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Light pollution in the Tatra National Park

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Abstract: Light pollution in the form of artificial sky glow affects not only the immediate surroundings of the towns that generate it but also more distant areas, including protected regions. This study examines the extent of the impact of the artificial sky glow, originating from Zakopane and the surrounding towns, on the western part of the Tatra National Park (TPN) in Poland. Due to the specific challenges of conducting night measurements in mountainous terrain, the valleys of the Western Tatras– Lejowa, Kościeliska and Chochołowska - were selected for the study. Sky brightness measurements were taken using Sky Quality Meter photometers (type SQM-L) under both cloudless and completely overcast conditions. The results show that in the case of a cloudless sky, the range of sky glow from nearby towns extends approximately 2-2.5 km from the valleys outlets. However, under cloudy conditions, this range increases to approximately 6 km. It was also observed that the ground illumination caused by the brightened sky is significantly lower than that produced by the brightest natural object in the sky, the Moon. Nevertheless, the night sky's brightness exceeds natural levels, which undoubtedly affects local mountain ecosystems.

Introduction

Many protected areas around the world are located near towns with intense artificial lighting. Improperly designed light sources, which are often too bright or directed above the horizon, scatter light on atmospheric molecules and aerosols, specifically particulate matter, or reflect it from clouds. This causes light pollution even in areas distant from cities (Kyba et al. 2011, **Ścieżor** et al. 2012). Consequently, these towns negatively impact surrounding ecosystems in various ways. Light pollution also affects areas that are legally protected, such as national parks or nature reserves, where nature protection takes priority over other forms of activity. Among its effects, light pollution disrupts the natural biological clocks that living organisms have developed over years of evolution. It adversely affects plants, altering their growing seasons, which may affect, among others, the composition of flower communities (Hölker et al. 2010) and, consequently, disturb the ecological balance and biodiversity in polluted areas. Additionally, light pollution disrupts the feeding, reproduction, migration and communication of animals in their natural habitats (e.g. Moore et al. 2000, Gotthard 2000, Longcore and Rich 2004, Rich and Longcore 2005, Randler 2014, Lacoeuilhe et al. 2014, Tałanda 2015).

There are two national parks in southern Poland located in the direct vicinity of large urban centres that are significant sources of light pollution. The first is Ojców National Park (OPN), located near the Kraków agglomeration, and the second is Tatra National Park (TPN), which borders Zakopane and nearby smaller towns.

For years, TPN has run a campaign called "Lead by example after dark", which educates the public about the ban on staying in the park after dark to ensure favorable conditions for wildlife. This is particularly important in early spring, during the mating season for many species. While the campaign targets tourists wandering through the park after dark, there are no legal regulations addressing light pollution from neighboring towns affecting these protected areas.

While the impact of surface water and atmosphere pollution in the TNP area has been well-documented (Krzan 1989, Żelazny 2012), the effect of artificial lighting, referred to as light pollution, remains poorly researched. This is particularly due to the challenges of conducting night-time measurements in difficult-to-access, where moving around after dark requires appropriate preparation and permits. Therefore, very few studies have focused on light pollution in protected areas in Poland (Ścieżor et al. 2012, Bury 2014, Mitura et al. 2017, Iwanicki 2022, Ścieżor et al. 2022, Ścieżor 2023).

As part of the research conducted by the Light Pollution Monitoring Laboratory at the Faculty of Environmental Engineering and Energy, Cracow University of Technology, nighttime light pollution measurements and their analysis were undertaken in the three westernmost Polish Tatra valleys: the Chochołowska (ChV), Kościeliska (KoV) and Lejowa (LeV) Valleys.

Time range of measurements

Reliable measurements of the brightness of the night sky glow required several conditions to be met. First, the measurements

Tab. 1. Specification of measurement nights
Research area: ChV – Chochołowska Valley; ZaR - Zakopane route; KoV - Kościeliska Valley; LeV Lejowa Valley

Date	Research area	Meas. points	Measurements time (CET)	Type of clouds	Cloud base height (m AGL)	Cloudiness (in the meter's field of view)	Fall
08.02.2021	ChV	C1-C8	20:09-22:36	St	600	100%	Yes
10.02.2021	LeV	L1-L6	20:55-22:40	Ns	1100	100%	No
14.02.2021	LeV	L1-L6	20:21-22:00	—	—	0%	No
15.02.2021	ZaR	Z1-Z6	20:55-23:22	—	—	0%	No
10.10.2021	ZaR	Z1-Z6	20:26-22:26	Ci	6000	~0%	No
07.11.2021	ChV	C1-C8	21:05-23:19	Sc + St	100	100%	Yes
04.12.2021	ZaR	Z2-Z6	20:29-23:19	Sc	1400	90-100%	Yes
21.04.2022	KoV	K1-K7	21:25-22:51	—	—	0%	No

Research area: ChV – Chochołowska Valley; ZaR - Zakopane route; KoV - Kościeliska Val-ley; LeV Lejowa Valley

had to be taken on moonless nights. Second, stable weather conditions were essential, meaning the sky had to be either completely cloudless or completely overcast throughout the entire measurement period. Additionally, the night needed to be long enough to avoid the influence of twilight or dawn brightening the sky. Due to the need for on-foot travel within the TPN area and the significant distances involved, the measurement period was limited to the autumn and winter months. During this time, astronomical night (when the Sun is at least 18° below the horizon) lasted at least 9 hours. As a result, each measurement cycle in a given valley took up to 6 hours (including the return trip), allowing measurements to be performed in only one valley per night. The conditions were met on the following nights (Table 1):

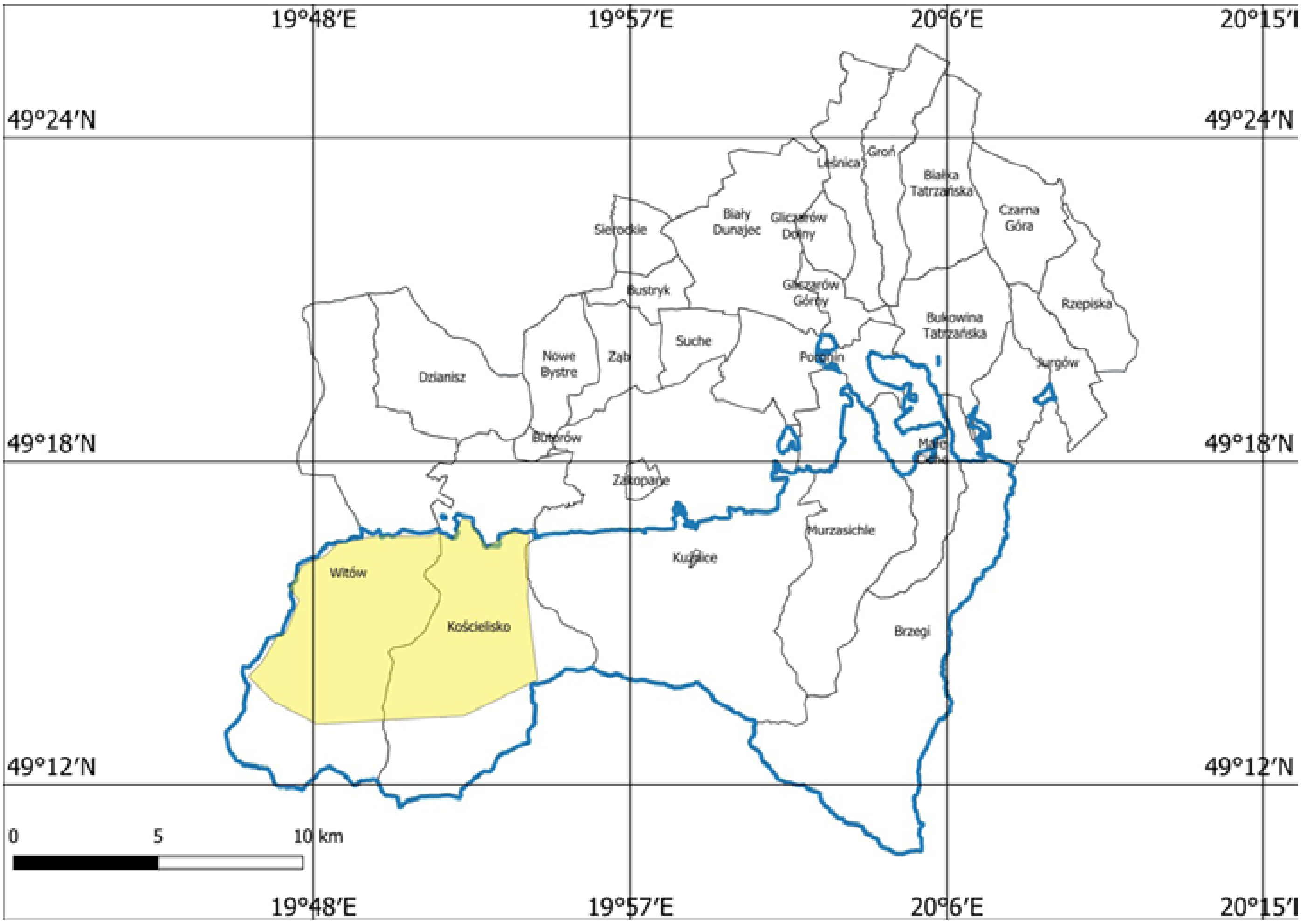

Fig. 1. Tatra County (Małopolskie Voivodeship, Poland) with the division into communes shown.
The boundaries of the TPN (blue line) and the measurement area (yellow background) are marked.

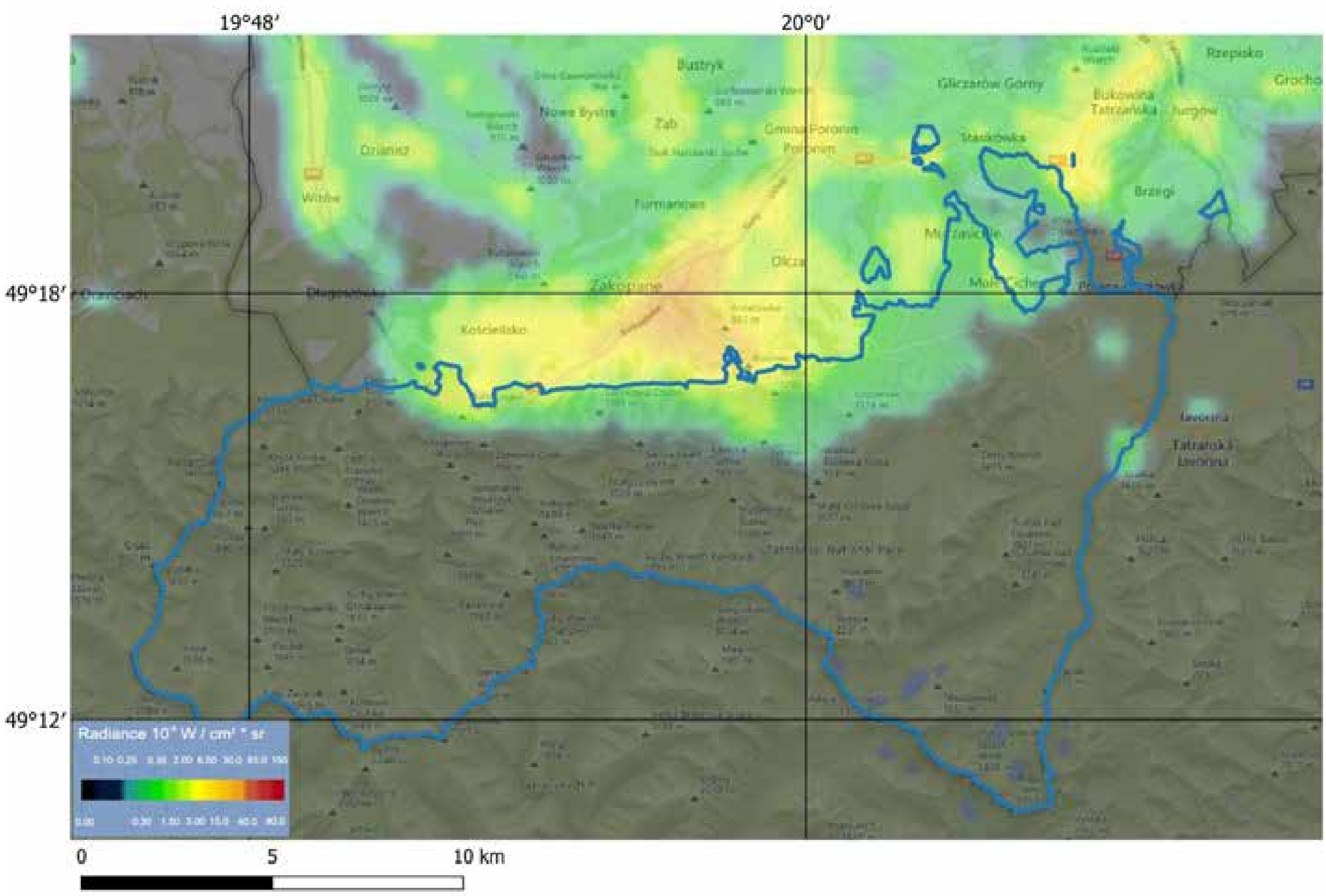

Fig. 2. Radiance measured by satellite in 2021 for the TPN area, with the Park border marked (blue line). The scale given is expressed in units of 10^{-9} W/cm^2 · sr (https://www.lightpollutionmap.info, Falchi et al. 2016b).

Research area

The area of TPN is 212 km^2, which makes it one of the largest Polish national parks. It is the only high-mountain national park in Poland. From the south, TPN is adjacent to the Slovak Tatra National Park (TANAP), and from the north to the city of Zakopane and the communes of Kościelisko, Poronin and Bukowina Tatrzańska. 22.3% of the Tatra protected area is located in Poland (TPN), while the remaining 77.7% is on the Slovak side (TANAP). TPN belongs to the UNESCO World Network of Biosphere Reserves and also meets the criteria of Natura 2000 areas for both habitat and bird protection.

The research area is located in the Chochołowska, Kościeliska and Lejowa Valleys in the Western Tatras, which constitute one of the three mountain ranges of the Tatra Mountains. Measurements of the brightness of the night sky glow were carried out along selected valleys in the western part of the TPN (Fig. 1). These valleys encompass an area of 51 km2, which represents 24% of the total area of the Park.

General characteristics of the research area

The geological structure of the TPN area influences the spread of light from surrounding towns through high mountain peaks (up to 2500 m AGL) and deep valleys. This structure also affects the ecosystems present in the area. While many interesting animals inhabit the TNP, this study focuses on those most endangered by light pollution, in particular insects, amphibians, birds and bats (Czaja et al., 2023). Special attention should be given to nocturnal birds, especially the protected species: *Bubo bubo*, *Glaucidium passerinum*, *Aegolius funereus*. The research area covered the Western Tatras, which are characterized by karst structures, including caves that serve as hibernation sites for bats, such as the protected species *Myotis myotis*, *Myotis mystacinus*, *Myotis bechsteinii*, *Myotis dasycneme*.

Measurement range

To conduct light pollution studies, several measurement transects were planned, running south from the northern border of the Park. These transects were designed analyze the impact of distance from the sources of light pollution: Kiry, Kościelisko and Zakopane, on the brightness of the night sky. Within the three studied valleys, 21 measurement stations were set up (Chochołowska Valley – 8, Lejowa Valley – 6, Kościeliska Valley – 7). Locating the measurement points in this area was particularly challenging, because it was necessary to measure the brightness of the night sky glow in locations where the sky vault was visible up to at least 20° from the zenith. Unfortunately, this requirement excluded most of the narrow valleys in the eastern part of the Tatra Mountains, where the measurement were obstructed not only by trees along the paths but also by high rock faces.

Among the Polish Tatra valleys crossing the northern part of the TPN, only the Chochołowska Valley fully meets these conditions. In the Lejowa and Kościeliska Valleys,

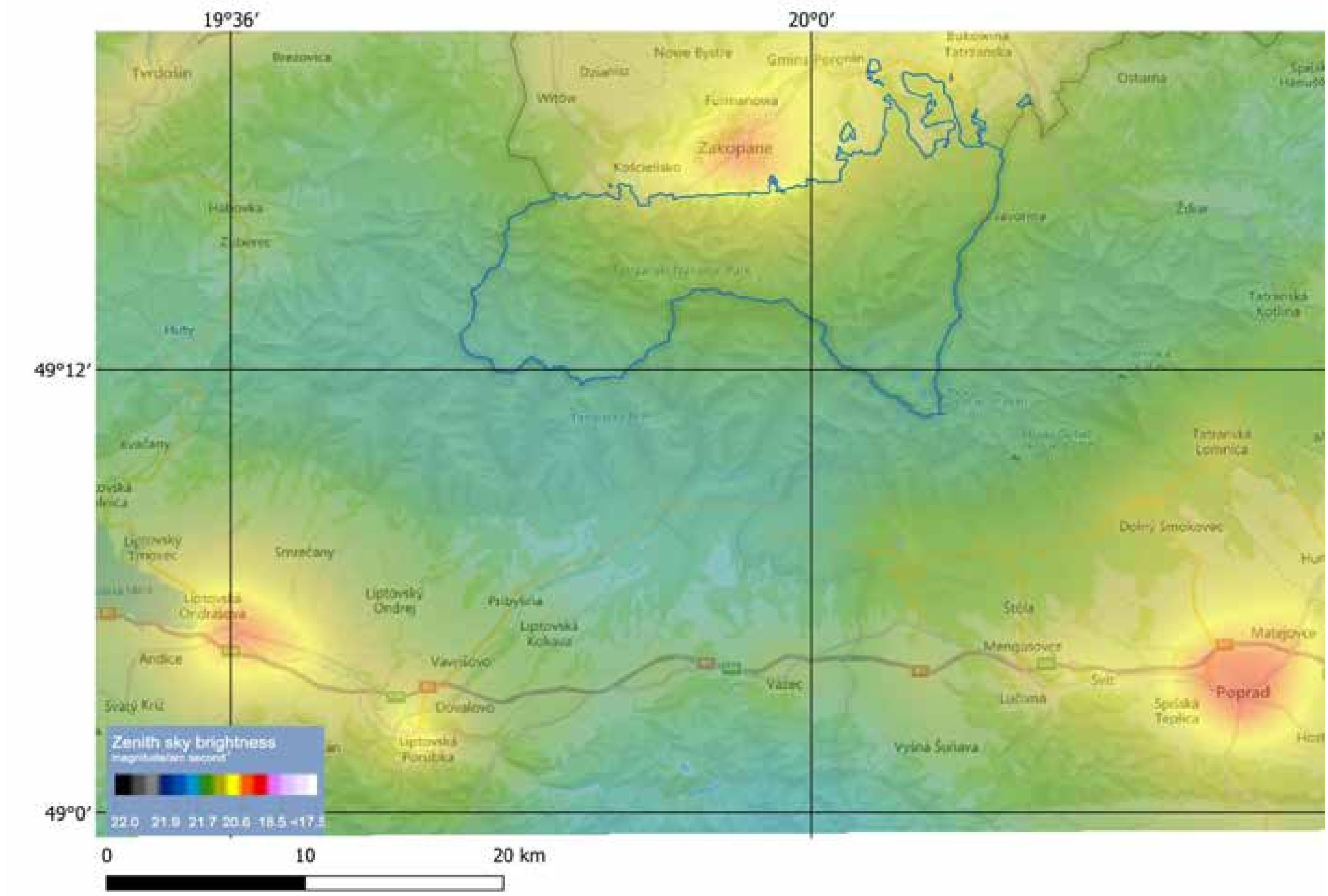

Fig. 3. Model brightness of the glow of a cloudless night sky for the Tatra Mountains, with the border of the TPN marked (blue line). The given scale is expressed in units of mag/arcsec² (https://www.lightpollutionmap.info, Falchi et al. 2016b).

measurements can only be taken up to approximately 2 km from their outlets; further south, these valleys narrow, and their rocky walls obscure the portion of the sky needed for measurements.

Analysis of the light pollution level in the study area

To determine the sources of light pollution in the study area, a map of satellite-measured radiance in 2021 was used (https://ladsweb.modaps.eosdis.nasa.gov/missions-and-measurements/products/VNP46A4) (Fig. 2).

The presented map shows that radiance across most of the TPN area is close to zero. The main sources of radiance are Kościelisko, Zakopane and Bukowina Tatrzańska. Within the study area, there are also smaller, nearby sources of high-intensity light, such as a seasonally operating ski lift and houses in the Biały Potok clearing.

The penetration of scattered light from Kościelisko and Zakopane into the northern part of the Park is also visible. The radiance map allows for the determination of its average value in the selected area. In the case of TPN, a polygon was marked extending up to 1 km south of the northern edge of the park, with the southern boundary defined by the disappearance of visible radiance on the map. The average radiance value for this area in 2021 was $0.9170 \cdot 10^{-9}$ W/cm^2 sr. However, it should be noted that the radiance detected by the satellite in this area is not necessarily proportional to the light scattered within that part of the park. In fact, most of the light is scattered in the higher part of the atmosphere along the path toward the satellite (Levin and Zhang 2017).

In 2016, *The New World Atlas of Artificial Night Sky Brightness* was published (Falchi et al. 2016a). This atlas contains maps of the predicted brightness of the glow of a cloudless night sky, based on satellite radiance measurements and atmospheric light scattering models. One of the maps in this atlas shows the night sky brightness predictions for Tatra Mountains, including the study area (Fig. 3).

This map shows that the sources of light pollution in the Tatra Mountains are: on the Slovak side, the cities of Liptowsky Mikulas (bottom-left) and Poprad (bottom-right), and on the Polish side, Zakopane (upper-centre). While the Slovak cities are located at a relatively large distance from the Tatra Mountains, Zakopane borders directly on the range, and the sky glow it generates covers most of the TPN (approx. 70% of the Park area). The map analysis shows that, theoretically, the surface brightness of the cloudless night sky within the TPN should vary from 20.8 mag/arcsec^2 at the northern border of the TPN to 21.7 mag/arcsec^2 deeper within the Park. One of the goals of the measurements was to experimentally verify the values predicted by the model.

Measuring apparatus

Measurements of the bright surface of the night sky were conducted using Sky Quality Meter (SQM) series meters from Unihedron. SQM meters are available in several versions. In

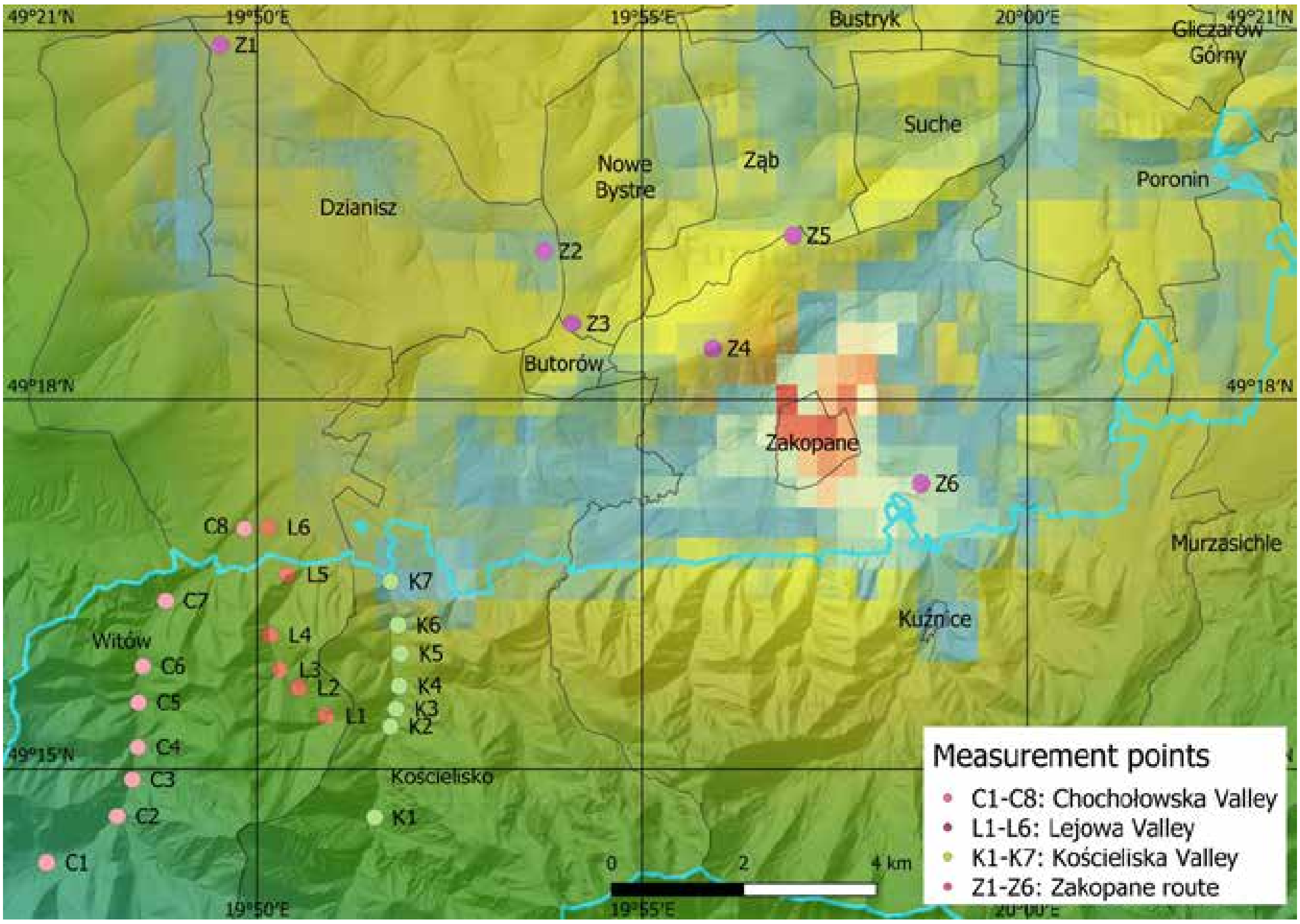

Fig. 4. Map of the central and western part of the TPN (border marked with a blue line) with marked measurement points in the valleys (from left): Chochołowska (C1-C8), Lejowa (L1-L6) and Kościeliska (K1-K7), as well as in Zakopane and surroundings (Z1-Z6). A model map of light pollution (that is, the brightness of a cloudless sky) was used as a base (Falchi et al. 2016a), where the colours, from blue through green and yellow to red, correspond to the increasing level of this pollution (S_a decreasing from 21.5 mag/arcsec² to 20.5 mag/arcsec²). The radiance from the area of Zakopane and its surroundings in February 2021 is also marked as the coloured pixels, where the colours, from blue to red, correspond to the increasing level of radiance (from $2 \cdot 10^{-9}$ W/cm² · sr to $18 \cdot 10^{-9}$ W/cm² · sr, respectively).

Fig. 5. Night sky glow of the overcast sky (northern direction). Chochołowska Valley, measurement point C4 (photo: Zofia Czaplicka).

this research, manually activated SQM-L models were used, which have a Full Width Half Maximum (FWHM) angle of about 20°. As a result, SQM-L meters allow for measuring surface brightness in a selected direction and area of the sky, which is particularly important in narrow mountain valleys.

SQM measurement results are reported in units of mag/arcsec^2 and are usually denoted as S_a. These non-SI surface brightness units are widely used in astronomy for spatially extended objects, such as galaxies or nebulae, and also in light pollution studies for the night sky background [Ges et al. 2018].

It is important to remember that this scale is logarithmic and inverse, i.e. a larger S_a value indicates lower surface brightness of the night sky. A difference of 1 mag/arcsec^2 means a more than twofold (specifically, 2.512) change in the surface brightness of the night sky.

Measurement methodology

Measurements of the night sky surface brightness were conducted simultaneously using two SQM-L meters, with the measuring windows of the meters directed towards the zenith. The measurements with SQM-L meters were repeated until the result stabilized, achieving an accuracy of 0.03 mag/arcsec^2 for three consecutive readings, at which point the average value was recorded.

The measurements covered the following valleys: Lejowa, Kościeliska and Chochołowska. As mentioned earlier, due to the requirement that the sky should not be obscured by trees and rock walls (as well as the varying lengths of the valleys), measurements in the first two valleys were carried out up to approximately 2 km from their outlets. In contrast, measurements in the Chochołowska Valley extended a distance of 5 km from its outlet (Fig. 4, Fig. 5).

Measurements were performed on selected nights, either when the sky was completely covered by low, even clouds or when the sky was cloudless. Additionally, a series of measurements were made in the area of Zakopane and the surrounding area under full cloud cover.

Meteorological conditions

Measurement nights were selected to ensure stable meteorological conditions throughout the duration of the measurements. Due to the variable mountain climate, achieving this stability over several hours of measurements was difficult. To differentiate between the effects of near and far light pollution (Ścieżor et al. 2012), cloudless nights were selected to analyze distant light pollution, while completely cloudy nights were selected for analyzing close light pollution. Table 1 summarizes the meteorological conditions during the subsequent measurement nights.

Results of the measurements

The results of sky surface brightness (S_a) measurements for the Chochołowska Valley (CH), Lejowa Valley (LE) and Kościeliska Valley (KO) are presented in the graph (Fig. 6). Measurements were taken under three conditions: clear sky (cl), total cloud cover with very low clouds (ovl), and low clouds (ol). The horizontal axis represents the distance measured from the outlet of each valley, which also serves as the northern border of the TPN.

Analysis and summary

As is known, the glow of a cloudless sky is caused by light coming not only from nearby but also from distant sources scattered on atmospheric aerosols (Ścieżor and Czaplicka

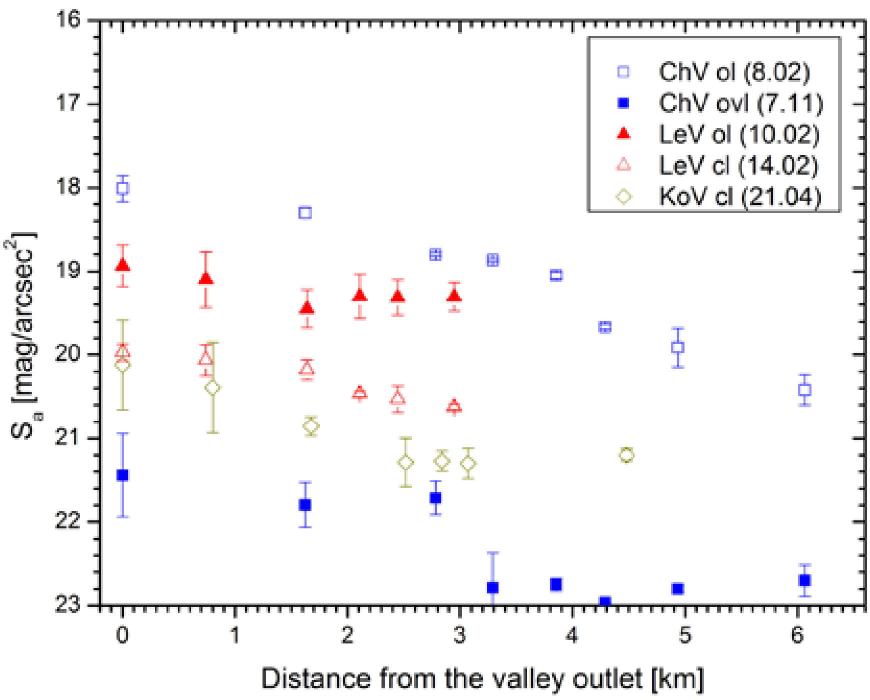

Fig. 6. Sky surface brightness values (Sa) for the Chochołowska Valley (ChV), Lejowa Valley (LeV) and Kościeliska Valley (KoV) under cloudless sky conditions (cl), with total cloud cover with very low clouds (ovl) and low clouds (ol). The distance measured from the valley outlet (the northern border of the TPN) is marked on the horizontal axis. The maximum error of the S_a value is marked for each measurement.

2020). The data presented in Fig. 6 show that in the Kościeliska Valley, the brightness of the night sky stops decreasing and stabilizes at about 2.5 km from its outlet. In the case of Lejowa Valley, the results are ambiguous, but the saturation distance appears to be similar. Nevertheless, even the minimum S_a values recorded in these instances (i.e. the maximum surface brightness of the night sky) have a relatively weak ecological impact on ground-level organisms (Ściężor 2020). However, even a cloudless sky is significantly brighter than a sky free from light pollution, which can affect numerous organisms. It influences several aspects of bird biology and ecology, including disruptions to circadian rhythms and disorientation during flight (Cabrera-Cruz et al. 2018).

A different situation occurs with a cloudy sky. In this case, clouds act as a screen, reflecting light coming from the Earth's surface while blocking light from natural sources such as the Moon, stars, or planets (Ściężor 2020). The key factor here is the height of the cloud base, which determines the extent of light exposure from surrounding towns, particularly Kościelisko. The strongest effect is observed with low cloud cover, where reflected light from Kościelisko affects the brightness of the sky even up to 6 km from the Chochołowska Valley outlet (Fig. 6). As has been shown that the illumination of the Earth's surface by a brightened night sky is equivalent to the illumination from a full Moon, with a S_a value of approximately 17 mag/arcsec^2 (Kyba et al. 2017, Ściężor 2018). Since the Moon is the only natural light source that regulates the behavior of nocturnal organisms, the given S_a value could be considered a threshold brightness of ecological significance. However, the amount of visible light on the Earth's surface at night varies by about three orders of magnitude throughout the lunar cycle (Kyba et al. 2017), whereas a light-polluted sky remains continuously brightened. As shown in Fig. 6, at the outlet of the Chochołowska Valley, under full cloud cover with low clouds, the S_a is approximately 18 mag/arcsec^2, like the case of the Lejowa Valley. This indicates that artificial light from nearby cities significantly brightens the sky across all analyzed valleys, which undoubtedly has an impact on the ecology, especially for nocturnal birds and bats (Cabrera-Cruz et al. 2018, Seewagen et al. 2023).

Comparative measurements conducted in Zakopane and its surroundings (north of the TPN, at measurement points Z1-Z4) under a completely cloudy sky showed an average S_a value of 19.51 mag/arcsec^2. At measuring point Z6 (an unlit clearing in Kuźnice), the S_a was 19.06 mag/arcsec^2, and at measuring point Z5 (a bay along the unlit part of the road), S_a measured 17.76 mag/arcsec^2. This means that under cloudy sky conditions, the brightness in areas outside the TPN is comparable to that measured in the valleys described above.

In the case of an overcast sky with very low clouds, observed on November 7th in the Chochołowska Valley, the measured surface brightness of the sky remains constant starting from approximately 3 km from the valley outlet. Throughout the entire length of the valley, this value is significantly lower than that measured under a cloudless sky. This reduction in brightness is because not only is artificial scattered light blocked, but light from natural sources, such as stars and planets, also fails to reach the valley.

A comparison was made between the measured S_a values for a cloudless sky and the values predicted by the *The New World Atlas of Artificial Night Sky Brightness* (Falchi et al. 2016a) (Table 2). The results indicated that for a cloudless sky, the measured S_a values were lower than the values predicted by the model (Falchi et al. 2016a), suggesting a greater surface brightness of the night sky. In the Lejowa Valley, this difference exceeded 1 mag/arcsec^2, while in the Kościeliska Valley, it was usually below 0.5 mag/arcsec^2. This discrepency may stem from the difference between the model 'sdcreation date (2015) and the measurement date, as well as the difficulty in modelling the brightness of the sky glow in mountainous conditions, as noted by the model's authors (Cinzano and Falchi 2020). The smaller difference recorded in the wide Kościeliska Valley compared to the narrow Lejowa Valley supports this explanation. However, the significant differences recorded at points L1 to L6 and K5, K6 and K7 warrant further investigation. The expected screening effect of mountains

Tab. 2. Comparison of measured and model S_a values

Name	Measurement point	Measured S_a	Modelled S_a
Lejowa Valley (LeV)	L1	20.63	21.54
	L2	20.53	21.57
	L3	20.47	21.53
	L4	20.18	21.53
	L5	20.07	21.48
	L6	19.97	21.43
Kościeliska Valley (KoV)	K1	21.20	21.42
	K2	21.30	21.50
	K3	21.27	21.50
	K4	21.29	21.50
	K5	20.86	21.61
	K6	20.39	21.33
	K7	20.12	21.33

would typically reduce sky brightness compared to the Atlas predictions. A likely explanation for the discrepancies could be temporary, very bright light installations in the proximity of these points. Notably, in the Biały Potok clearing (at the outlet of the Lejowa Valley), there are high-intensity light sources, including ski lift lighting and nearby houses. Unfortunately, it is impossible to verify the impact of this lighting on the VIIRS data since the ski lift lighting is turned off around the time the satellite captures images (approx. 1 CET) the is already.

Conclusions

Based on the measurements, it is evident that the lighting from surrounding cities affects the western part of the Tatra National Park. Although the illumination of the ground is is much lower than that from the brightest natural source of light at night - the Moon – this artificial lighting remains constant. Moreover, the brightness of the sky glow is well above the natural background level, which undoubtedly impacts a wide range of nocturnal organisms ecologically. It should be also noted that the measurements were taken at the zenith, while the sky is significantly brighter towards the horizon, especially in the northern direction. Similar studies should be conducted in the eastern part of the Tatra National Park, particularly near Zakopane or Kuźnice, to assess the surface distribution of sky brightness. However, terrain obstacles pose significant challenges to perform such measurements very difficult to perform.

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References

Bury, R. (2014). Obszary ochrony ciemnego nieba narzędziem wspomagającym rozwój regionów peryferyjnych i marginalizowanych. *Prace i Studia Geograficzne*, 53, pp. 145–163.

Cabrera-Cruz, S. A., Smolinsky, J. A. & Buler, J. J. (2018). Light pollution is greatest within migration passage areas for nocturnally-migrating birds around the world. *Scientific Reports*, 8, 3261. DOI: 10.1038/s41598-018-21577-6.

Cinzano, P. (2007). Report on Sky Quality Meter, version L. Internal Report, v.0.9, Istil, Thiene.

Cinzano, P. & Falchi, F. (2020). Toward an atlas of the number of visible stars. *Journal of Quantitative Spectroscopy and Radiative Transfer*, 253. 107059. DOI:10.1016/j.jqsrt.2020.107059.

Czaja, M., Iwanicki, G., Kołomański, S., Kołton, A., Kotarba, A.Z., Kunz, M., Nawalkowski, P., Skorb, K., Skwarło-Sońta, K., Szlachetko, K., Ściężor, T., Tabaka, P. & Żuchowicz, (2022). *Light Pollution. Identification and Prevention. A Multidisciplinary Guide.*LPTT, Sopotnia Wielka 2022. Vb (in Polish)

Falchi, F., Cinzano, P., Duriscoe, D., Kyba, C.M., Elvidge, C.D., Baugh, K., Portnov, B. A., Rybnikova, N. A. & Furgoni, R. (2016a). The new world atlas of artificial night sky brightness, *Science Advances,* 2(6), e1600377. DOI:10.1126/sciadv.1600377.

Falchi, F., Cinzano. P., Duriscoe, D., Kyba, C. C. M., Elvidge, C. C. D., Baugh, K., Portnov, B., Rybnikova, N. A. & Furgoni, R. (2016b): Supplement to: The New World Atlas of Artificial Night Sky Brightness. V. 1.1., *GFZ Data Services.* DOI:10.5880/GFZ.1.4.2016.001.

Ges, X., Bará, S., García-Gil, M., Zamorano, J., Ribas, S. J. & Masana, E. (2018). Light pollution offshore: Zenithal sky glow measurements in the mediterranean coastal waters. *Journal of Quantum Spectroscopy and Radiative Transfer*, 210, pp. 91-100. DOI:10.1016/j.jqsrt.2018.02.014 .

Gotthard, K. (2000). Increased risk of predation as a cost of high growth rate: an experimental test in a butterfly, J. *Anim. Ecol*. 69, pp. 896–902.

Hölker, F., Wolter, C., Perkin, E.K. & Tockner K. (2010). Light pollution as a biodiversity threat, *Trends in Ecology and Evolution*, 25, 12. Pp. 681-682.

Iwanicki, G. (2022). Astro-tourism in the Czech-Polish Izera Dark Sky Park, [in:] *Handbook of Niche Tourism*, Novelli, M., Cheer, J., Dolezal, C., Jones A. & Milano, C.(eds.), pp. 1-13. DOI:10.4337/9781839100185.00009.

Krzan, Z. (1989). The extent and spatial distribution of air pollution in the Tatra National Park. *Chrońmy przyr. Ojcz*., 45, 2, pp. 26 - 33. (in Polish)

Kyba, C.C.M., Ruhtz, T., Fischer, J. & Hölker, F. (2011). Cloud Coverage Acts as an Amplifier for Ecological Light Pollution in Urban Ecosystems, *PLoS ONE,* 6(3), e17307. DOI:10.1371/journal.pone.0017307.

Kyba, C.C.M., Mohar, A. & Posch, T. (2017). How bright is moonlight? *Astronomy & Geophysics*, 58, 1, 1.31-1.32. DOI:10.1093/astrogeo/atx025

Lacoeuilhe, A., Machon, N., Julien, J.-F., Le Bocq, A. & Kerbiriou, C. (2014). The Influence of Low Intensities of Light Pollution on Bat Communities in a Semi-Natural Context. *PLOS ONE*, 9,10, e103042. DOI:10.1371/journal.pone.0103042

Levin, N. & Zhang, Q. (2017). A global analysis of factors controlling VIIRS nighttime light levels from densely populated areas. *Remote Sensing of Environment*, 190, pp. 366-382. DOI:10.1016/j.rse.2017.01.006.

Longcore, T. & Rich, C. (2004). Ecological light pollution, *Front Ecol. Environ*, 2(4), pp. 191–198.

Mitura, T., Bury, R., Begeni, P. & Kudzej, I. (2017). Astro-tourism in the area of the Polish-Slovak borderland as an innovative form of rural tourism, *European Journal of Service Management*, 23, pp. 45-51. DOI:10.18276/ejsm.2017.23-06.

Mooe, M.V., Pierce, S.M., Walsh, H.M., Kvalvik, S.K. & Lim, J.D. (2000). Urban light pollution alters the diel vertical migration of Daphnia*, Ver. Internat. Verein. Limnol*., 27, pp. 1-4.

Randler, C. (2014). Sleep, Sleep timing and chronotype in animal behavior*, Animal Behav*., 94, pp. 161-166. DOI: 10.1016/j.anbehav.2014.05.001

Rich, C. & Longcore, T. (2005). Ecological consequences of artificial night lighting, *Island Press*., pp. 191-198.

Seewagen, C. L., Nadeau-Gneckow, J. & Adams, A. M. (2023). Far-reaching displacement effects of artificial light at night in a North American bat community. *Global Ecology and Conservation*, 48, e027729. DOI:10.1016/j.gecco.2023.e02729.

Ściężor, T., Kubala, M. & Kaszowski, W. (2012). Light Pollution of the Mountain Areas in Poland. *Archives of Environmental Protection,* 38. 4, pp. 59-69. DOI:10.2478/v10265-012-0042-4

Ściężor, T. (2018). Natural and anthropogenic factors of the night sky glow. *Monografie Politechniki Krakowskiej*. Politechnika Krakowska, Kraków. (in Polish)

Ściężor, T. (2020). The impact of clouds on the brightness of the night sky, *Journal of Quantum Spectroscopy and Radiative Transfe*., 247, 106962. DOI:10.1016/j.jqsrt.2020.106962.

Ściężor, T. & Czaplicka, A. (2020). The impact of atmospheric aerosol particles on the brightness of the night sky. *Journal of Quantum Spectroscopy and Radiative Transfer*, 254, 107168, DOI:10.1016/j.jqsrt.2020.107168.

Ściężor, T., Czaplicka, A. & Kotra, A. (2022). Light pollution in the Tenczyński Landscape Park. Space. *Problemy Nauk Biologicznych*, 71, pp. 487-496. DOI:10.36921/kos.2022_2866. (in Polish)

Ściężor, T. (2023). Light pollution in the area of the Beskid Mały Landscape Park, [in:] Light pollution of the night sky. Towards interdisciplinary knowledge, monitoring and counteracting, Kunz M. (ed.). Wydawnictwo Naukowe UMK, Toruń, pp. 151-170. DOI:10.12775/978-83-231-5192-0. (in Polish)

Tałanda, J. (2015). Ecological Light Pollution: When Artificial Light at Night Disrupts the Natural Light-Dark Cycle in an Ecosystem, *Kosmos. Problemy Nauk Biologicznych,* 64, 4 (309), 611-616. (in Polish)

Żelazny M. (2012). Time-spatial variability of physicochemical properties of waters in the Tatra National Park, *Instytut Geografii i Gospodarki Przestrzennej UJ*. Kraków. (in Polish)

Zanieczyszczenie świetlne Tatrzańskiego Parku Narodowego

Streszczenie: Zanieczyszczenie świetlne w postaci sztucznej poświaty niebieskiej wpływa nie tylko na bezpośrednie otoczenie miejscowości będących jego źródłem, ale także na dalsze okolice, w tym na obszary chronione. W pracy zbadano zasięg oddziaływania sztucznej poświaty, której źródłem jest Zakopane i okoliczne miejscowości, na zachodnią część Tatrzańskiego Parku Narodowego (TPN). Ze względu na specyfikę pomiarów nocnych prowadzonych na terenach górskich, wybrano doliny Tatr Zachodnich – Lejową, Kościeliską i Chochołowską. Za pomocą fotometrów Sky Quality Meter (typu SQM-L) wykonano pomiary jasności świecenia nocnego nieba, zarówno w warunkach bezchmurnego, jak i całkowitego zachmurzenia. Stwierdzono, że w przypadku nieba bezchmurnego zasięg łuny pochodzącej z pobliskich miejscowości wynosi około 2-2,5 km od wylotów dolin, natomiast w przypadku nieba zachmurzonego zasięg ten wzrasta do około 6 km. Wykazano, że oświetlenie gruntu przez rozświetlone niebo jest wielokrotnie niższe niż w przypadku oświetlenia przez najjaśniejszy naturalny obiekt na niebie, jakim jest Księżyc. Jednak jasność nocnego nieba znacznie przekracza poziomy naturalne, co niewątpliwie wpływa na lokalne ekosystemy górskie.