Eastern Alpine and Großmugl starlight areas, Austria

Günther Wuchterl

1. Identification of the property

1.a Country/State Party: Austria

1.b State/Province/Region: Lower Austria, Upper Austria and Styria. The Großmugl Starlight Oasis is within the Korneuburg district, Lower Austria

1.c Name: Eastern Alpine Starlight Reserve / Großmugl Starlight Oasis

1.d Location

EASTERN ALPINE STARLIGHT RESERVE

Elliptical area including Dürrenstein Wilderness Area, Gesäuse National Park and Kalkalpen National Park:

Long axis (approx. W–E): 47° 11′ N, 13° 50′ E to 47° 58′ N, 16° 55′ E

Short axis (approx. N–S): 47° 50′ N, 14° 27′ E to 47° 18′ N, 14° 52′ E

Alternative elliptical area additionally including Nockberge National Park (Carinthia):

Long axis (approx. W–E): 46° 52′ N, 13° 35′ E to 47° 58′ N, 16° 55′ E

Short axis (approx. N–S): 47° 50′ N, 14° 27′ E to 47° 18′ N, 14° 52′ E

GROßMUGL STARLIGHT OASIS

Latitude 48° 29′ 18″ N, longitude 16° 13′ 23″ E, elevation 265m above MSL (Large tumulus)

1.e Maps and Plans

Fig 12.1 shows the general location of the proposed core areas of the Eastern Alpine Starlight Reserve and of the Großmugl Starlight Oasis. Fig 12.2 shows the proposed core zone and buffer zone of the Großmugl Starlight Oasis.

1.f Area of the property and buffer zone

EASTERN ALPINE STARLIGHT RESERVE

Core area:

Total 34,304 ha, comprising

- 20,850 ha (Kalkapen National Park),
- 11,054 ha (Gesäuse National Park), and
- 3,500 ha (Dürrenstein Wilderness Area).

Buffer zone:

~ 19,000 km² (~ 100 × 60 km).

Alternative including Nockberge National Park: ~ 41,000 km² (~ 220 × 60 km).

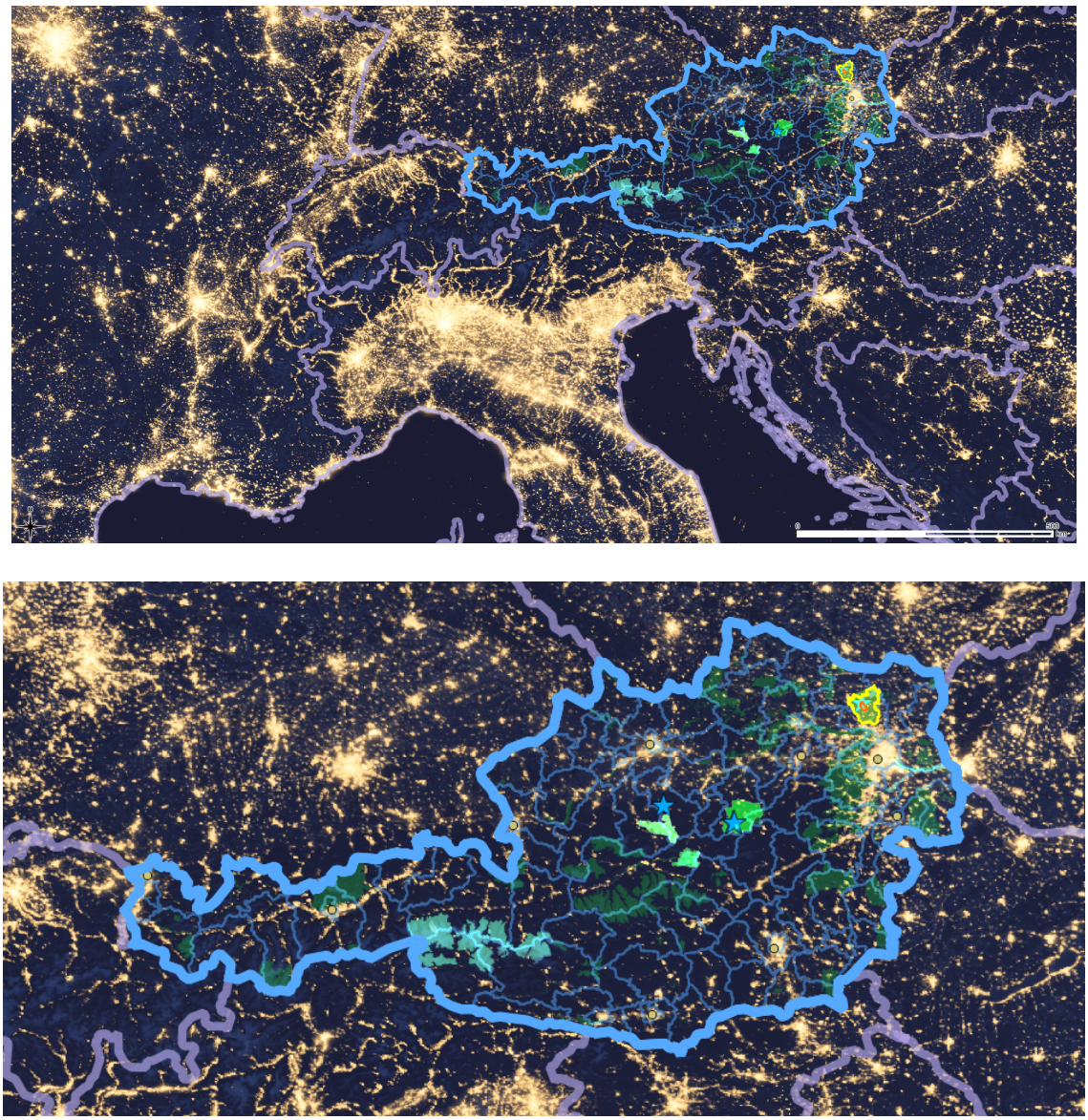

Fig. 12.1: The Alpine Arc and Central Europe at night. **Top:** Upward light from satellite measurements (background image), with state boundaries superimposed in purple, and the Austrian border highlighted in light blue. The bar at the lower right indicates 500 km. **Bottom:** Magnification of the part within Austria. Provincial boundaries are shown in blue. Bright green patches show the proposed Eastern Alpine Starlight Reserve cores and the Großmugl Starlight Oasis (with yellow boundary). Blue-green denotes additional IUCN category I and II protected areas in Austria, while dark green marks selected nature protection areas (for orientation). Blue stars denote light-monitoring stations that were set up for this study. They monitor light levels resulting from light shining downwards onto the sites. Chart and image: G. Wuchterl. Background image: NASA Black Marble

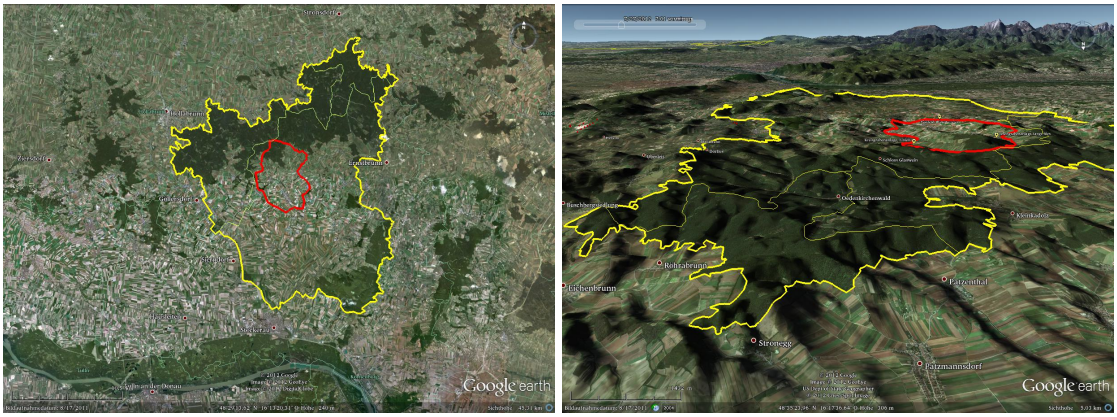

Fig. 12.2: The core-zone (red) and buffer-zone (yellow) of the Großmugl Starlight Oasis. **(Left)** As viewed from overhead. The area shown is about 30 × 40km, 30 km NNW of central Vienna; the Danube is visible at the bottom. **(Right)** As viewed from the north. The Vienna basin is visible at the upper left; the eastern end of the Alps is in the upper right corner.

GROßMUGL STARLIGHT OASIS

- Core area: approx. 25 km²
- Buffer zone: approx. 300 km²

The *core zone* (red line in Fig. 12.2) has a radius of approximately 3km. It covers an area of about 30 × 40km and is situated 30km NNW of central Vienna (the Danube is visible at the bottom of Fig. 12.2 [Left]). It contains some major prehistoric remains—the large tumulus, the Steinabrunn and Linen circular ditched enclosures (Fig. 12.3) —as well as a number of important sky-observing spots and viewpoints.

The *buffer-zone* is an area approximately 10km in radius around the large tumulus at Großmugl. Its border (yellow line in Fig. 12.2) follows the visible landscape horizon, which is largely shaped by the "inner ring" of a natural light protection system created by the topography. In the directions towards the main Alpine chain, where remote high mountains up to 200 km distant may be seen, the horizon is defined by clearly visible mountain peaks. Towards the north and between the south and south-east (the general direction of Vienna) the border follows mountains or ridges. In other directions the buffer zone extends to hill-crests, forests patches and landscape "divides" in order to include the topographical features that shield the area against the influx of light (Fig. 12.2 [Left]; see also Fig. 12.4).

The buffer zone, or high-sensitivity zone, will thus include the nearby area that can be directly seen from the core zone, thereby guaranteeing that the effects of air or light pollution will not affect the core zone (cf. *Starlight Reserve Concept*[1] p. 20). It also protects the wide and unobstructed views towards and above the horizon and, in particular, ensures full access to the celestial hemisphere. This combination provides protection for the entire night-landscape as seen from the tumulus-area and other viewpoints in the core zone.

In sum, the sky-landscape system of the core zone is protected by the buffer zone, which prevents unwanted artificial light intrusion into the site while enabling natural light-flow within it.

[1] http://www.starlight2007.net/pdf/StarlightReserve.pdf

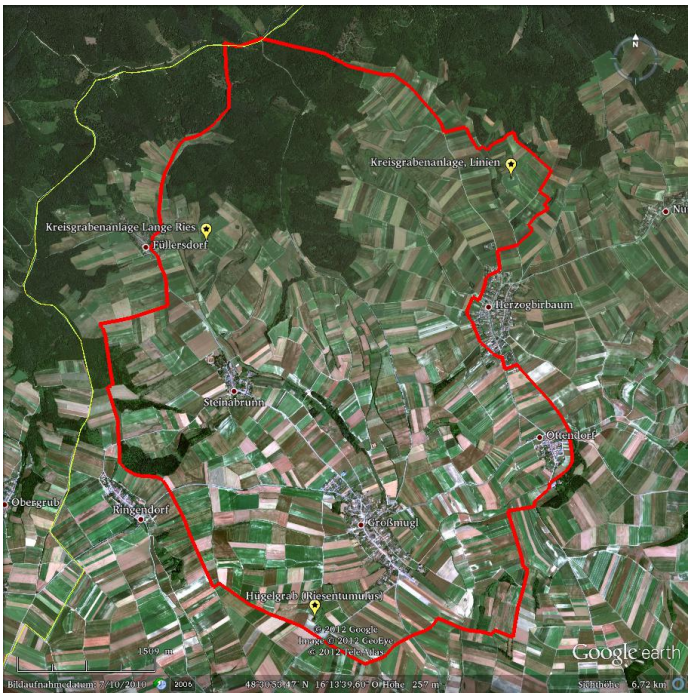

Fig. 12.3: Prehistoric remains (yellow symbols) in the core zone (marked in red) of the Großmugl Starlight Oasis. They include the Großmugl large tumulus (lower centre), the Steinabrunn circular ditch system and the Linen ditch and grave-field.

Fig. 12.4: Bird's eye view (looking south) of the topography at the site that protects the core-zone from the lights of Vienna. The shielding effect against the artificial sky brightening caused by Vienna's lights and light dome can be imagined by looking at the shadows cast by a low morning Sun. The triple hill chains between the core zone (in red) are visible towards the upper left with the Vienna-basin in the corner. Two of the hill-chains are included in the buffer zone that is outlined in yellow. The village of Großmugl is visible in the lower right corner with the large tumulus just above it (yellow marker). The conspicuous mountain in the upper right is the Schneeberg (2076m).

2. Description

2.a Description of the property

EASTERN ALPINE STARLIGHT RESERVE

The iconic landscape of the Alpine range together with its comparatively less known, very wide eastern third form a ~1000 km² area containing natural skies above a unique mountain landscape.

The core-zone of the proposed Eastern Alpine Starlight Reserve is comprised of three of the most secluded areas in the widest part of the Alpine arc, each of which is an IUCN-recognised Austrian nature conservation area. These are:

1. The Wildnisgebiet Dürrenstein (Dürrenstein Wilderness Area) in Lower Austria (IUCN category I), of which the Urwald Rothwald (Rothwald primary forest) (IUCN category Ia) is a component;
2. The Nationalpark Kalkalpen (Kalkalpen National Park) in Upper Austria (IUCN category II); and
3. The Nationalpark Gesäuse (Gesäuse National Park) in Styria (IUCN category II).

Together they span a "starlight triangle" which is readily visible as a central European dark spot on satellite imagery.

GROßMUGL STARLIGHT OASIS

The Großmugl administrative unit (established in 1970) is a community in the hill-lands of Lower Austria's Weinviertel (Wine Quarter) with an area of 64.38 km². It is a rural, agricultural area to the NW of Vienna with a particular elevated-plane topography and villages in depressions. An "archaeological landscape" extends around the large tumulus at its centre (Fig. 12.3). The main prehistoric remains are:

- the large tumulus from the Hallstatt period (lower centre),
- the Steinabrunn circular ditched enclosure belonging to the mid-Neolithic period (upper left), and
- the Linen circular ditched enclosure and grave-field (upper right).

A full inventory of remains is beyond the scope of this case study and necessarily must involve additional archaeological and conservation studies.

The open landscape features wide horizons that allow access to the entire firmament (almost a full hemisphere) with a dependable deep Milky Way sky that guarantees the visibility of the Zodiac and Western stellar constellations. The site is naturally protected against artificial light at night by the particular village-structure and a unique natural light-rejection system, consisting of three hill-chains shielding the sky-landscape-system from the city of Vienna with its centre at a distance of 33 km (see Fig. 12.4).

The core zone and a large proportion of the buffer zone constitute a rural area whose starry sky view forms part of its recognised identity ("Großmugl an der Milchstraße") and values. It comprises a group of ten small villages ("Katastralgemeinden") keeping the night sky reasonably free from atmospheric and light pollution effects by (at least in part) explicitly realising and following the definition of a *Starlight Oasis* in the *Starlight Reserve Concept*, p.13. The ten villages are Füllersdorf, Geitzendorf, Großmugl, Herzogbirbaum, Nursch, Ottendorf, Ringendorf, Roseldorf, Steinabrunn and Schloß Glaswein.

2.b History and development

EASTERN ALPINE STARLIGHT RESERVE[2]

This remote area, where the borders of three provinces meet, has long proved difficult for human access because its mountains and basins are protected by long and narrow access gorges. It was overlooked by the Alpine tourism that began in the Western Alps in the 19th century and by the hydroelectric power development of the 20th century. The Kalkalpen and Gesäuse National Parks and the Dürrenstein Wilderness Area were declared in the 1990s and early 2000s to protect against more recent development pressures.

[2] This section is prepared on the basis, and largely following the history chapter, of the *Dürrenstein Wildernis* book by the Reserve's present director, Christoph Leditznig, with kind permission of the author. Information on the Kalkalpen National Park is mostly based on sources from the Park Administration with kind permission of its director Erich Mayrhofer.

Within the Kalkalpen National Park area, stone tools (found in the Ramesch cave) show that hunting practices extended as far back as 65,000 BCE, and bone-tools have also been found (e.g. in Losenstein) dating from 18,000–10,000 BCE. From the Late Neolithic onwards, pastoral farming on seasonal high-elevation meadow meadows—"Alms" or "Alps"—became essential in order to sustain the human presence in this area. During the Bronze Age, cattle were driven into the woods for grazing in the Dürrenstein area and pasturage on the high-elevation meadows of the Dürrenstein commenced in the first century BCE. The first written documents relating to Alm-management date back to the 16th century for the Schaumbergalm and Jörgl-Alm, and to 1647 for the Annerl-Alm in the Kalkalpen National Park.

In all three core areas, mining activities drove humans into the most secluded valleys. Copper melting spots are documented in the Gesäuse from 1800 BCE. Metal tools found within the Kalkalpen National Park area demonstrate the use of the natural north-south passes through the Alps by about 1000 BCE. Iron production drove humans towards the most inaccessible woodlands, the limit being set by their ability to extract it using the waterways. Iron-Age activities in the Alps are recognised in the "Hallstatt-Dachstein/Salzkammergut Cultural Landscape" World Heritage Site (whc.unesco.org/en/list/ 806): *ferrum noricum* (Noric steel) was exploited through antiquity.

Population pressure reached a first peak with medieval deforestation, which also progressed deeply into the valleys. The earliest written records, from the monastic period, show that in 1330 just 2700 ha of primary forest remained in the Dürrenstein Wilderness Area (the Habsburgs' endowment to the Carthusians (Karthäuser)), less than 10% of the stipulated area in the modern communities of Gaming, Scheibbs, St. Anton and Lunz am See.

The "Rothwald" primary forest in the Dürrenstein Wilderness was protected into the 19th century by an enduring gridlock between timber harvesting by the Carthusians in Gaming and the "competing" Benedictine Monastery in neighboring Admont, which had been founded in 1074 by the Archbishop of Salzburg at the western entrance of the Gesäuse valley. (Admont Abbey, which includes the largest monastic library hall in the world, is at the centre of the Eastern Alps and forms the core of the settlements around the Gesäuse National Park.) While the Carthusians at Gaming owned the land use rights, the limited capacity of the waterways would, in practice, only permit the transportation of timber across land owned by the Benedictians in Admont. Nonetheless, a settlement between the monasteries of Admont and Gaming in 1689 did allow further exploitation of wood driven by the huge energy demand of the nearby iron production in the "Eisenwurzen" (literally, "root of iron") area. It is estimated that 25% of Europe's iron production at the time came from that region. The Carthausian monastery was secularized in 1782 by a decree of Emperor Josef II. The Rothwald primary forest was reduced to 1520 ha under the following imperial state ownership. Private ownership commenced in 1825, reducing the Rothwald by a further 950 ha.

By 1750 the wood shortage had become so acute that woodcutting started in the most remote valleys. This happened as late as 1765 in the Jörglgraben, now part of the Kalkalpen National Park. Trees there were only harvested once in history and it is suspected that patches of primary forest survived into the present between the "secondary" forest. In 2000 a total of 37 ha of primary forest could be identified.

With the energy-hungry industrialization, wood was harvested on a large scale, driven in particular by the relative proximity, downstream, of the rapidly growing imperial capital, Vienna, and its demand for firewood. Today, Vienna still takes advantage of this proximity: its water supply comes from the Eastern Alpine mountains with two of the three main source areas overlapping with the cores of the starlight reserve.

Just before industry moved to fossil fuel in the 20th century, a new wave of timber exploitation reached the Alps, halted only by inaccessibility and a water system that could not

be controlled by late 19th century technology. The “Aktiengesellschaft für Forstindustrie” (a stock company) acquired a large fraction of the forests in the Dürrenstein area in 1865. It introduced log rafting on the Ybbs river to feed a steam-driven sawmill on the Danube. Massive modifications of the Ybbs river were undertaken in order to allow large-scale timber transportation, which left a devastated landscape plagued by landslides and flooding when the company went into bankrupcy in 1875.

These activities overlapped with the opening of the first large-scale conservation area, the Yellowstone National Park, in 1872. After the bankruptcy large pieces of land, including 420 ha of primary forest, remained and were purchased by Albert Rothschild, who already had held a share of the Forstindutrie AG. Now the sole owner, he realized the value of the untouched wilderness and protected the remaining Rothwald primary forest. It is due to him that the Rothwald survived against both the pressures of technology — which now provided possibilities for timber extraction without using the waterways — and the pressures to improve nature as vocalized by the Academia of the time. (They used the primary forest for teaching, as an example of the chaos and decay that will occur without human intervention and improvement.)

In 1935, parts of the forest — which now constitutes some of the Western areas of the Dürrenstein Wilderness — were sold following the “Creditanstalt Crisis”, one of the triggers of the global economic crisis. The remaining properties were appropriated in 1938 after the “Anschluß” of Austria to Nazi Germany. Since the Rothschild family had taken over, only 20 ha of primary forest had been lost, after wind damage. The ecological importance of deadwood was not recognized at the time and thus the area had been cleaned out. This also led to the realization that the untouched forest could not resist all forces of nature.

During the Second World War the primary forest was declared a nature conservation area, with somewhat arbitrary zoning. In 1946–47 the properties were returned to the Rothschild family but some parts in the west were traded by Louis Rothschild to what is now the Second Austrian Republic in exchange for pension duties. In 1988, a modern zoning concept was implemented after the inclusion of the Rothwald II area.

The Dürrenstein Wilderness area was founded in 1997, supported by a European Union nature conservation project. Nature conservation is handled by provincial governments, and in May 2001 the government of the State of Lower Austria finalized legal protection. Recognition by the IUCN as a Category Ia Protected Area following two years later.

The Kalkalpen National Park reached its present area after extensions in 2001 and 2003.

In addition to the areas in the Forstverwaltung Langau that are still owned by the Rothschild family, Austrian National Forestry properties on the south-west slopes of the Dürrenstein mountain-massif were added in 2002, yielding a total of 2,400 ha (24 km²) in 2013. Today’s size of 3,500 ha was reached in 2014 by including partially protected neighboring areas and placing the whole Wilderness Area under the legal umbrella necessary for the IUCN category I by a new decision of the provincial government.

GROßMUGL STARLIGHT OASIS

Human presence in Austria’s Danube area is witnessed by some of humanity’s earliest known pieces of art. Probably the most famous of these is the “Venus of Willendorf”, estimated to be 27,000 years old, discovered in 1908 near Willendorf, about 64 km south-west of Großmugl.

The region around Großmugl in north-eastern Lower Austria is recognized to be the oldest cultural landscape in Austria with continuous settlement. Abundant finds in the 19th century had already indicated the area’s significance for early human history. In 1871, the archaeologist Matthäus Much first reported the tumuli of the Großmugl area, locally known as *Leeberge* (“grave hills”).

The fertile hills around Großmugl with their Löß (loess) soils have been a favoured area for settlement since the first farming cultures developed in central Europe during the 6th millennium BCE. Stone tools of all shapes and sizes together with fragments of Linearbandkeramik (LBK) pottery have helped identify numerous early Neolithic settlements in Großmugl, Herzogbirbaum and Roseldorf. Farm buildings of the era were huge houses up to c. 35 m long constructed of timber posts. Goats and sheep were domesticated at first, followed by cattle.

New influences from the lower Danube arriving in the early 5th millennium BCE resulted in the appearance of larger village complexes which became foci for smaller settlements. Agriculture and cattle breeding were practised simultaneously: aurochs still constituted a significant proportion of the cattle. Lengyel Culture settlements are documented in Großmugl, Herzogbirbaum and Steinabrunn.

Kreisgrabenanlagen (circular ditched enclosures), which reached their highpoint in the Middle Neolithic, are among the most impressive prehistoric monuments of Central Europe, although their function is still unclear. Almost all of the 40 examples known in Austria are located in Lower Austria's Wine Quarter. One of the most impressive is Lange Ries, about 1300 m to the North of Steinabrunn. Built between 4800 and 4500 BCE, the maximum diameters of its outer and inner ditches are 88 m and 58 m, respectively.

In the Early Bronze Age, 20th to 16th century BCE, a metal-processing centre apparently existed in the Großmugl area. In the Moravian-Lower-Austrian border region, Bronze was predominantly traded in the form of ingot torcs (ring-shaped bars). Two depots have been found in Geitzendorf. More than 61 ingot torcs were discovered in the Geitzendorf fields in 1910, another 39 in 1949 (as well as six arm-spirals), and another in 1979. Further depots surfaced in Senning and Sierndorf, to the south. In Großmugl, four of the typical Hockergräber (crouched burials) of this era were found as well as a ceramic depot and four Siedlungsgruben (settlement pits) belonging to an extended Early Bronze Age settlement. More settlements are known in Füllersdorf, Herzogbirbaum, Steinabrunn and Roseldorf.

In 2008–09 a burial ground was discovered in Geitzendorf. The fifteen graves were classified as belonging to the classical stage BzA2 of the Únětice Culture. One of them contained an archaeological highlight that brought worldwide attention: the first evidence of a female metal worker in the Early Bronze Age. Together with costume and ceramic remains, her grave contained a stone anvil and hammer and flint chisels as used for metal-processing, in particular the fabrication of jewellery.

In the Middle Bronze Age (16th to 14th century BCE) the Hügelgräberkultur (Tumulus Culture) shaped an area from eastern France to western Hungary. The mounds clearly contain elite burials: the grave-goods typically include many heavy arm-rings and elaborate necklaces for women and weaponry such as axes and daggers for men. Many influences are already apparent from the Minoan-Mycenaean cultures of the Aegean and these left traces in Großmugl. In 1966–67, spectacular caches were uncovered featuring a double-handled amphora and other pottery demonstrating the artistic richness of the era.

At the onset of the 13th century BCE a new cultural complex was spreading into Central Europe characterised by their practice of cremating corpses and burying their ashes in urns. Four Urnfield Culture graves discovered near Großmugl in 1939 contained numerous bronzes together with a famous "violin-bow" fibula. There are also numerous finds from the era in Herzogbirbaum and Steinabrunn. Two grape-seeds from the Urnfield Culture period, dated 992–810 BCE, have been found in Stillfried an der March, east of Großmugl in the Wine Quarter. They provide some of the oldest evidence for the cultivation of grape vines in Central Europe. (Today the Wine Quarter, with 14,000 ha of vineyards, is the largest wine-producing region in Austria.)

For Großmugl the most evident and important prehistoric era is the Hallstatt period (Early Iron Age, 8th to 5th century BCE). The largest tumulus from the Hallstatt Culture in Central Europe, 16m in height, is found less than 1 km outside the village, and gives the village its name. It is first mentioned in 1293 as “Grassemugel” (Slavic *krasa* “beautiful” + mogyla “burial mound”). The mound is untouched; it has never been scientifically investigated. Another tumulus 50 m to the NW, much smaller today, is known locally as the “Queen’s Grave”. Excavations between 1950 and 1956 uncovered the remains of a wooden chamber and numerous large ceramic vessels, but their state of conservation rendered scientific studies impossible. Two further flattened tumuli in the immediate vicinity have been identified on aerial photographs.

A number of Hallstatt Culture sites have been found around Großmugl. Excavations in 1938–39 and 1989 to 1994 uncovered large settlement areas at the “Todtenweg” (way of the deaths), including a fireplace and aligned loom-weights that indicate a weaving hut.

Late Iron Age (5th century BCE to 0) settlements of the La Tène (Celtic) Culture are known in Großmugl, Herzogbirbaum and Roseldorf. The "Fürstensitz Keltenstadt” on the Sandberg ridge near Roseldorf is the largest known Celtic settlement in Austria. The site contains Austria’s oldest known mint: some 1500 gold and silver coins were found here. Typical ceramic potsherds containing graphite have come to light in Großmugl.

Germanic settlement in Lower Austria during the 1st and 2nd century CE was focused in the central and eastern Wine Quarter and was dense north of the Danube. But only stray finds from the Roman imperial period (1st to 4th century) are known from Großmugl. An excavated settlement on the widely visible Oberleiserberg at Ernstbrunn, in the Centre of the Weinviertel about 50 km north of Vienna, contains a residence in the style of a Roman palace and various facilities for the artisanal production, suggestive of a manor house built during the migration period.

The arrival of Slavic population groups during the 5th to 10th centuries is evident from 9th-century burial fields. Little is known about daily life in Slavic settlements, although a socketed lance-head (Tüllenlanzenspitze) has been uncovered in Großmugl.

The Christianization of the Danube area in the 8th century progressed from Passau under Charlemagne; a large mission started up in the Weinviertel between 1000 and 1150. Forest clearance resumed as the population grew in Medieval times, requiring additional farmland. It was at this point that drainage commenced of a landscape characterized until then by abundant standing water such as moors and wetlands. On the other hand, the large-scale regulation of rivers and streams only began in the 19th and 20th centuries.

Lower Austria was quick to develop an awareness of its history and prehistory. In 1970, the Museum of Prehistory was opened in the castle of Asparn an der Zaya, Mistelbach, 22 km NE of Großmugl. It is one of the most important of its kind in Europe. It includes an archaeological open-air exhibition with life-sized reconstructions of buildings from the Neolithic through to the Iron Age, and an artefact collection that, since the addition of Early Medieval objects in 2014, spans 40,000 years.

The Großmugl Oasis is a generic prototype for a “Starlight Oasis”. It was established at an existing observing site of the Kuffner-Sternwarte Society following the adoption in 2007 of the La Palma Declaration for the Right to Starlight both by the Society and by the community of Großmugl. While the area has been used intensively for agriculture and forestry throughout many millennia, one of Europe’s first bat censuses was undertaken in Großmugl and six Natura 2000 areas are now established in the Weinviertel, one overlapping with the proposed buffer zone.

3. Justification for inscription

3.c Comparative analysis

A comparative analysis of natural values other than dark-sky quality, important as they are, is beyond the scope of this case study.

EASTERN ALPINE STARLIGHT RESERVE

Satellite data show clearly that, at least as far as light-sources on the ground are concerned, the Alpine Arc is the largest dark spot in central Europe (see Fig. 12.1). Along this arc, the Eastern Alpine location is optimal because the effects of scattered light on sky quality are minimized: the light-intense regions of northern Italy and the strongly developed western Alps are at the greatest distance that can be achieved within the mountain range.

The extent to which light is reduced depends upon the comparative height and width of the mountain range. A 1000m-height difference reduces a large fraction of the aerosol scattering, and the skies certainly benefit from additional height. That is also true for the light-blocking effect where a mountain system acts as a natural baffle. For that, the width of the mountain range is important. That is a particularity of the Alps. It is shared with the Rocky Mountains, the Northern Andes and the Himalayas.

An additional factor in the Alps is the absence of high-altitude plains that attract human settlement. This reduces light pollution pressure compared to, say, Salt Lake City in the Rocky Mountains. A similar but narrower mountain chain can certainly protect skies of similar quality in less populated areas than Europe, the exceptional sky quality of the Aoraki-Mackenzie region of New Zealand (see Ch. 11), adjacent to the Southern Alps, being a case in point. The Natural Bridges Dark Sky Park located on the high altitude Colorado plateau is also sparsely populated. Sample measurements by the author showed that the sky quality there is broadly indistinguishable from that in the Eastern Alpine Starlight Reserve. However, at this very high level of sky quality, natural seasonal variations in the appearance of the Milky Way, airglow, and extinction (due, for example, to aerosols above the desert) are major factors and many measurements at both sites would be required for a meaningful comparison.

In any case, a comparison based on sky quality alone is insufficient because the night sky—and the twilight—varies with latitude. These latitudinal variations are significant and produce skies of very different character, the most commonly appreciated distinction being that between the Northern and Southern sky.

Nightscapes are as rich and diverse as the landscapes with which they are associated, and a classification of sky-landscape systems is surely necessary for a complete inventory of unique sky-heritage. A first step could be to distinguish, for example, high-elevation plains with open skies from summit-gorge areas such as canyon-lands, or places where parts of the horizon is formed by an ocean. It is evident that more specific comparisons are possible. The value of landscapes under the Moon or seen by the light of a starry night sky is becoming more commonly appreciated.

The latitude of the Alps (both Northern and Southern) together with their height produces a relatively rare feature: icy or snowy summits all year round, which create a particular impression when starlight or moonlight shines on the white ground, maximizing the contrast.

GROßMUGL STARLIGHT OASIS

At Großmugl the night sky quality is not exceptional *per se*, but does stand out strongly, if not uniquely, given its proximity to a city with a population (in the metropolitan area) of some 2.4 million people. Around other cities, as well as in other directions from Vienna, much larger distances (by an estimated factor of 2–5) are generally prerequisite for a sky and night-time envir-

onment of comparable quality. The designation as a "starlight oasis" indicates this combination of night-sky quality and ease of human accessibility. The Starlight Reserve document suggests, as a prototype for a Starlight Oasis (see *Starlight Reserve Concept*, pp. 13–15), the skies of inhabited areas, of small villages reasonably free from light pollution. That implies access to the Milky Way in the better cases and roughly reflects the pre-light-pollution situation of the 1960s when the Milky Way still could be seen from cities with more than a million inhabitants.

Key indicators of night-sky quality are as follows.

1. The brightness of the location. Excessive illumination by light pollution threatens the integrity of sky and landscape.
2. The irradiance—energy flux per unit area (in our case) on the ground and through a horizontal surface. This is relevant for the environment, flora and fauna, as well as for humans at night when their perception is naturally in mesopic or scotopic mode.
3. Night-sky emission, natural and artificial. This is typically measured towards the zenith. The light emission per unit area of sky—more precisely per unit solid angle—is often expressed in relation to the magnitude of stars and thus given in magnitudes per square arc-second (mag/″²).
4. The emission of artificial light from the area towards the zenith as seen from satellites. This is a proxy for the artificial light input into the atmosphere (although it actually uses the fraction of the light that escapes directly into space, and so is not a factor degrading the sky quality for an observer on the ground, who is presumably mostly effected by light emitted near the horizontal).

Proximity, as far as artificial sky brightness is concerned, is usually discussed in the context of empirical rules of thumb based on city-population and distance. Typically, 100 km is a plausible distance to get to a fairly good sky with stars visible down to magnitude 6 (for a conspicuous Milky Way and thousands of stars—this value is often quoted as the limit of visibility for naked eye stars) or 7 (a near-natural sky with about three times more stars/less sky brightness) for a city population of 1 million. Vienna, the 9th largest city in the European Union, has a population of about 1.7 million (2.4 million in the metropolitan area).

Großmugl, at 33 km from the city centre, provides a weather-robust, conspicuous and impressive Milky Way. A visual limiting magnitude beyond 6 is typical for moonless nights. Hand-held sky-quality meter (SQM)-measurements[3] yield 21.15 mag/″² in the core zone and around 21 mag/″² through most of the buffer-zone. For comparison, observatory skies are measured around 21.6 with significant natural variations (Patat 2004).

A pioneering study of the large-scale distribution of sky brightness around the city of Perth, Western Australia (Biggs *et al*. 2012) gives 20.5 mag/″² at 30 km from the central business district in the least light-polluted northeasterly direction, which is also located behind a mountain range. Given (i) the differences in climate and consequently the natural variability in extinction, (ii) the fact that Perth is one of the most isolated cities in the world and thus there is no contribution from "neighbouring" cities, (iii) the reduced airglow in Perth due to its lower magnetic latitude, (iv) the fact that measurements in Perth were taken at solar minimum, and (v) that the metropolitan population of Perth is 1.7 million compared with Vienna's 2.4 million, we can be very confident that the sky quality near the zenith around Großmugl is significantly better than around Perth, by at least 0.5 magnitudes. In addition, coastal extinction (not measured in the Perth study) is expected to decrease the natural sky brightness in low light-pollution environments, as compared to the continental Großmugl site, at an elevation of 300 m.

[3] Using a Unihedron sky quality meter. This measures sky brightness using an instrumental photometric system that is oriented towards but not equivalent to astronomical visual magnitudes. See Biggs *et al*. (2012) for a discussion in the present context.

3.d Integrity and/or authenticity

It is beyond the scope of this case study to attempt a complete, integrated discussion of integrity and authenticity including both astronomical and non-astronomical aspects. Instead, we focus upon the possible connections and relations between astronomically determined environmental factors in a broad sense and potential additional cultural, archaeological and science-historical values.

From a cultural perspective, the authenticity of the night sky must surely concern how well its appearance today reflects its appearance to the cultures that had a connection with it in the past. From a natural perspective, the question is perhaps how well the integrated sky-landscape system conveys the exceptional nature of both together. Either way, a critical factor is sky quality, as discussed in other sections. Complete visibility of the entire firmament is an important factor that can relate to integrity if natural views have been compromised.

While a relatively intact night sky remained in most places long after astronomers first noted light pollution in the 19th century, it is now evident that the night-time situation has significantly changed the appearance of many heritage sites—including World Heritage Sites—at night. Part of this may even result, ironically, from efforts to enhance the appearance of the heritage itself, by lighting it at night. In this context it is significant that the large tumulus at Großmugl, itself intact and unopened, sits beneath an authentic night sky (Fig. 12.5), even though the tomb itself has no evident material connection to the sky. The possibility of such connections has been explored in the case of the Lange Ries circular ditched enclosure near Steinabrunn (Zotti *et al.* 2009) but they have low credibility (Zotti and Neubauer 2015).

Fig. 12.5: Moonrise at Großmugl large tumulus. Note the reddened moon, coloured clouds and blue sky with stars (Cassiopeia and Pegasus). The colours of the moon physically are the colours of the sun, with the same spectrum and the same scattering: the moonlit night sky is as blue as during the day with the same shadow-casting. The unique moonshine appearance is created by the human eye in mesopic (twilight) mode, which perceives bluish colour tones and hard pitch-black shadows. Photograph: Norbert Fiala (kuffner-sternwarte.at)

Fig. 12.6: 1852 painting of Friedrich II playing the flute under the "crown-light", a symbol of ultimate luxury. Creative Commons license.

Given their proximity to the Großmugl site, we can use the two World Heritage Sites in Vienna— its historic centre (whc.unesco.org/en/list/1033) and the Schönbrunn Imperial Castle (/786)—to illustrate what integrity and authenticity, and their loss, may mean at night in a cultural environment.

Today it is impossible to see Schönbrunn Castle or St. Stephen's Cathedral in authentic night-light, but seeing them by starlight or moonlight, especially during the long winter nights, was as normal at the time they were built as the daytime view still is for us now. And much of the representative "luxury" of such sites may well be related to the particularities of night-culture. In "enlightened" courts the ultimate luxury was the crown-light (candelabrum) (Fig. 12.6): one used by King Friedrich II[4] cost the equivalent of 5 annual salaries of his court musician Karl Phillip Emanuel Bach. Being able to afford to sleep during the day and sustain night-time activities against the classic dangers of darkness was one of the highest social privileges. Yet light levels were surprisingly dim (5 Lux for the scene in Fig. 12.6, as measured in a recent reconstruction experiment). The crown-light and all the candles and mirrors were not creating brightness but rather a "Christmas tree" atmosphere, making the room come to life. In those days people came into the royal light from a dark park outside, through a sequence of court-rooms with slowly increasing candle-contingent and smaller crown-lights, not through rooms housing modern ceiling floodlights which reveal all the splendour in something as close to daylight as present-day lighting technology can provide. The dimness seems unnatural to us because we have lost the "art of seeing" at night—we are culturally night-blind.

Regarding the exterior of Schönbrunn Castle, a significant effort has been made to reconstruct the authentic daytime view of the façade in the "Schönbrunn-yellow" colour that was "iconic" in the Austro-Hungarian empire. But what of the night-time view? The Gloriette originally

[4] The court of Friedrich II shown in the picture is actually in Potsdam, not in Vienna.

appeared as a moon-lit prominence in the imperial gardens as viewed from a candle-lit mirror ballroom. Nowadays it has to fight for contrast with the modern ballroom illumination, a fight for the attention that can only be won for the viewer inside by using lighting technology on the megawatt scale.

In general terms, a comparatively well-preserved night sky can strengthen the authenticity of astronomical attributes of value not only at a cultural site—including helping to provide a physical context for astronomical narration—but also at a natural one, since the sky forms the upper half of the natural environment, with the landscape below. Genuine night-light contributes to the integrity of the night-time environment (e.g. by allowing the original species to survive and exhibit their authentic behaviour) and is thus a basic contributing factor to the heritage value of a range of natural and cultural monuments and artefacts, both indoors and outdoors. Just as a curator's efforts to better display pieces of art by bringing daylight into the exhibition is action towards the goal of authenticity, the Starlight Reserve or Starlight Oasis is a tool for similar efforts at night. It maintains the natural night-time illumination upon our heritage in places where people still live and conserves important elements of the night-time environment in an inhabited area.

3.a Potential criteria under which inscription might be proposed

Criterion (v): Sustaining human habitability in the extreme Alpine environment has engendered a wide range of cultural activities since the Bronze Age.

The region around Großmugl is the oldest cultural landscape in Austria with continuous settlement, which extends back more than seven millennia. The Großmugl large tumulus is iconic of the early Hallstatt period, and the surrounding archaeological landscape includes the Lange Ries circular ditched enclosure, 88m in diameter, and other monuments and grave-fields that bear witness to human activity on the northern shores of the Danube as far back as the early 5th millennium BCE.

Criterion (vii): In the Eastern Alpine Starlight Reserve, the ragged mountain scenery and the superb sky quality combine to produce nocturnal phenomena of the utmost aesthetic importance.

The Großmugl area, with its wide horizons and remarkable sky quality, contains a sky-landscape system that also provides exceptional day and night-time beauty, including the spectacular sight of the Milky Way arching above the large tumulus.

Criterion (x): The Alpine primary forest within the Dürrenstein Wildernis area contains significant natural habitats for the *in situ* conservation of biological diversity, including threatened species.

3.b Suggested statement of outstanding universal value

The Dürrenstein Wildernis area, with its last remaining stretch of Alpine primary forest, contains the ultimate in-situ conservation area for numerous species, including unique species, supported by and depending on the original soil and dead-wood organisms with their fungi and micro-flora and fauna. The larger species form a prototypical Urwald (primeval forest), where the "Urlicht" (pristine sky) naturally blends in with the ragged mountain scenery resulting in exceptional beauty both by day and by night.

In addition to their own important species, the Gesäuse and Kalkalpen national parks sustain and protect Alp management—the human land-use practices such as high-altitude agriculture that have supported human life over the millennia as well as the other species that have adapted to it.

At Großmugl the combination of sky, prehistory, history and city is exceptional. The Großmugl Starlight Oasis is a sky-landscape system with outstanding remains from the Hallstatt and mid-Neolithic periods including an outstanding large tumulus in an authentic night-time environment of exceptional beauty, including nocturnal phenomena of aesthetic importance such as the arching Milky Way, situated close to Vienna, a city that is itself of considerable significance in the development of Renaissance astronomy.

4. Factors affecting the property

4.a Present state of conservation

EASTERN ALPINE STARLIGHT RESERVE

The Dürrenstein Wilderness Area contains the largest contiguous stretch of primary forest in the Alpine arc. This has not been cultivated or managed since the last Ice Age and thus supports a variety of Alpine flora and fauna (for more detail see www.wildnisgebiet.at). Following IUCN guidelines it is divided into the following zones (see www.wildnisgebiet.at/en/portrait/zoning/):

- A natural zone where no measures are implemented except for the regulation of game. Visitors may enter certain parts of this zone when participating in guided tours. This covers approximately 88% of the Wilderness Area.
- A natural zone with woodland management. For a limited period of time, secondary spruce forests are being transformed into mixed forests with a high proportion of deciduous trees. This comprises less than 5% of the Wilderness Area.
- An Alpine pasture management zone where cattle grazing is permitted to the same extent as prior to the zoning. This maintains the grasslands which provide habitats for a large number of rare species of plants and insects, as well as for black grouse and ptarmigan. This covers about 7% of the Wilderness area.
- A wildlife management zone overlapping the zones above, where the number of deer and other ungulates is regulated in order to protect the balance between forest and game. This comprises about 25% of the Wilderness Area.

The Kalkapen National Park contains Reichraminger Hintergebirge, part of one of the most unspoiled wooded areas in Austria. So far this mountain forest has not been affected and destroyed by public transportation routes or settlements.

The Gesäuse National Park embraces two limestone massifs: the Buchsteinmassiv and the Hochtorgruppe. It is largely untouched and has high biodiversity.

The sky quality in all three areas is exceptional. Light levels generally compare with those for natural skies, both by day and by night. The darkest night skies (Fig. 12.7) are the most frequent and occur under prevailing weather conditions—not just in exceptional circumstances. The brightness of the sky is comparable to the one of the best astronomical sites of the world—though of course not with the same number of clear nights.

These pristine skies above pristine Alpine mountain landscapes sustain biodiversity by providing habitats with natural conditions both by day and by night (Fig. 12.8). They support the nocturnal majority as well as numerous daytime-active rare species and their habitats (Fig. 12.9).

GROßMUGL STARLIGHT OASIS

An assessment of the “non-astronomical” state of conservation of the archaeological sites within the Starlight Oasis is beyond the scope of this text, except to say that the large tumulus is well preserved and unopened.

Under median sky conditions on moonless nights there is a dependable visual limiting magnitude beyond 6, and the Milky Way is impressive, although light pollution from Vienna is noticeable.

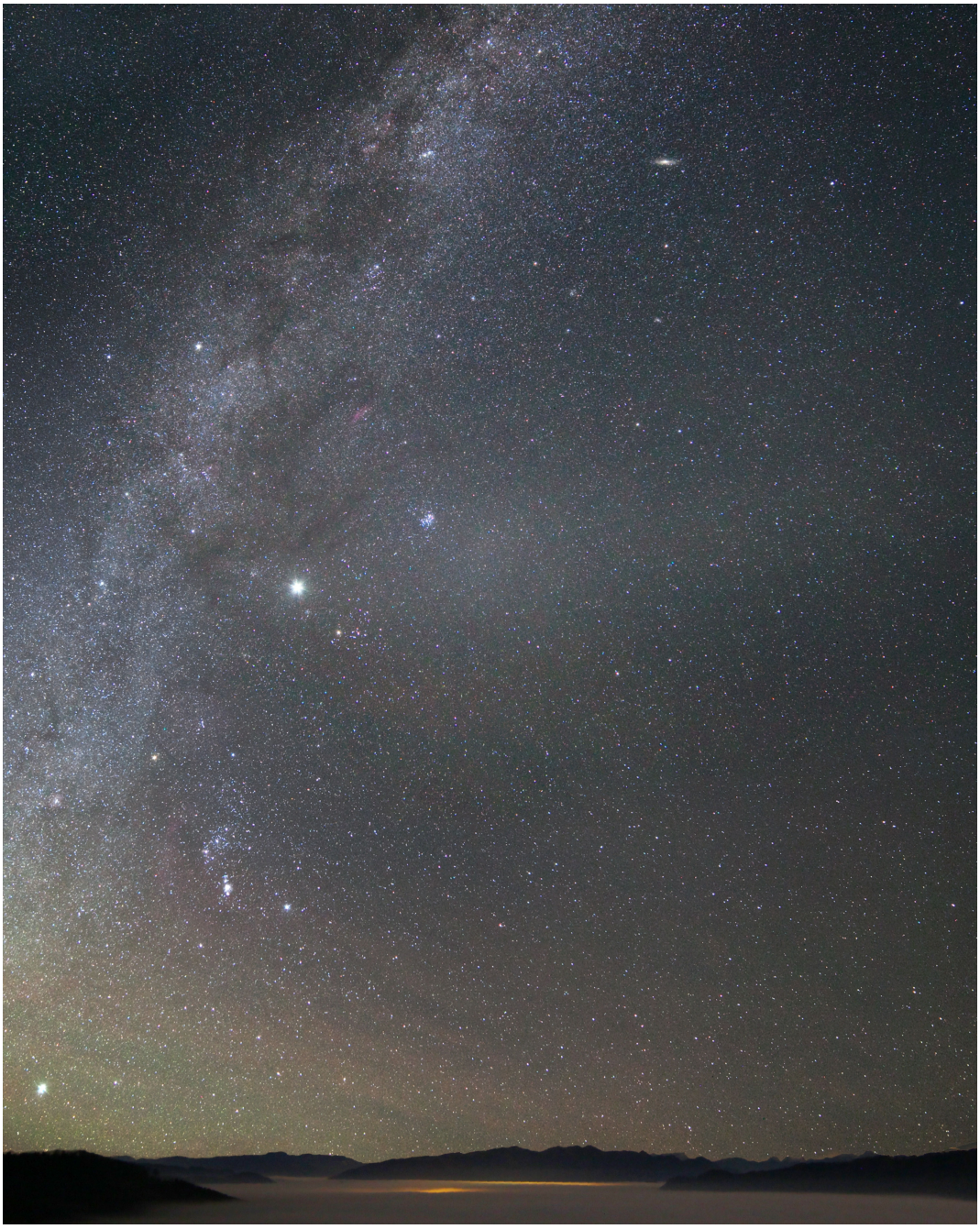

Fig. 12.7: Gegenschein in the zodical band (centre) in the Eastern Alpine Starlight Reserve above the Kalkalpen National park as seen from the “Hohe Dirn” (1000m). The Milky Way is rising on the left. Photograph: R. Dobesberger, Sternfreunde Steyr

4.b.i Developmental pressures

EASTERN ALPINE STARLIGHT RESERVE

The population of the area is shrinking and skiing activities in neighbouring regions have declined, and will decline further, owing to climate change. Thus, fragmentation by urban development is not an issue in this area.

Fig. 12.8: The moon above Gesäuse National Park, showing the point where the River Enns emerges from the canyon (partly obscured by patches of mist) on the left. The bright moonlight brings out colours in this image that are visible in a moderated way to the human eye in mesopic mode. Note the stars in the blue sky. Photograph: Norbert Fiala (kuffner-sternwarte.at)

Fig. 12.9: The boreal owl (*aegolius funereus*, a precious nocturnal species) looking north together with the sky above its frequent hunting and nesting grounds in the Dürrenstein Wilderness Area. Image: P. Buchner, www.birdlife.at (owl), G. Wuchterl (stars), K. Einhorn (montage)

GROßMUGL STARLIGHT OASIS
- The Vienna-Prague road near the west end of the buffer-zone.
- City-dwellers from Vienna: retirement sub-urbanization?
- The possible further development of wind farms.

4.b.ii Environmental pressures

EASTERN ALPINE STARLIGHT RESERVE
There could possibly be an increase in light-pollution from the growth of cities more than 100 km away.

GROßMUGL STARLIGHT OASIS
The development of the Vienna-light-dome.

4.b.iii Natural disasters and risk preparedness

GROßMUGL STARLIGHT OASIS
A new flash-flood management system was installed in 2010.

4.b.iv Visitor/tourism pressures

EASTERN ALPINE STARLIGHT RESERVE
Skiing and other Alpine outdoor activities.

GROßMUGL STARLIGHT OASIS
There are about 3000 visitors per year to events in the area. The site itself is open access and so the actual number of visitors is likely to be significantly greater.

4.b.v No. of inhabitants

EASTERN ALPINE STARLIGHT RESERVE
None in the 3 IUCN-recognised areas; an estimated 100,000 in the buffer-zone.

GROßMUGL STARLIGHT OASIS
617 people live in the core zone (mostly in the village of Großmugl); there are a few thousand inhabitants in the buffer zone.

5. Protection and management

5.a Ownership

EASTERN ALPINE STARLIGHT RESERVE
There is mixed ownership: a large proportion is state-owned land managed by the Austrian Federal Forest Administration (Österreichische Bundesforste). For example, 88% of the Kalkapen National Park is state-owned, with 11% in under private ownership and 1% municipal property.

GROßMUGL STARLIGHT OASIS
The area around the large tumulus is owned by the Erzdiözese Wien (Catholic Archdiocese of Vienna) and leased to the community of Großmugl. The remainder of the core and buffer zones is under mixed ownership.

5.b Protective designation

EASTERN ALPINE STARLIGHT RESERVE
The natural heritage is protected by federal National Park law and by state nature protection law. The area is a Starlight Natural Site in the context of the Starlight Reserve Document.

GROßMUGL STARLIGHT OASIS
The tumuli, Steinabrunn and Herzogbirbaum circular ditched enclosures, and various other archeological sites are protected historic monuments. The Starlight Declaration and Starlight Reserve document are endorsed by the community of Großmugl.

5.c Means of implementing protective measures

EASTERN ALPINE STARLIGHT RESERVE
A set of nature-protection regulations recognized by the IUCN is in place for the conservation of the three components of the core zone. State light-pollution laws, with sections on conservation areas, are in preparation. The spread of national light-pollution laws, already existing in the Czech Republic, Slovenia and many provinces of Italy, could counteract the threat of light-spill from the growth of distant cities.

GROßMUGL STARLIGHT OASIS
A construction codex has imposed a “no-building zone” around the large tumulus, while federal monument protection applies to the prehistoric sites (and other monuments in the area). State light-pollution laws, in preparation, include sections on conservation areas. The protection of the core zone is managed by the community of Großmugl (www.grossmugl.at).

5.d Existing Plans

EASTERN ALPINE STARLIGHT RESERVE
It is planned to increase the existing night-oriented activities, managed by the park administrations in cooperation with astronomical organizations such as the Kuffner Observatory (www.kuffner-sternwarte.at) and Sternfreunde Steyr (www.sternfreunde-steyr.at).

GROßMUGL STARLIGHT OASIS
Plans by the Keltenberg Observatory (www.keltenbergsternwarte.at) include an infrastructure extension for night-sky observation, thematic pathways, a small planetarium, visitor management, and the extension of a public observatory in the village.

5.g Sources of expertise and training

Sources of astronomical expertise and training include
- Institute for Astronomy, University of Vienna (didactics of astronomy education for teachers);
- the Kuffner-Sternwarte Society (amateur and professional astronomers and physicists);
- the Linzer Astronomische Gemeinschaft;
- Sternfreunde Steyr;
- Hochbärneck Observatory; and
- the Keltenberg Observatory (for Großmugl).

National Park institutions provide expertise and training relating to other issues in the Eastern Alpine Starlight Reserve. The Museum of Prehistory at Asparn an der Zaya (www.urgeschichte.at) provides archaeological expertise in the Großmugl area.

5.h Visitor facilities and infrastructure

EASTERN ALPINE STARLIGHT RESERVE
The National Parks and Wilderness Area provide visitor centres and infrastructure. In the conservation zone of the primary forest of the Dürrenstein Wilderness area, human access is only possible under exceptional circumstances.

GROßMUGL STARLIGHT OASIS
The Großmugl community assembly room has facilities and a capacity of 200. Restaurant Schillinger (www.charlys.at) has a lecture/event room with a capacity of 100 that acts as an information base and contact point. The Austrian “rights of way” law guarantees public access throughout the core and buffer zones.

5.i Presentation and promotion policies

EASTERN ALPINE STARLIGHT RESERVE
The National Park and Wilderness Area have already included night-time activities in their programmes.

GROßMUGL STARLIGHT OASIS
See www.starlightoasis.org; www.grossmugl.com.

6. Monitoring

6.a Key indicators for measuring state of conservation

The key indicators are:
- Illumination levels and total radiation.
- Complementary background sky brightness or near zenithal average sky brightness (SQM-measurements) and all-sky brightness distribution.
- An air-quality related value (visibility versus haze):
  * total aerosol optical depth
  * mass fraction of particulate matter with respect to an upper size limit specified by μm
  * ozone (health)

EASTERN ALPINE STARLIGHT RESERVE
Continuous monitoring of the sky quality in the proposed reserve is carried out by the Kuffner-Sternwarte Society in collaboration with the Dürrenstein Wilderness area and the Sternfreunde Steyr.

GROßMUGL STARLIGHT OASIS
Continuous monitoring of day and night total radiation is carried out by the Kuffner-Sternwarte Society and the Großmugl Starlight Task Force of the Großmugl Community Council, chaired by the mayor of Großmugl.

The sky quality at Großmugl and the development of the Vienna light-dome is continuously monitored by a network of Lightmeters (see www.lightmeter.astronomy2009.at), which permits control of the sky quality and an assessment of protective measures. The sky quality above Großmugl itself has been continuously monitored since October 2009 by measuring the horizontal illumination and total radiation using a Lightmeter on the roof of the Schillinger Inn inside the village. There are public street-lights in the village, which is the largest in the core zone, and thus the sky quality at other locations (such as around the large tumulus) will be slightly better due to the complete absence of lights.

7. Documentation

7.a Photos and other AV materials

EASTERN ALPINE STARLIGHT RESERVE
Extensive multilingual documentation is available at www.wildnisgebiet.at (for the Dürrenstein Wilderness Area), www.nationalpark.co.at (for the Gesäuse National Park) and www.kalkalpen.at (for the Kalkalpen National Park).

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For an extensive bibliography on the Eastern Alpine Starlight Reserve area see the park websites: www.wildnisgebiet.at (Dürrenstein Wilderness Area), www.nationalpark.co.at (Gesäuse National Park) and www.kalkalpen.at (Kalkalpen National Park).