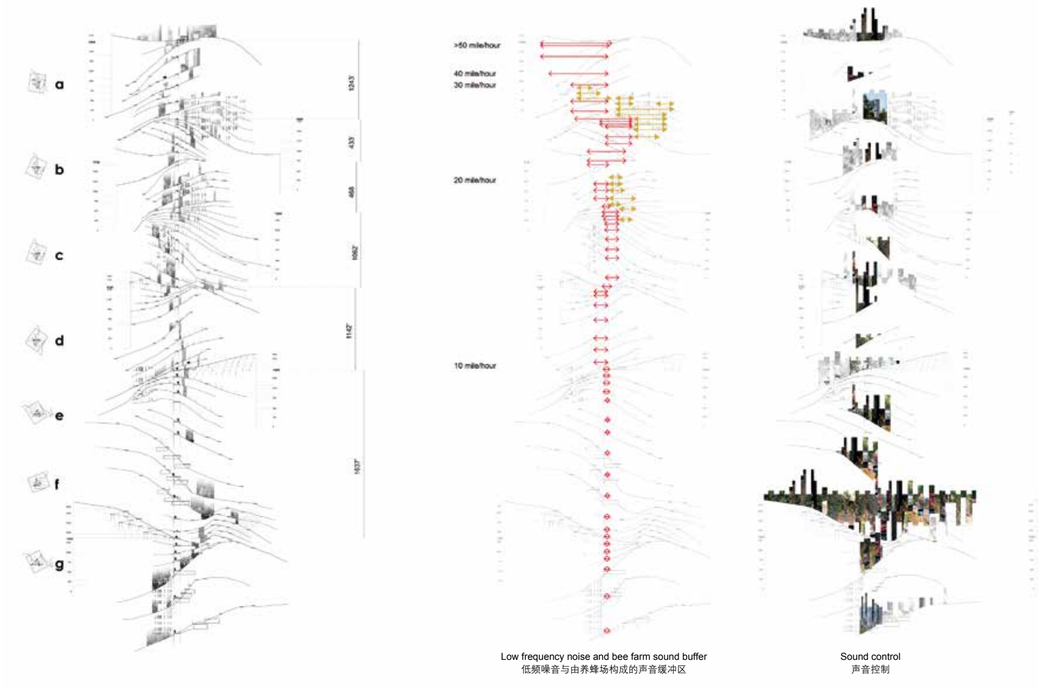

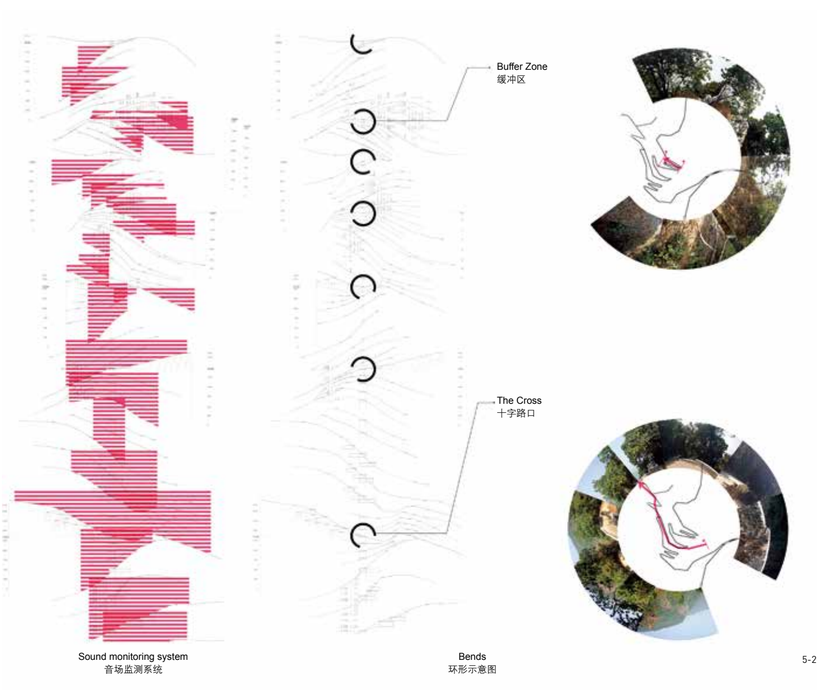

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The project separates the whole site as two parts and provides interventions independently:1) Buffer Zone: upper and lower parts of the zigzag mountain road; 2) The Cross: middle part of the zigzag mountain road.

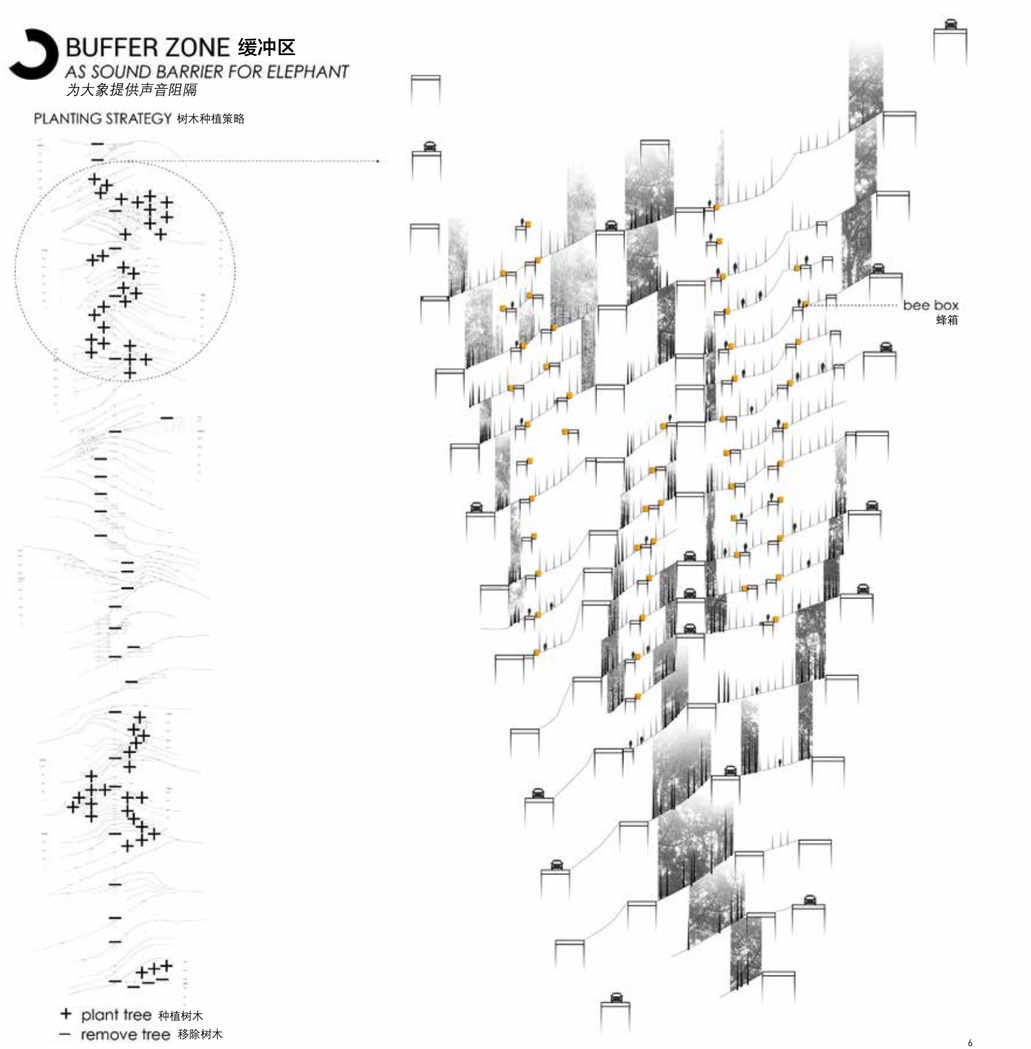
Buffer Zone

I defined the upper and lower parts of the zigzag mountain road as a buffer zone in order to orient the elephant to the middle part of the road.

Lucy E. King, Lain Douglas Hamilton, and Frit Vollrath conducted a research about testing the reaction when elephants hear the different sound from predators. For the leopard growl playback, elephant reacts with suspect and nervousness. For the tiger and villager's playback, elephant has surprisingly no acute reactions. The most interesting finding was that the significant majority of elephants, in a sample of 18 well-known families and subgroups of varying sizes, reacted negatively — immediately walking or running away — when they heard

5. 序列剖面图

5. Series sections



6

the buzz of disturbed bees. The bee sound has a high frequency sound which has a short transmission distance. Based on the research, I proposed several linear bee farms in the upper and lower part of the road. For one, it could become a productive landscape, not only a bee farm, but also orchard nurseries since the flowers of fruit trees could be the food resource for bees. For another reason, it works as a buffer zone to orient the elephant to the middle part of the zigzag road.

The Cross

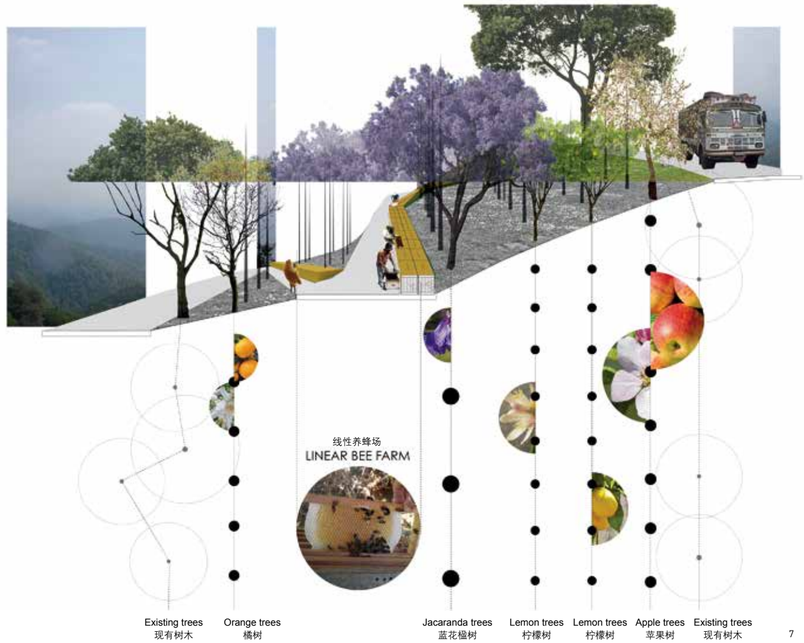
By reshaping the landform and extending the width of the existing road, an elephant gateway was proposed in the middle of the zigzag mountain road. Rather than a separation, the gateway provides a shared ground for elephants and people. By setting up a sound monitoring sensor system in and around the gateway and connecting this system to a traffic light system, drivers would be aware of closeby elephants and would have sufficient time to either avoid them or share the road with them. Multiple extra spaces and paths were designed for emergency avoidance. A sound ecology research center was proposed on the site since the gateway will become a popular gate for not only elephants, but also other species to pass through.

Sound Database

Besides the function of reconnecting the elephant corridor, the sound monitoring sensor system has another significant function — recording the sound consistently in this ecological hotspot. If we consider The Cross as an infrastructure and set it up at all over zigzag mountain road spots in the Western Ghats, we are also building a monitoring network which can consistently record sound data of the whole forest area. The sound database of the Western Ghats will become a precious raw database to support multiple ecological researches for the area in the future.

Conclusions

Soundfield aims to study the ecological environment of the Western Ghats through acoustics, a significant element of design that has always been neglected. Acoustic design is used as a lens to understand the conflict between people and elephants, providing an intervention to shape the acoustic environment



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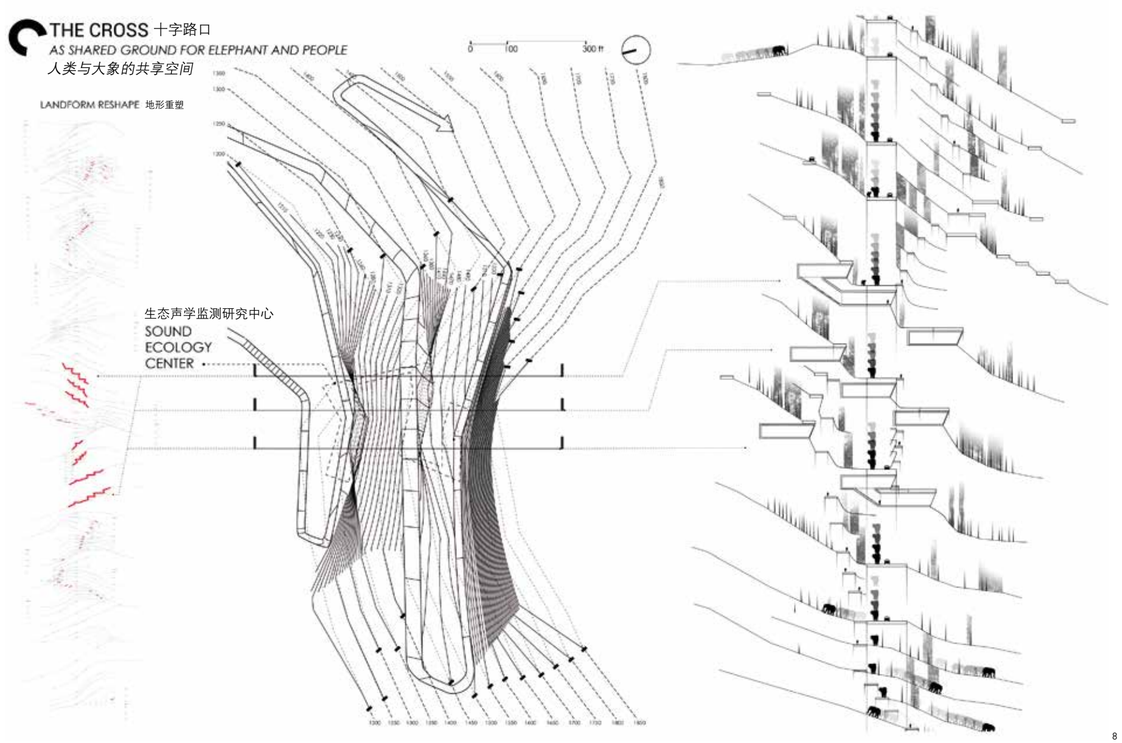
6. 缓冲区
7. 缓冲区效果图

6. Buffer Zone
7. Rendering of the Buffer Zone



8

at certain points in order to reconnect the elephant corridor that has been broken-down by human development.

We could evaluate the project via three different perspectives: From the village scale perspective, drivers will have a safer drive environment and bee farms and a sound ecological center will provide potential job opportunities to local residents. From ecological evaluation perspective, one Cross would be able to repair at least one 50-kilometer elephant corridor and alleviate the conflict between human and elephant. From future potential perspective, the network database collected by hundreds of Cross would be able to provide a new lens for ecologists to understand the Western Ghats monsoon forest ecology system. **LAF**

8. 十字路口
9. 音场生态监测系统。粉红色线段表示音场监测系统所能覆盖的范围。

8. The Cross
9. Acoustic ecology monitoring system. The pink transects represent the area that the system can cover.

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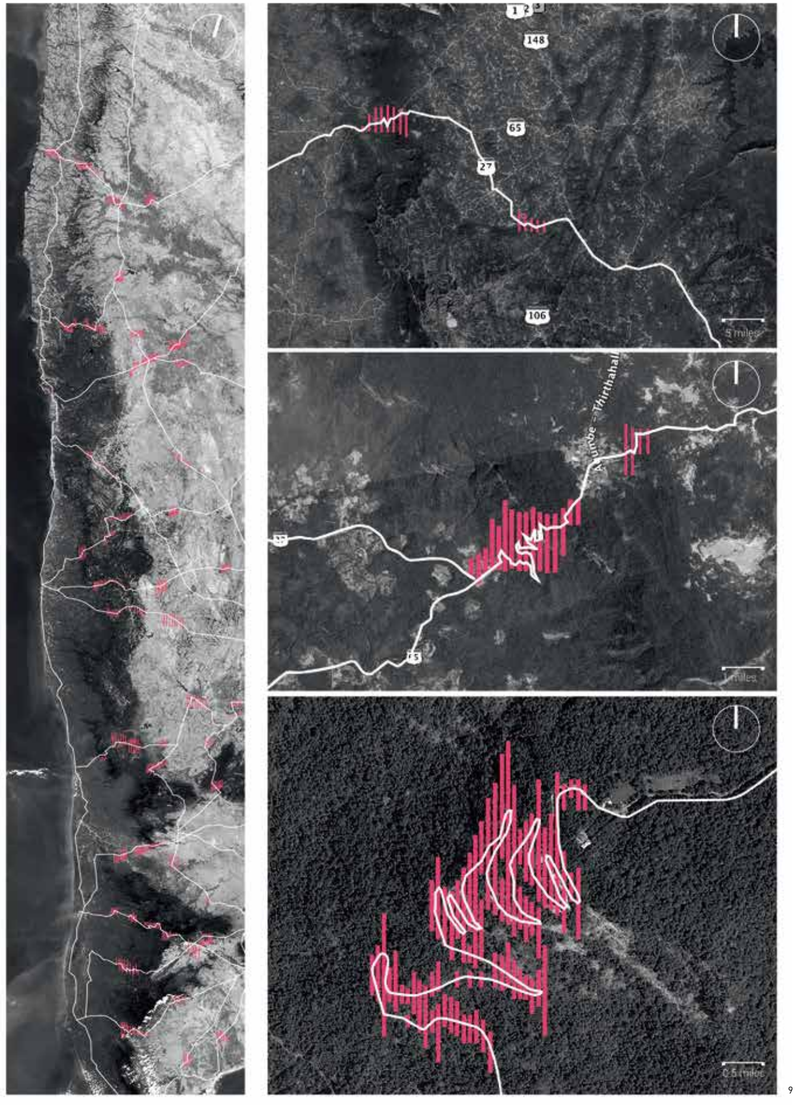

9