DANUBEPARKS Position Paper:

Electric Power Lines and Bird Conservation along the Danube River

Project co-funded by the European Union (ERDF, IPA funds)

DANUBEPARKS network of protected areas

Interreg Danube Transnational Programme

EUROPEAN UNION

DANUBEparksCONNECTED

Imprint

In cooperation with BirdLife Österreich and Danube Delta National Institute

Editing & Text:

Remo Probst (BirdLife Austria), Alexandru Dorosencu (Danube Delta National Institute) & Georg Frank (DANUBEPARKS)

Contributions:

Stephanie Blutaumüller, Walter Böhmer, Gabriela Cretu, Attila Fersch, Andrea Froncova, Sigfired Geißler, Lucia Deutschová, Marek Gális, Gyula Kiss, Gabriela Morozov, Tibor Mikuška, Ion Munteanu, Tibor Parrag, Emiliya Petkova, Vltako Rožac, Thomas Schneider

Layout:

Maps: Alexandur Dorosencu, Damir Masic (DANUBEPARKS), Raphael Prinz (DANUBEPARKS)

Cover Pictures: Georg Frank (DANUBEPARKS)

Proofreading: Benjamin Seaman

Print: Kontraszt Plusz Kft.

This project is co-funded by the European Union (ERDF, IPA funds).

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1. Synopsis and aims of the Position Paper

- The Danube River is a backbone of biodiversity in Europe. The area is home to many bird species that breed, rest or spend the winter here.

- There is an abundance of power lines throughout the entire Danube basin, decreasing in density from west to east (with the exception of Romania). However, further economic rebuilding and an associated increase in electricity consumption will lead to an expansion of electricity grids in all of the Danube states.

- Overhead lines can have a negative impact on birds. Collisions and electrocution are particularly well-known and serious risks.

- Despite the cross-border and transnational dimension of bird conservation along power lines, in the Danube region the necessary attention has so far only been paid on a regional basis. However, the high importance of this mortality factor was noted in an expert survey (questionnaire) and immediate implementation of protective measures was called for. Out of all respondents, 75% considered a Danube-wide approach to bird protection along power lines to be very important, 25% considered it important.

- The purpose of this position paper is to raise further awareness of this problem and to present assessment methods as well as technical solutions for mitigation.

- Central demands are that no power lines be erected at all in high-ranking protected areas or areas with high bird densities, and that retrofitting be started as a matter of priority in these areas.

- The methods for assessing the hazardousness of a power line are separated according to the two risks, collision and electrocution, and include prioritisation. This takes account of the fact that financial resources are limited and that particularly dangerous lines must be defused first.

- Numerous technical solutions are proposed, including new constructions, retrofitting, and considering different variants of construction types and their respective problems of collision and electrocution.

- The organisational backbone for this position paper is DANUBEPARKS – The Danube River Network of Protected Areas. Within the DANUBEparksCONNECTED project, funded by the Interreg Danube Transnational Programme, the DANUBE FREE SKY initiative has been launched. Efforts are now being made all along the Danube to minimise the negative influence of power lines on birds.

- DANUBE FREE SKY strongly builds on cross-sector cooperation between the conservation and energy sectors. This position paper aims to further promote this fruitful cooperation through the demonstration of good practice examples.

- The EU Danube Region Strategy Priority Area 6 "Biodiversity and Landscape" and Priority Area 2 "Sustainable Energy" support DANUBE FREE SKY on a political level.

- The position paper is intended as a guideline for protected area administrations, nature conservation associations, power line operators and environmental policy makers. Based on good practice pilot actions, the DANUBE FREE SKY wants to promote the consequent step by step implementation of bird-friendly solutions for all power lines along the Danube.

- Considering the importance of large rivers for birdlife and migration, the DANUBE FREE SKY initiative should act as role model for other rivers in Europe.

2. Birds and power lines – introductory background

Bird populations are influenced by naturally limiting factors (e.g. food, predation, weather, etc.), but are increasingly also affected directly and negatively by humans. Anthropogenic impacts range from the destruction or conversion of entire stretches of habitat, over the manifold negative effects of intensified agriculture and forestry and the increased disturbances caused by expanding leisure activities, to "technical pollution", for example through wind turbines or power lines, and this list is by no means exhaustive.
Power lines are an integral part of the functioning of modern societies. However, they also pose multiple hazards to the bird world, with electrocution and collision being the best known (FERRER & JANSS 1999). These two factors are also dealt with in this position paper. However, it should not be forgotten that power lines also lead to a fragmentation of landscapes and alter the structure in open countryside, thereby potentially disrupting competitive conditions and, thus, changing the composition of the avifauna (ANDREWS 1990, BENÍTEZ-LÓPEZ et al. 2010).

Basically, it can be assumed that the main causes of mortality in birds along power lines are electrocution in the case of medium-voltage lines, and collision in the case of high-voltage lines. This is due to the fact that insulator distances are too great in high-voltage power lines to be overcome by birds. An often fatal electrical discharge occurs either as a result of a conductor-earth-contact or a conductor-conductor-contact. The distinction between medium-voltage and high-voltage lines is not uniform; medium-voltage lines range from 1 kV up to and including 52 kV (according to https://de.wikipedia.org/wiki/Mittelspannungsnetz). All lines above this range are considered high-voltage and extra-high-voltage lines.

Electrocution from medium-voltage power lines has often been proven to be a major cause of human-induced death in birds (e. g. APLIC 2006, HAAS & SCHÜRENBERG 2008, PRINSEN et al. 2011, KARYAKIN 2012, HOHENEGGER 2014). To provide an international example, between 0.9 and 11.6 million birds are estimated to be killed by electrocution in the United States per year (LOSS et al. 2014). In a study conducted throughout Hungary between 2004–2014, 3,400 avian carcasses were identified after surveying 57,486 pylons (DEMETER et al. 2018). Electrocution casualties included species of high conservation concern such as Saker Falcon (Falco cherrug), Red-footed Falcon (Falco vespertinus), European Roller (Coracias garrulus) and Eastern Imperial Eagle (Aquila heliaca). In a Bulgarian study, DEMERDZHIEV (2014) found 205 victims along 2,116 electricity pylons. With 50 individuals, White Storks (Ciconia ciconia) were by far the most frequently killed birds. These findings agree with the fundamental analysis of BEVANGER (1997) that larger birds regularly perching on poles are most frequently affected. These include, in particular, species with slow reproduction rates such as birds of prey, falcons, owls, storks and also some songbirds (cf. also SERGIO et al. 2004, GUIL et al. 2015). As DEMERDZHIEV (2014) was able to show, birds are especially vulnerable in the open countryside, where trees are scarce and poles are often the only perches providing commanding views.

The collision of birds on power lines is well studied in some countries and there are estimates of overall losses. For the United States, LOSS et al. (2014) give a figure of 8–57 million birds killed per year, while for Canada, RIOUX et al. (2013) estimate 2.5–25.6 million (here, high-voltage lines only). From the Danube riparian states, there is an overall figure of 1.5–2.8 million birds killed per year in accidents in the whole of Germany (TNL UMWELTPLANUNG 2017). In addition to these high figures, it should be noted that rivers are considered high risk areas for a number of reasons. On the one hand, rivers naturally gather large numbers of water-associated birds (VDE/FNN 2014), and on the other hand, many of these are particularly poorly able to avoid obstacles. BEVANGER (1997) showed that species with a high wing loading and low aspect ratio run a high risk of colliding with power lines. These species are characterised by fast flight, whereas the combination of a heavy body and small wings restricts swift reactions to unexpected obstacles. BEVANGER (1997) confirms water-associated bird groups like divers, grebes, swans, ducks, cormorants and rails (all of which occur in high numbers along the Danube) to have an increased collision susceptibility.

However, these enormous losses are also juxtaposed by conservation project successes. A good example is provided by the efforts from Hungary (DEMETER et al. 2018). More than 10,000 of the 57,000 electricity pylons examined were retrofitted to avoid electrocution of birds. As a result, only 3% of all dead birds were found under such secured poles. On average, one carcass was found per 15 non-retrofitted pylons surveyed compared to one carcass per 89 retrofitted pylons, an 83% difference in frequency. A similar success can be quoted for the collision problem. For example, JÖDICKE and colleagues (2018) in Germany were able to show that the collision rates of many bird species fell by 79–91% after the earth cable was marked on high-voltage lines. These figures prove that protective measures actually work!

Fig. 1: Collision and electrocution – relevant risks for bird lives in the Danube Region. (photo: LIFE Energy/Raptor Protection of Slovakia)

3. The Danube – facts and figures

3.1. Profile

The Danube is the second largest river in Europe, after the Volga, with a length of 2,860 km. It originates in the Black Forest, Germany, and flows through large parts of South-East Europe to the Danube Delta. The Danube crosses or touches many countries, namely Germany, Austria, Slovakia, Hungary, Croatia, Serbia, Romania, Moldova and Ukraine. Its drainage basin with no less than 815,000 square kilometres extends into nine more countries. For this reason, the Danube is one of the most international rivers in the world. A wealth of further general information can be found, for exam ple, on the homepage of the International Commission for the Protection of the Danube River (https://www.icpdr.org/main), in books like the one by STANČIK & JOVANOVIČ (1988), or in popular overview works such as that of VASIĆ (1997).

3.2. Backbone for biodiversity

Although rivers account for only 2% of the Earth's surface water, rivers and streams as well as their adjacent floodplains and alluvial forests are distinguished by a rich fauna and flora (e.g. ALLAN & FLECKER 1993, WARD et al. 1999, DAVIS 2010). For the Danube, this can be demonstrated, for example, for fish and amphibians, and not least for the birds, which are of particular interest in this position paper. Ultimately, out of all taxonomic groups, birds are most affected by the negative effects of power lines, with the exception of a few electrocutions in climbing mammals and the collisions of bats, which should not be underestimated.

More than 300 bird species breed along the Danube. It is an important resting place and a backbone of bird migration and also attracts many birds who overwinter on the river or in the immediate vicinity. As is to be expected, waterfowl and species and groups associated with aquatic habitats are particularly common. They include representatives of Anseriformes (ducks, geese and swans), Podicipediformes (grebes), Gruiformes (rails, gallinule, coot and cranes), Otidiformes (bustards), Gaviiformes (loons), Ciconiformes (storks), Suliformes (cormorants), Charadriiformes (waders, pratincoles, gulls and terns), Accipitriformes (birds of prey) and Falconiformes (falcons), and Pelecaniformes. The last group includes the Glossy Ibis *(Plegadis falcinellus)* and Eurasian Spoonbill *(Platalea leucordia)* from the Threskiornithidae family, all herons (Ardeidae) and the eponymous pelicans (Pelecanidae) themselves.

The following examples should highlight the Danube's enormous importance, not only for breeding species, but also for migrating and wintering birds. Starting with nesting species, the Dalmatian Pelican *(Pelecanus crispus)* and Great White Pelican *(Pelecanus onocrotalus)* breed along the Danube. The total Palearctic population of Great White Pelicans is estimated at 7,345–10,500 pairs at 23–25 colonies, with 3,000–3,500 pairs at the Danube delta in Romania alone (ELLIOTT et al. 2018a). This would result in a 29–48% share of the total Palearctic population. However, MARINOV et al. (2016a), based on studies with an unmanned aerial vehicle (drone), indicate a population of 15,000-19,000 breeding pairs for the Danube delta alone, which results in a completely different assessment of the actual situation. Incidentally, the situation is somewhat reversed for the Dalmatian Pelican, where ELLIOTT et al. (2018b) confirm 450 pairs for the Danube delta, but MARINOV et al. (2016b) only indicate 240–330 pairs for the whole of Romania.

The river and its extensive wetlands are key wintering grounds for many waterbird populations. As an example, the eastern and central part of the Danube course region at times holds almost the entire world population of Red-breasted Geese (*Branta ruficollis*; KEAR 2005, GORIUP et al. 2007). Ultimately, the area is also of outstanding importance as a stopover site for migratory birds. Because of its location at the junction of the Mediterranean, Pontic and Eurasian subzones of the Palearctic faunal realm, millions of birds use the lower Danube to replenish their energy during migration (NEWTON 2010, SÁNDOR et al. 2014).

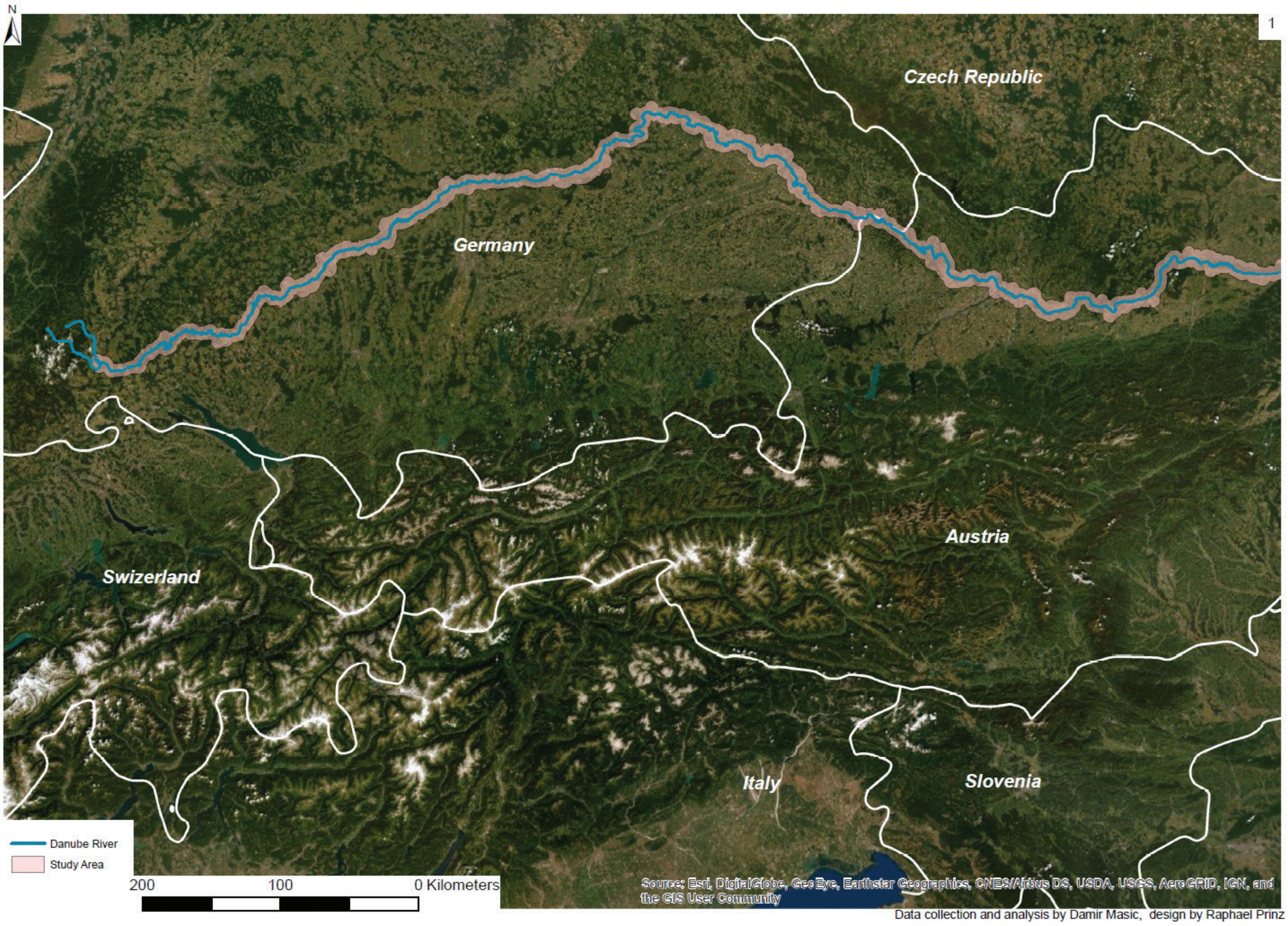
For the White-tailed Sea-eagle, the Danube is an important breeding, resting and wintering place. As for wintering, PROBST and colleagues (2014) counted up to 700 eagles during the first winter census in January 2014. Hotspots of occurrence were the Central Danube floodplains – the area encompassing the lower Hungarian section (Danube-Drava National Park), Kopački rit Nature Park (Croatia), the Gornje Podunavlje Special Nature Reserve (Serbia) and the Danube Delta Biosphere Reserve. As far as breeding individuals are concerned, NEMESHÁZI et al. (2016) have shown that there is a certain genetic autonomy of the White-tailed Sea-eagle population in the Carpathian Basin, i.e. in a region whose backbone is the Danube.

Another approach is to look at the Natura 2000 areas along the Danube, which are home to many different representative bird species to be protected along the Danube. The result of the Special Protected Areas and Important Bird Areas standard data forms (https://www.eea.europa.eu/data-and-maps/data/natura-9; http://datazone.birdlife.org/site/factsheet/gornje-podunavlje-iba-serbia/details; http://natura2000.eea.europa.eu/#) show the high relevance of these sites when it comes to birds conservation in Europe.

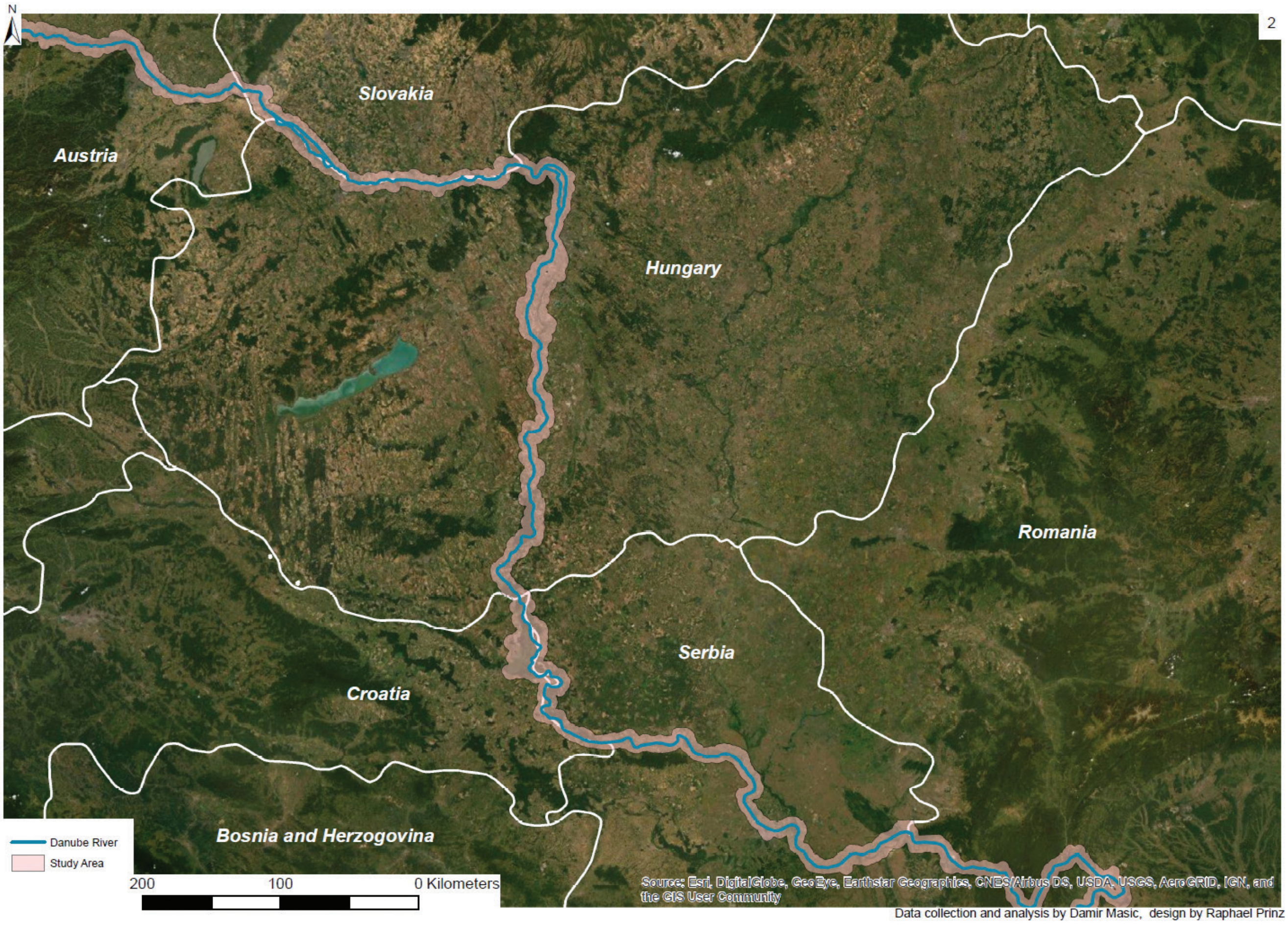
3.3. Study area

The target area of DANUBE FREE SKY is generally the Danube river and the adjoining riparian zone (alluvial forests, tributaries, open land), it does not correspond with the "Danube basin" as a whole. For clear analyses it was necessary to define this area exactly, which was done as follows: first a line shapefile of the river Danube (http://www.danubegis.org/) was added to Quantum GIS 2.14. Then a buffer with a distance of three kilometres on each side of the river was created. Second, all active and observable riparian zones (https://land.copernicus.eu/local/riparian-zones/riparian-zones-delineation) of the Danube were added to the layer. Every active and observable riparian zone polygon within the aforementioned three-kilometre Danube buffer was selected. Then a second buffer with a distance of three kilometres was created around the selected polygons. Kopački rit and the Danube delta were added separately (https://www.eea.europa.eu/data-and-maps/data/natura-8/natura-2000-spatial-data/natura-2000-shapefile-1), since both are very large and important wetlands along the Danube and their area would otherwise be underrepresented by the previous selection. A three-kilometre buffer was also created around these two Natura 2000 areas. Finally, all polygons were merged to a single, large project area. The final delimited area has a size of 30,741.2 square kilometres and can be seen in Fig. 1.

Fig. 2: The Danube River – a backbone for biodiversity and one of Europe´s most important bird flyways (photo: D. Petrescu)



Data collection and analysis by Damir Masic, design by Raphael Prinz



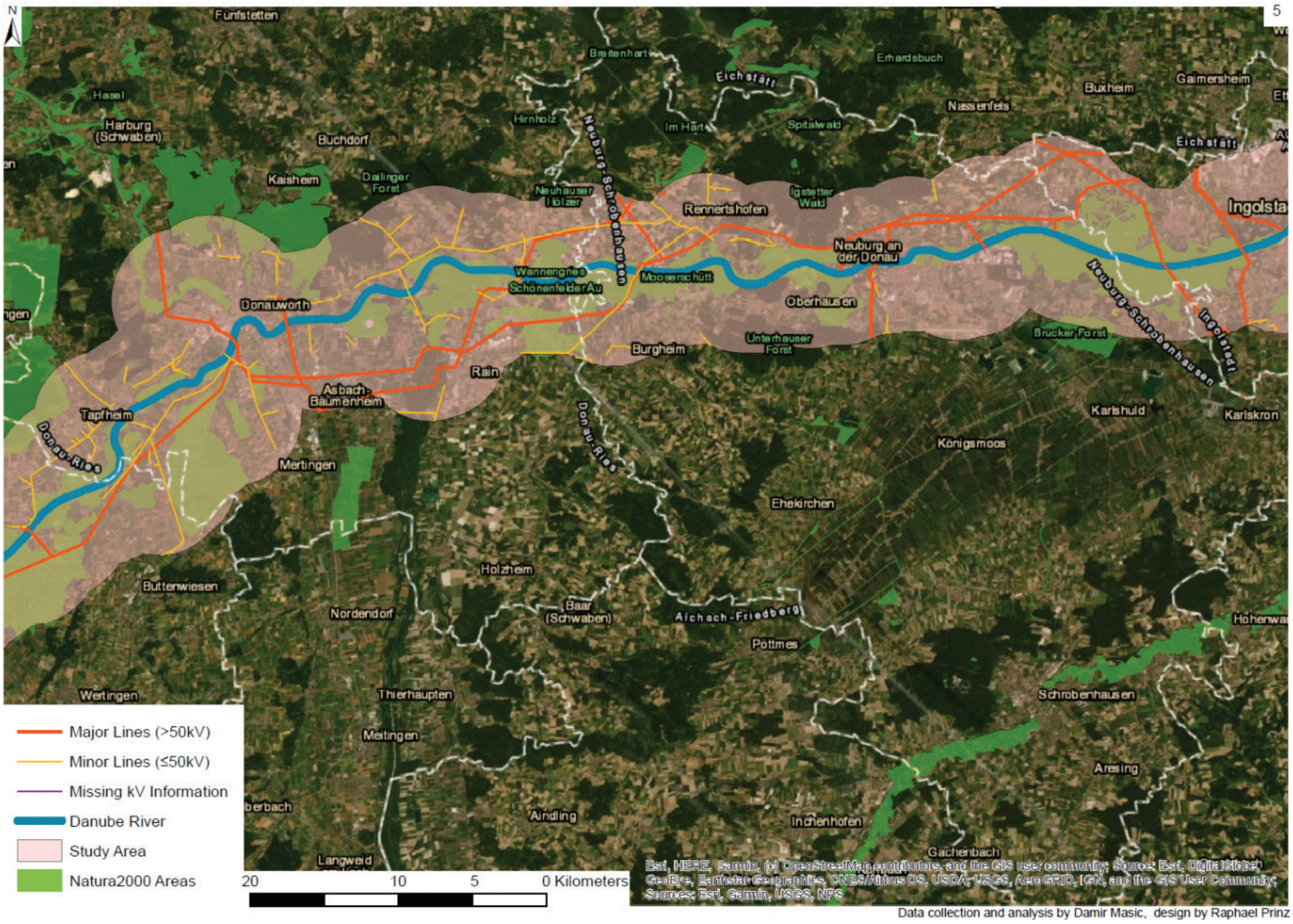
Data collection and analysis by Damir Masic, design by Raphael Prinz

Fig. 3: Project area along the Danube. It comprises the river itself as well as the neighbouring riparian zone.

3.4. Power line network

In the next step, the locations of power lines had to be determined for the project area (defined in chapter 3.3). Unfortunately, there is no single layer that is readily accessible at an EU level, so we had to summarise several sources here. This results in an inventory which is largely, but not quite complete. The main source of information was OpenStreetMap. Open source data (http://www.geofabrik.de/) was downloaded for each country along the Danube. The OpenStreetMap files were imported into Quantum GIS 2.14 and prepared for further processing. Topology was exported to a new layer by choosing polylines and selecting only attributes with the following tags: "name", "power", "voltage", "operator" and "ref". An SQL query was used to set a provider filter on the attribute tagged "power". Chosen values were tagged "line" and "minor_line". This was done for every country, resulting in one layer per country containing all power lines which can be found on OpenStreetMap. All layers were merged to one big layer, which was then split by voltage attributes into three shapefiles: one with every line above 50 kV, one with every line equal to or below 50 kV or every line tagged "minor_line", and one for all remaining power lines with missing voltage values. Additionally, each partner region provided data from local network operators to complete the map of transmission lines as best possible. The coordinate reference system used was ETRS 1989 LAEA Europe. All power lines intersecting the project area were clipped with Quantum GIS 2.14 and used for further calculations.

In summary, around 12,000 kilometres of high and medium-voltage power lines run along and across this "Danube corridor". More than 200 high-voltage lines span the river, while many other medium and low-voltage lines cross the river landscape (comp. Fig. 2). Two thirds of power lines are medium-voltage lines, while one third are high-voltage lines. Of the high-voltage lines, approximately 16% intersect Natura 2000 areas and therefore represent the highest risk to protected bird species regarding collision. Among the medium-voltage lines, around 27% are situated in Natura 2000 areas and pose the biggest problem in terms of electrocution.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Wertingen
Nordendorf
Holzheim
Thierhaupten
Meitingen
Baar (Schwaben)
Pöttmes
Aindling
Langweid
Wannengries
Schönenfelder Au
Moosenschütt
Burgheim
Rennertshofen
Neuburg an der Donau
Oberhausen
Unterhauser Forst
Ingolstadt
Karlshuld
Königsmoos
Ehekirchen
Schrobenhausen
Aresing
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Gachenbach
Karlskron
Eichstätt
Neuburg-Schrobenhausen
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Major Lines (>50kV)
Minor Lines (≤50kV)
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Danube River
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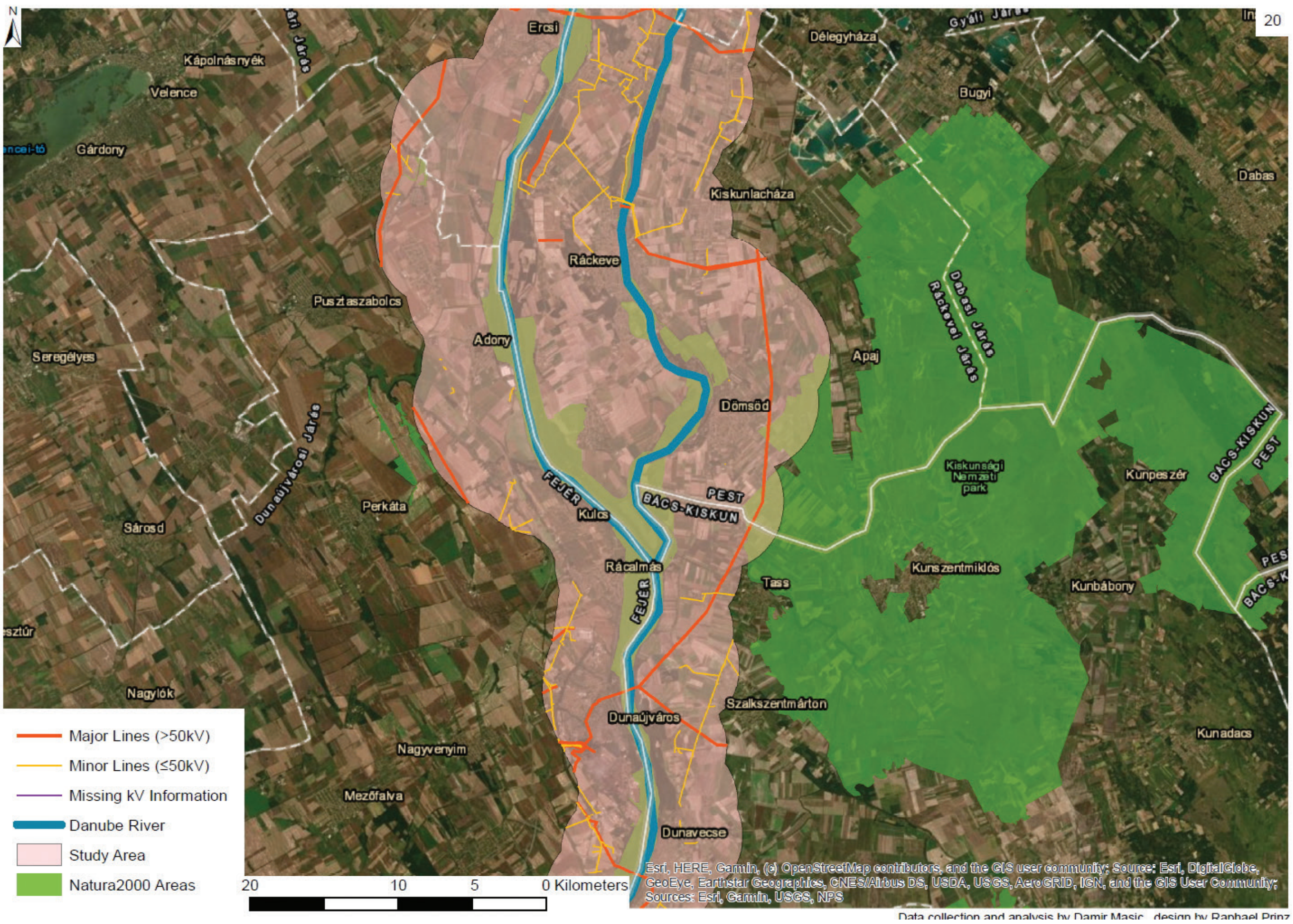
Esri, HERE, Garmin, (c) OpenStreetMap contributors, and the GIS user community; Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community; Sources: Esri, Garmin, USGS, NPS
Data collection and analysis by Damir Masic, design by Raphael Prinz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Rácalmás
Tass
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Nagylók
Dunaújváros
Szalkszentmárton
Kunadacs
Nagyvenyim
Mezőfalva
Dunavecse
Dabasi Járás
Ráckevei Járás
Dunaújvárosi Járás
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Major Lines (>50kV)
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Esri, HERE, Garmin, (c) OpenStreetMap contributors, and the GIS user community; Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community; Sources: Esri, Garmin, USGS, NPS
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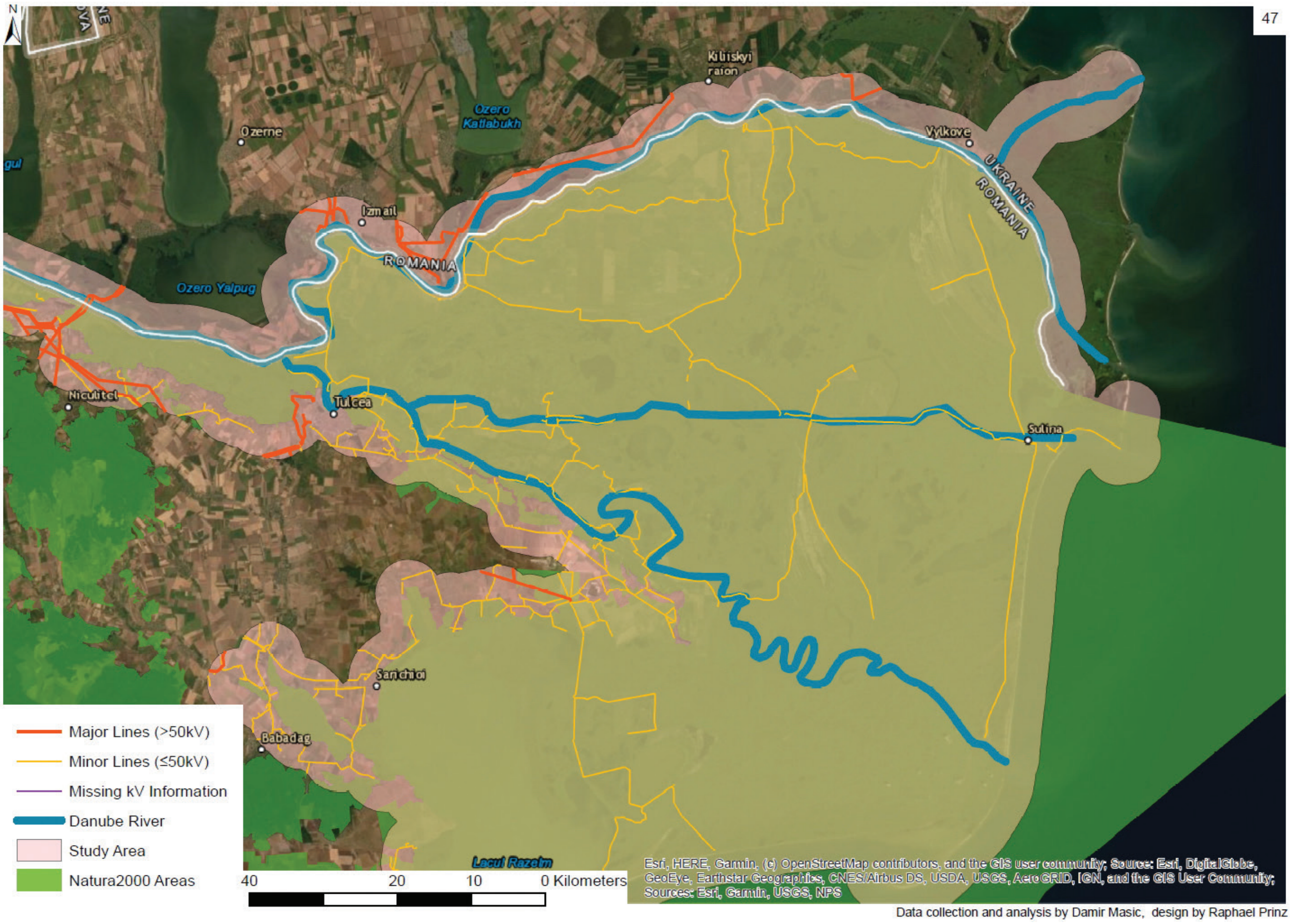


Fig. 4: Power lines along the Danube. In the selected project area, power lines generally decrease from west to east (see Annex 1). Exemplary maps are shown for the Upper Danube (Germany), the Middle Danube (Hungary south of Budapest) and the Lower Danube (Danube Delta).

However, the power lines are not evenly distributed across the study area. As can be seen from Table 2, the total length of power lines intersecting the project area per country generally decreases from west to east. Considering, for example, that Austria and Hungary have practically the same total length of power lines, but border the river for 350 kilometres and 417 kilometres respectively, this difference can be striking. Croatia, Serbia and Bulgaria, meanwhile, only have comparatively small electricity grids. An exception to this "general rule", however, is Romania, which is marginally ahead in terms of high-voltage line length, and clearly ahead in terms of medium-voltage line length.

As the availability of public data differs significantly from country to country, this statistic also reflects the quality and quantity of data surveyed and provided within the DANUBE FREE SKY initiative.

Voltage/ country	GER	AUT	SK	HU	HR	RS	BG	RO
High	1,002.38	664.29	147.95	526.20	46.00	311.88	122.97	1,097.48
Medium	1,369.81	670.66	509.08	694.71	59.63	5.94	5.99	3,150.95
Low	2.25	9.44	0.00	29.51	0.00	0.00	0.00	0.00
Unknown	3.44	11.45	19.19	111.60	5.22	172.99	357.45	634.01
Sum	2,377.88	1,355.84	676.22	1,362.02	110.85	490.81	486.41	4,882.44

Tab. 1: Length of the power lines in the investigation area along the Danube, divided according to different voltages.

3.5. Current knowledge

In summary, it must be stated that knowledge regarding the negative effects of power lines on birds in the study area is rather limited. Although there are some very valuable efforts at the national level (e.g. DEMETER et al. 2018) or unconnected to the river (e.g. GERDZHIKOV & DEMERDZIEV 2009, DEMERDZHIEV 2014), few studies have been carried out directly on the Danube itself. The most important of these studies and their results are presented below.

There are no specific Danube-related surveys in Germany or Austria so far. However, in Germany there is a wealth of investigations concerning this topic (e.g. TNL UMWELTPLANUNG 2017, JÖDICKE et al. 2018), while in Austria the first camera-based investigations of the Danube are currently in progress (S. Aberle, Austrian Power Grid, pers. comm.).

In Slovakia, a large LIFE Energy project was started in 2014 (M. Gális, pers. comm.). 81 specially trained field assistants have surveyed almost 7,000 kilometres of power lines (22 kV and 110 kV) in 13 SPAs and spent almost 2,000 days in field. A total of 4,364 bird carcasses (belonging to 86 identified species) have been recorded. In the majority of birds, the determined cause of death was electrocution (about 78%) or collision (about 22%). The species most prone to electrocution were Eurasian Buzzard (*Buteo buteo*, 34% of casualties) and Eurasian Magpie (*Pica pica*, 20%). The species most prone to collision with wires were Mute Swan (*Cygnus olor*, 21%) and Common Pheasant (*Phasianus colchicus*, 13%). Of the bird species affected, those with a particularly high nature conservation value include Eagle Owl (*Bubo bubo*) and White Stork (*Ciconia ciconia*) in the case of electrocution, and Purple Heron (*Ardea purpurea*), Lapwing (*Vanellus vanellus*) and Skylark (*Alauda arvensis*) in the case of collision. Electrocution cases were concentrated in fields (often alfalfa), probably because these habitats often combine a high supply of small mammals as prey with a low number of perches. Collisions occurred very often where wetlands and feeding areas are separated by power lines, meaning they have to be frequently crossed by birds switching between resting and foraging sites. Overall, this largest of all investigations with a share in our study area shows that the Danube, as a supra-regionally important wetland area, is also a high-risk area for bird mortality on power lines. Of the 7,000 kilometres investigated, 551 kilometres fall within the study area selected for this position paper. Of these, 193 km (35%) fall into the highest risk class for bird collisions.

In Hungary, bird protection on overhead lines has a tradition of more than 40 years. The Danube region was not specifically or separately treated (FIDLÓCZKY et al. 2014, DEMETER et al. 2018) and, after a risk analysis, the most problematic areas (at least regarding electrocution on medium-voltage lines) were found to be in the eastern Hungarian lowlands. Within the framework of DANUBE FREE SKY, first surveys were conducted by the Fertö-Hanság National Park Directorate in the Szigetköz region.

In Croatia, investigations were carried out only in coastal areas, i.e. far away from the Danube (T. Mikuska & M. Zec, pers. comm.; ZEC & KATANOVIĆ in prep.). Within DANUBE FREE SKY, a first inventory of the most critical sections of power lines in Kopački rit Nature Park and the Croatian Podunavlje region was conducted.

In Serbia, there are no studies dealing with the topics of electrocution and collision so far. An investigation into electrocution has just begun in the Banat Region of the Danube (M. Ružić, pers. comm.).

In Bulgaria, great efforts have been made to improve bird protection on power lines. Most of the measures were carried out in open and hilly, raptor-rich areas of the country (Rhodopes and South-East Bulgaria), within the framework of the projects Save the Raptors LIFE+, LIFE for Safe Grid, Neophron LIFE+, Saker Falcon LIFE+ and LIFE for Burgas Lakes. The last project also aims to protect many waterbirds along the Via Pontica flyway, but not in the Danube area itself. However, the operational territory of the ongoing Life Birds on Power Lines project also includes parts of the Danube plain in Bulgaria. It will cover the SPAs Belene Islands Complex, Svishtov-Belene lowland, Nikopolsko plateau, Zlatiayata, and Orsoya fishponds (S. Cheshmedjiev & D. Dobrev, pers. comm.).

In Romania, there is only a single scientific article that expressly refers to the collision of bird species in the current perimeter of the Danube Delta Biosphere Reserve (KISS & MARINOV 1977). In the study, which was limited to only two survey days in the coastal area of the Danube Delta, a total of 58 cadavers were found over 10 kilometres. 22 bird species that collided with telephone lines were identified. The highest mortality was recorded for Whiskered Tern (*Chlidonias hybrida*) with 24 dead individuals, followed at some distance by Mallard (Anas plathyrhynchos) and Coot (*Fulica atra*) with four individuals each, and Caspian Gull (*Larus cachinnans*) with three individuals.

3.6. Expert assessment and potential impacts

It is clear from what has been outlined in chapter 3.5 that investigations are in short supply. This is due to the high personnel expenditure of such studies, which in turn entails high financial costs. Due to the limited data available, we are unable to make a scientifically acceptable estimate of the number of birds killed in our investigation area as a result of electrocution or collision. However, based on data from the USA, Canada, Germany and Slovakia (LOSS et al. 2014, RIOUX et al. 2013, TNL UMWELTPLANUNG 2017; M. Gális, pers. comm.) we must reckon with thousands of birds killed by electrocution and tens of thousands, probably even hundreds of thousands, of birds killed by collision along the Danube every year.

To gain an impression of the importance of this problem, DANUBE FREE SKY conducted an expert questionnaire survey. As a result, representatives from 20 protected areas stated that both electrocution and collision on overhead lines are relevant or very relevant problems in bird protection. Specifically, 72.2% of experts surveyed stated that collision was a very relevant mortality factor for the protected areas along the Danube, while 27.8% rated it as important. Electrocution was seen as a very important mortality factor by 33.3% of respondents and as important by 61.1%, while only 5.6% of experts surveyed rated it as insignificant. Despite the clear importance attributed to the risk of power lines, only 11.8% of the surveyed protected area representatives said they had already implemented safety measures. Also, such measures related only to single pylons or lines, while 88.2% of the electricity network are considered completely unprocessed. In addition, 70.6% or respondents stated they had never had any contact with a transmission systemn operator before DANUBE FREE SKY. Ultimately, interest in concrete bird protection projects was high (31.3%) to very high (68.8%).

3.7. Current mitigation measures

Not least due to the DANUBE FREE SKY initiative, there has recently been an abundance of protective measures. It was generally recognised that the problem is so obvious that, even without lengthy and expensive investigations (which in many areas have no chance of realisation in the near future), immediate action must be taken. With regard to the individual states, the following can be summarised:

In Germany, a DANUBE FREE SKY national meeting with transmission system operators resulted in the agreement to identify power lines crossing the Danube river which can be marked in the short term. Netze Baden-Württemberg implemented the marking of a power line crossing the Danube close to Sigmaringen (marking with fireflies by drone). Together with Bayernwerk GmbH a pilot marking of 4 Danube crossing powerlines in Ingolstadt and Neuburg is envisaged for 2020. With support of DANUBEparksCONNECTED, meanwhile, Deutsche Bahn Netze, LEW Verteilnetz GmbH and Bayernwerk Netz GmbH expressed their interest to join the LIFE+ DANUBE FREE SKY follow-up project with financial contributions and concrete actions.

In Austria, the cooperation with APG (Austrian Power Grid) and numerous other operators (EVN Netz Niederösterreich, Wiener Netze, Netz Oberösterreich), as well as BirdLife Austria, resulted in the DANUBE FREE SKY agreement to mark nearly all 36 lines crossing the Danube. As a first step, the ground wire is marked with lamellae deflectors. First pilot markings took place in winter 2018/2019, implemented and financed by the power line operators. Step by step, more installations took place in 2019. In the DANUBE FREE SKY follow-up LIFE+ project proposal, insulation actions are foreseen for a railway line along the Danube floodplains in cooperation with the Austrian Federal Railway (ÖBB).

In Slovakia, 77 km of power lines representing the highest risk of collision have so far been marked by installation of diverters, using FireFly bird protection, Orange Spiral and RIBE lamellae. In most cases, all lines (conductors as well as the earth wire) were marked. Since April 2016, field assistants have walked almost 1,330 km in about 333 hours (42 days) under treated power lines searching for possible collision victims. Only individual victims could be found, which confirms the high efficiency of protection actions and the almost 100 % effectiveness of the three types of diverters installed. However, of the 77 kilometres secured so far, only one is within the study area selected for this position paper. This means that dozens of kilometres of high-risk power lines are still unsecured along the Danube (cf. chapter 3.5). In spring 2019, a critical 22 kV power line in the Danube corridor was marked with FireFly diverters along a length of 1 km, co-financed by DANUBE FREE SKY.

In Hungary over the past decades, various projects have mainly focused on measures against electrocution. In the Duna-Ipoly and Duna-Dráva National Parks alone, more than 10,000 pylons have been defused. Within the pilot action in DANUBEparksCONNECTED, the Duna-Ipoly National Park and transmission system operator MAVIR marked a 400 kV power line at river kilometre 1614/1615. Two types of bird flight diverters were used in order to achieve maximum results. Bird diverters of the Birdmark Afterglow type were installed by drones (total of 263 pieces) and RIBE type diverters (40 pieces) were installed by MAVIR specialists. Later in 2019, another follow-up action was implemented by MAVIR south of Budapest (G. Kiss, pers. comm.).

Based on the survey in the Fertö-Hanság National Park (see 3.5), the highest-risk medium-voltage pylons have been retrofitted within the framework of DANUBE FREE SKY. In the Duna-Dráva National Park, the DANUBE FREE SKY initiative resulted in the modification of the head structures of 55 pylons – implemented by transmission system operator E-ON – along a 4-kilometre stretch of medium-voltage power line in the core breeding area of White-tailed Sea-eagle and Black Stork. Additionally, the sections of this power line were marked against collision.

In Croatia, so far no mitigation measures have been installed within the study area (M. Zec, pers. comm.). The DANUBE FREE SKY national meetings between Kopački rit Nature Park and transmission system operators resulted in a joint project partnership for conservation actions within the framework of the LIFE+ follow-up project. Additionally, Memorandum of Cooperations have been signed between Kopački rit Nature Park and power line operators within DANUBE FREE SKY, to define future steps of cooperation.

There are hardly any implementation measures in Serbia so far, but attempts are currently being made to prevent the construction of a power line over the Important Bird Area Labudovo Okno, an area of extraordinary biodiversity and a national stronghold of wintering waterfowl such as geese, ducks, cormorants, swans, etc. (M. Ružić, pers. comm.).

In Bulgaria, the DANUBE FREE SKY initiative resulted in the retrofitting of 40 low and medium-voltage pylons along the Danube, based on investigations of power lines between Rus and Silistra. There is no high-voltage power line crossing the Danube. Most of the numerous measures implemented so far were outside of the Danube region, not least in the very important waterfowl area of the Burgas lakes. Almost 1,000 diverters against collision were installed and around 60 pylons were defused against electrocution in this area. However, there are plans to install bird diverters in the SPA Belene Islands Complex (Persin Island) and the SPA Svishtov-Belene lowland, due to the large concentrations of waterfowl there. For all project SPAs (Belene Islands Complex, Svishtov-Belene lowland, Nikopolsko plateau, Zlatiayata, and Orsoya fishponds) there are plans to insulate the most hazardous electricity pylons with the highest importance for the target species (S. Cheshmedjiev, pers. comm.).

In Romania, the Danube Delta Biosphere Reserve Authority implemented the installation of 250 diverters along 2.5 km of power lines with very high collision risk. FireFly diverters were used in this case. The installation took place in 2019 as part of the DANUBE FREE SKY cooperation.

4. Prioritisation of protection measures

4.1 Need for prioritisation

It is clear that safety measures are urgently needed. However, since financial and human resources are limited, the choice of implementation location must be prioritised. It is not feasible to wait for studies, because they are lengthy and costly. Methodologically, it is not simple to assess mortality rates on power lines, which is reflected in the high personnel costs or costs for other procedures (e.g. camera systems). In the one-year German study by JÖDICKE et al. (2018), for example, teams carried out search runs every two days during the bird migration periods, and every five days otherwise. Thus more than 100 inspections were necessary. Furthermore, methodological errors were attempted to be kept to an absolute minimum. To this end, six experiments on the search rate ("How much do observers overlook?") and 26 camera-based experiments on the clearance rate ("How many carcasses are removed by scavengers?") were carried out. In addition, bird species, flight directions and flight behaviour were recorded comprehensively, so that an elaborate data matrix is now available that is complex to interpret.

For this reason, in chapters 4.2 and 4.3, we present simple methods of prioritisation, separated according to collision and electrocution. They can be applied at any spatial level along the Danube and guarantee rapid action against a problem that has so far been highly underestimated.

4.2 Collision

There are a minimum of 12,000 km of existing transmission and distribution overhead electric lines in the Danube study area (30,741.2 km2). It is anticipated that transmission and distribution upgrades will be required in the coming years to fulfil the energy demand in this strategic area. This projected growth in transmission and distribution lines would inevitably lead to higher bird collision risks. It is important to note that collisions can occur equally with transmission and distribution lines, and even occasionally with telephone lines (although much less frequently, as they are usually more visible).

In order to prioritise the collision risk of birds with overhead electric lines along the Danube, we used GIS data available for the study area. Rivers, canals, wetlands (lakes, marshes, reservoirs, etc.) and coastal waters that overlay the study area were selected from the Corine Land Cover vector data set (https://land.copernicus.eu/local/riparian-zones/riparian-zones-delineation). Within the Natura 2000 network, the Special Protected Areas comprise the most valuable areas for birds along the Danube. These areas are documented as being the most important breeding, migration, feeding and resting areas for birds (https://www.eea.europa.eu/data-and-maps/data/natura-9). For the non-EU countries (e.g. Serbia) that are not yet part of the Natura 2000 network, the Important Bird Area network has been considered to be the best available data source on this topic.

Power lines that span waterbodies plus a 100-metre radius and/or are located in SPA Natura 2000 sites represent the highest priority for the implementation of the protection measures against collision (FERRER 2012). Based on the literature and practical field experience we classified four risk classes with regard to collision:

1. **Waterbodies in Natura 2000 - SPAs:** Overhead electric lines crossing waterbodies and/or adjacent areas (100-metre radius) in SPAs. Very high potential risk of collision for high, medium and low-voltage power lines in the area.
2. **NATURA 2000 - SPAs further than 100 m from waterbodies:** Overhead electric lines in SPAs, but not crossing waterbodies or adjacent areas (100-metre radius). High potential risk of collision for high and medium-voltage power lines in the area. For low-voltage lines, the risk is situation-dependent.
3. **Waterbodies outside of SPAs:** Overhead electric lines crossing waterbodies and/or adjacent areas (100-metre radius) outside of SPAs. High potential risk of collision for high, medium and low-voltage power lines in the area.

4. **Outside NATURA 2000 - SPAs:** Overhead electric lines outside of SPAs and not crossing waterbodies or adjacent areas (100-metre radius). For high and medium-voltage power lines, the risk is situation-dependent, while a low risk is considered for low-voltage lines.

Prioritisation of conservation measures		Risk of collision		
		High-voltage power lines	Medium-voltage power lines	Low-voltage power lines
Worthiness of Protection	Waterbodies in SPAs	Very High	Very High	Very High
	SPAs further than 100 m from waterbodies	High	High	Situation-dependent
	Waterbodies outside of SPAs	High	High	High
	Outside SPAs	Situation-dependent	Situation-dependent	Low

Fig. 5: Matrix for the prioritisation of conservation measures against collision on overhead lines. On the one hand, a distinction must be made between NATURA 2000 sites and Non-NATURA 2000 sites (Worthiness of Protection), and on the other hand the risk of collision is taken into consideration.

Interpretation guide for the matrix:

Very High Risk: An immediate need for action exists!

High Risk: An immediate need for action exists! Only "very high" risk power lines have to be secured with even greater priority.

Situation-dependent: The security measures must be implemented in the medium term. They are to be weighed up according to local distributions and concentrations of birds, resources for implementation etc.

Low Risk: The security measures must be implemented in the long term

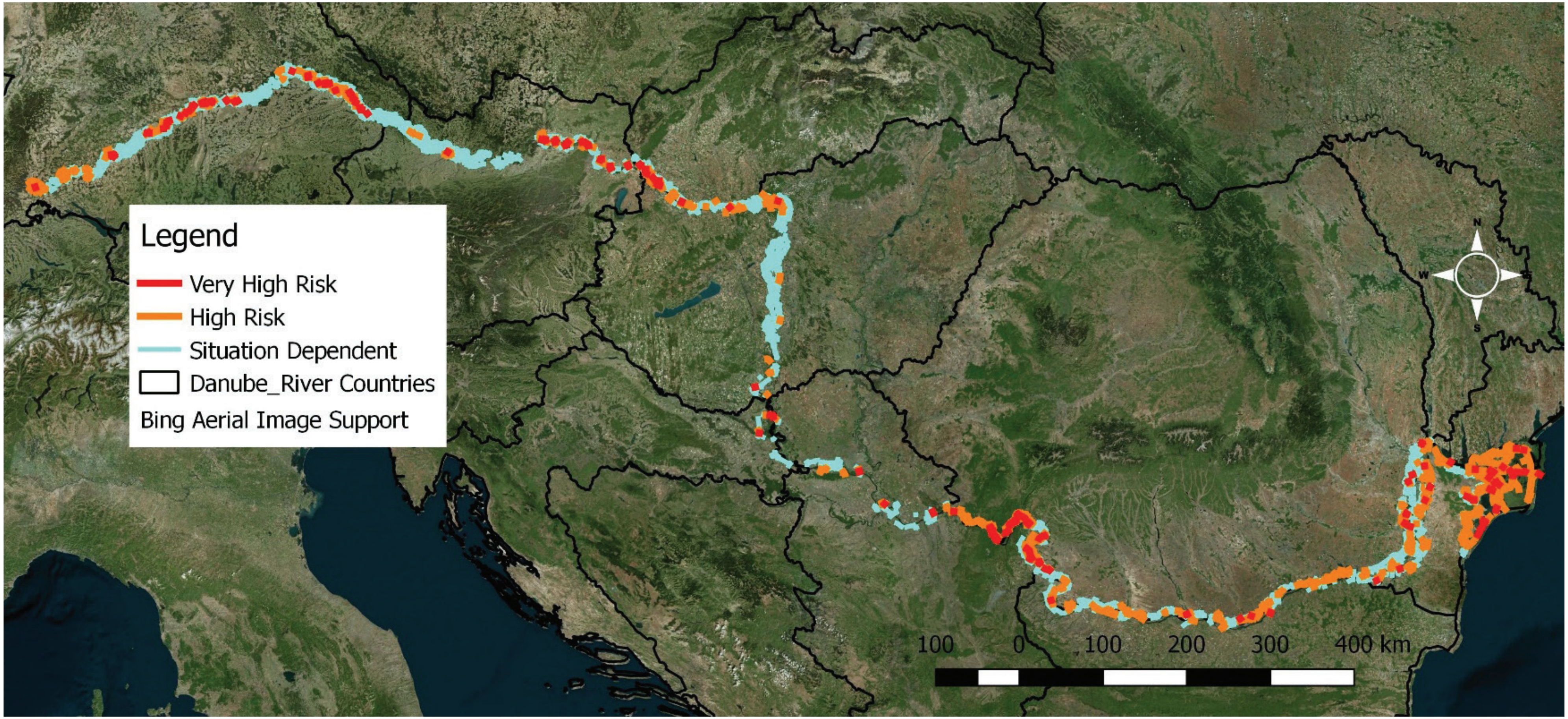


Fig. 6: According to these criteria for prioritisation, there are 2,347 km of power lines in the categories "very high risk" and "high risk" (19%). 4,520 km of power lines pose a situation-dependent risk (37%). For 44% of power lines (5,263 km) a low risk of bird collision was pre-determined (maps: A. Dorosencu).

According to the prioritisation criteria, the "need-for-action map" is presented for each partner country along the Danube course (Fig. 5-12).

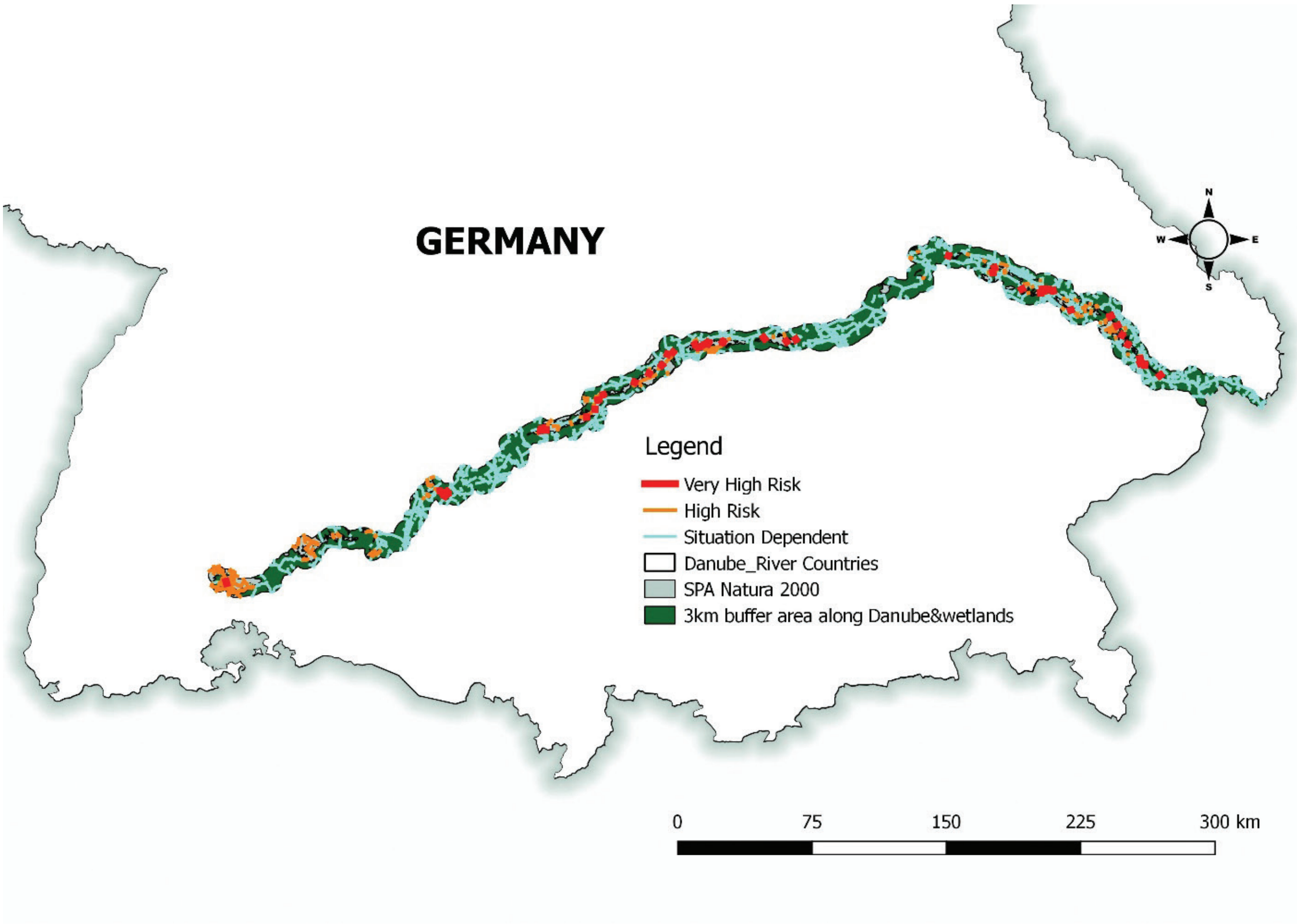


Fig. 7: Need for action map for Germany

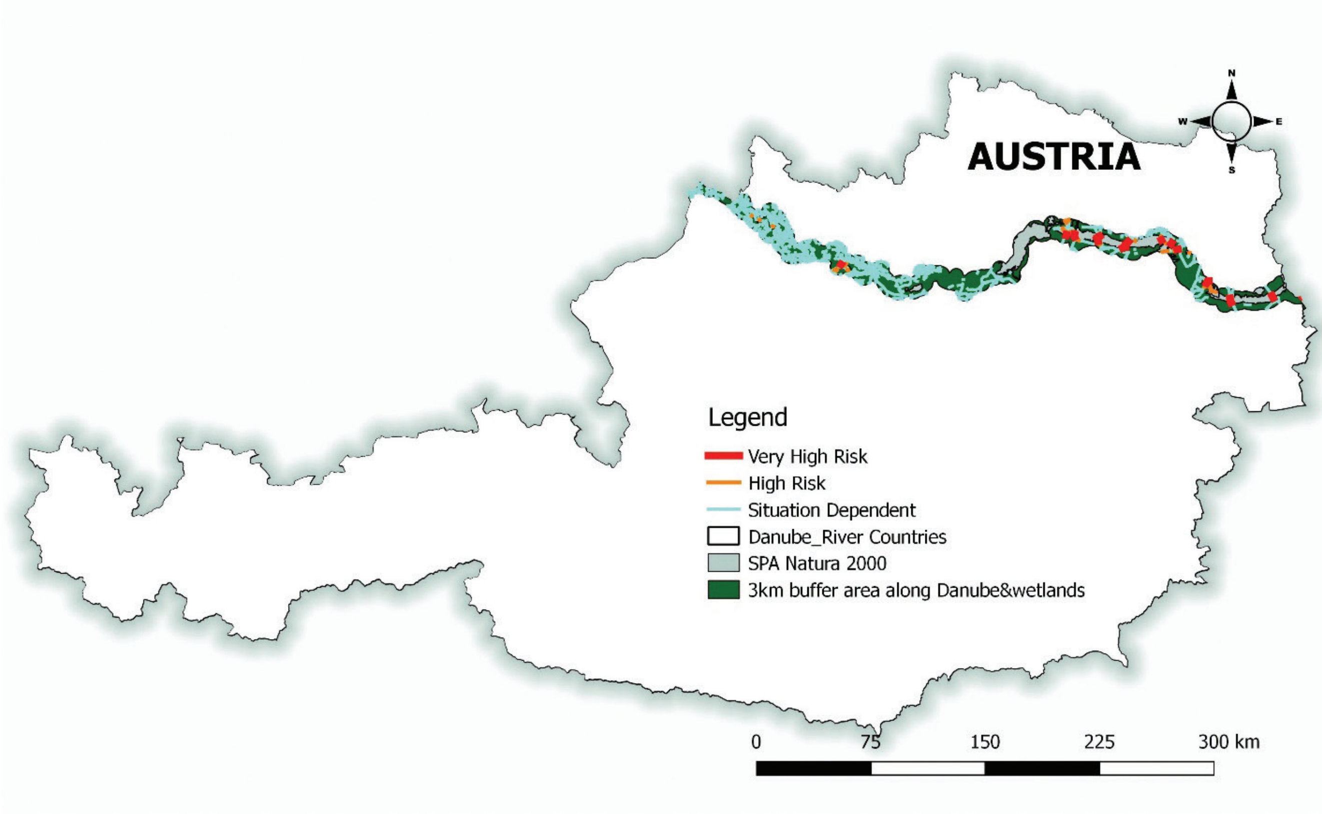


Fig. 8: Need for action map for Austria

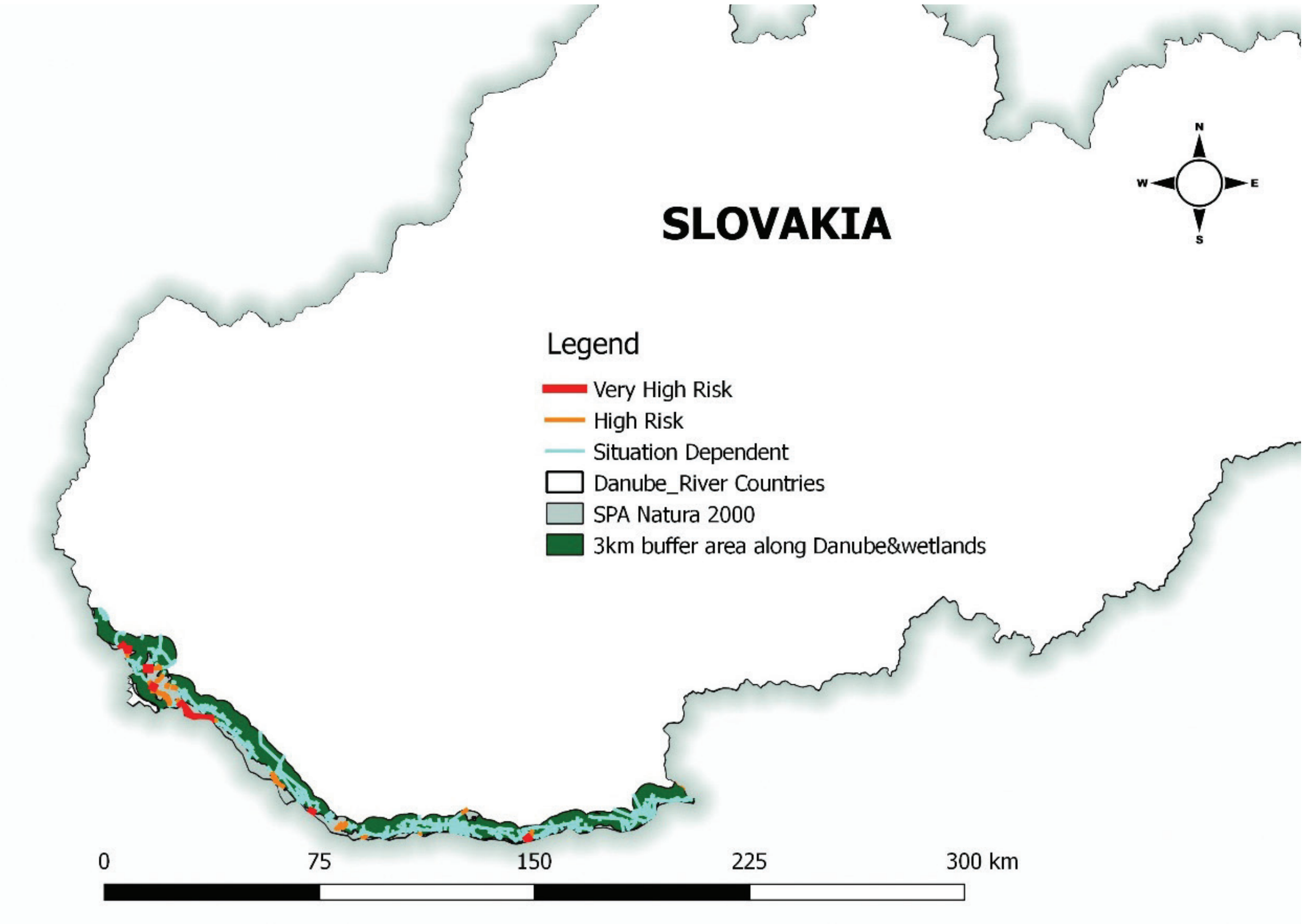


Fig. 9: Need for action map for Slovakia

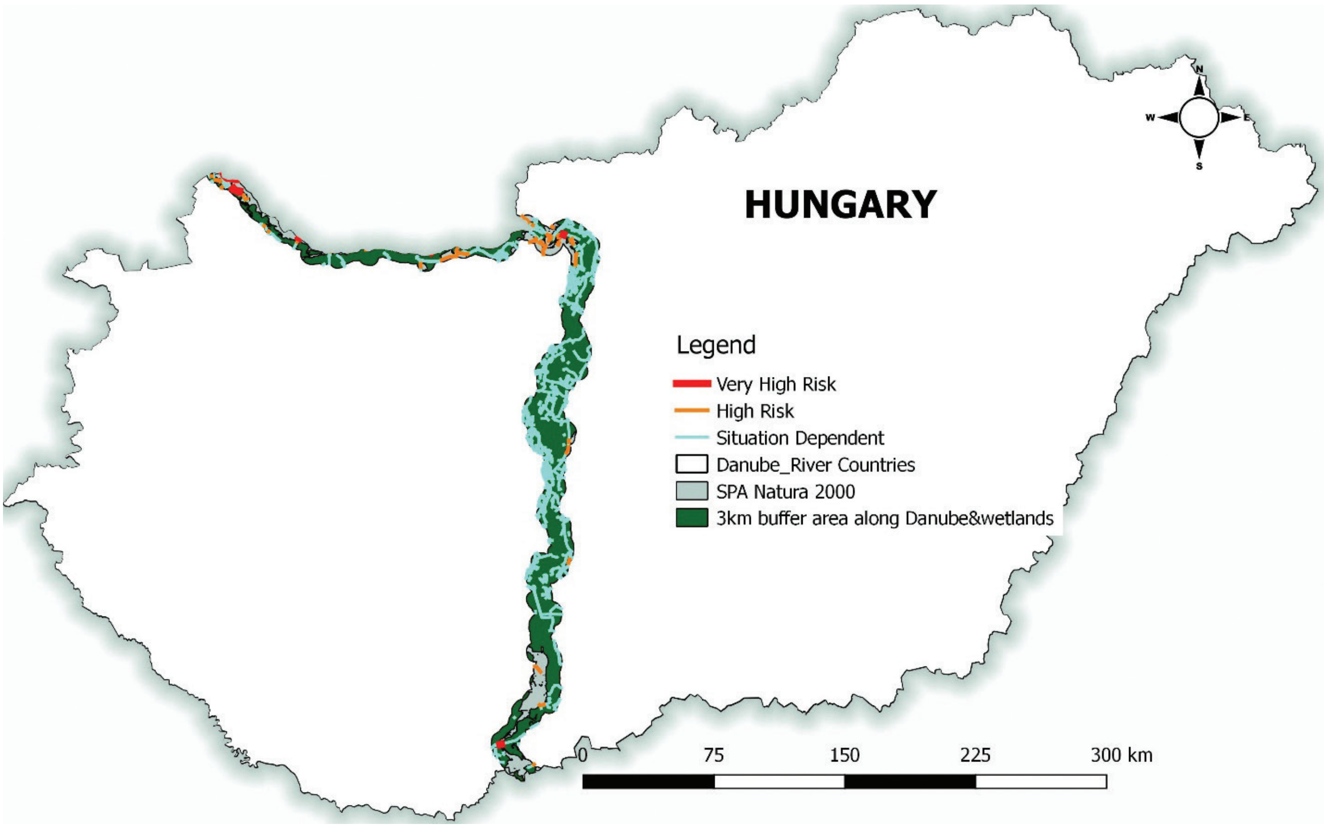


Fig. 10: Need for action map for Hungary

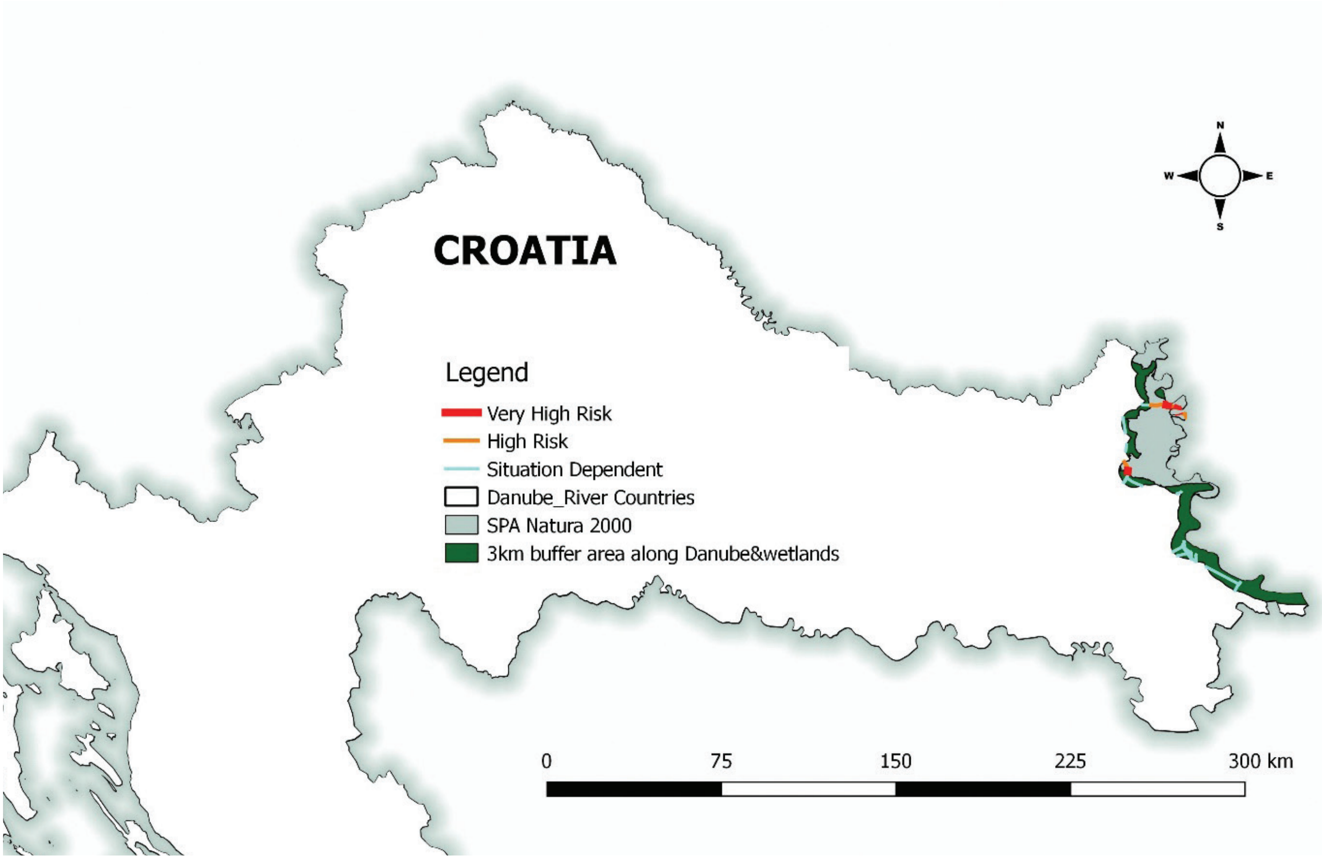


Fig. 11: Need for action map for Croatia

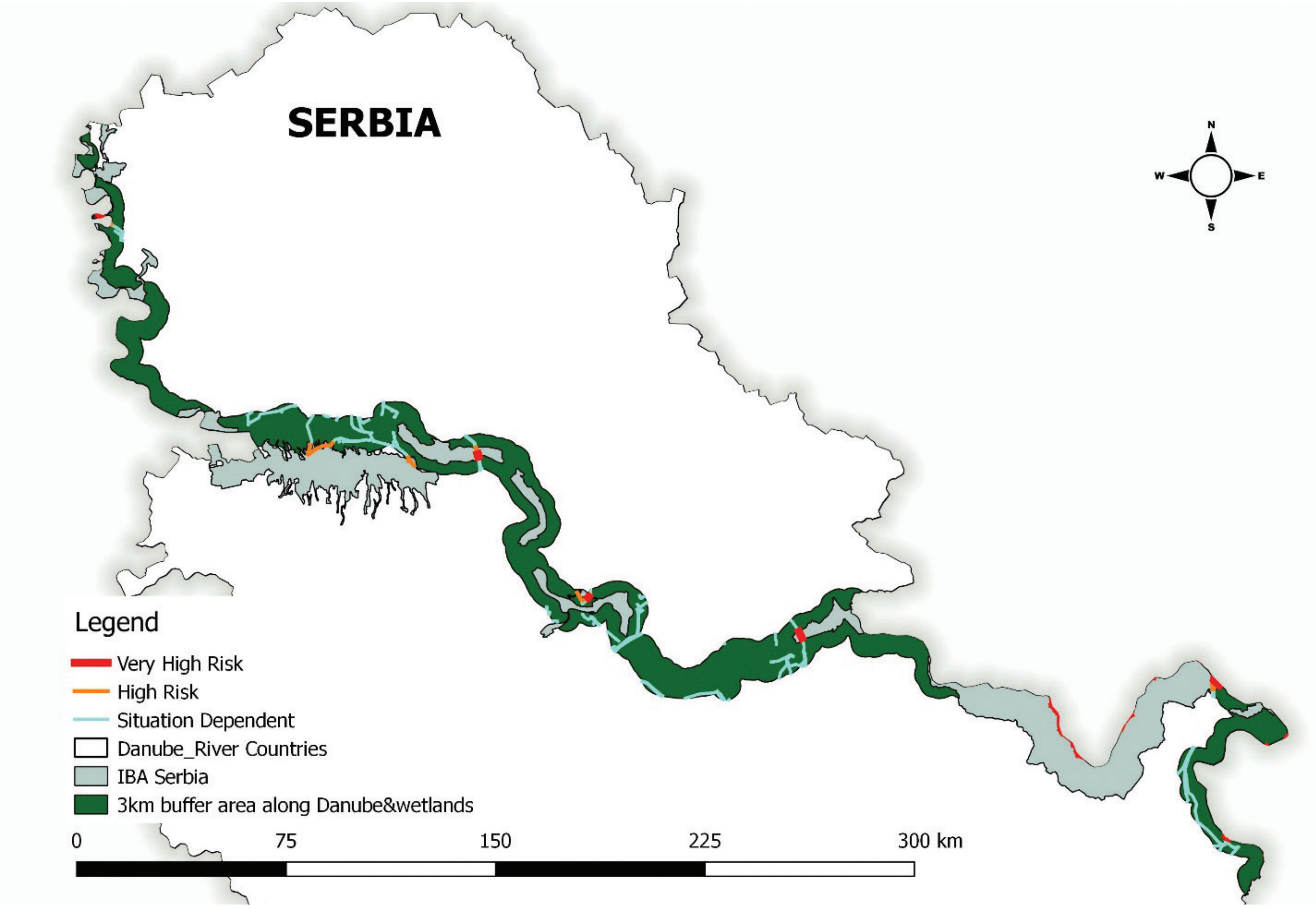


Fig. 12: Need for action map for Serbia

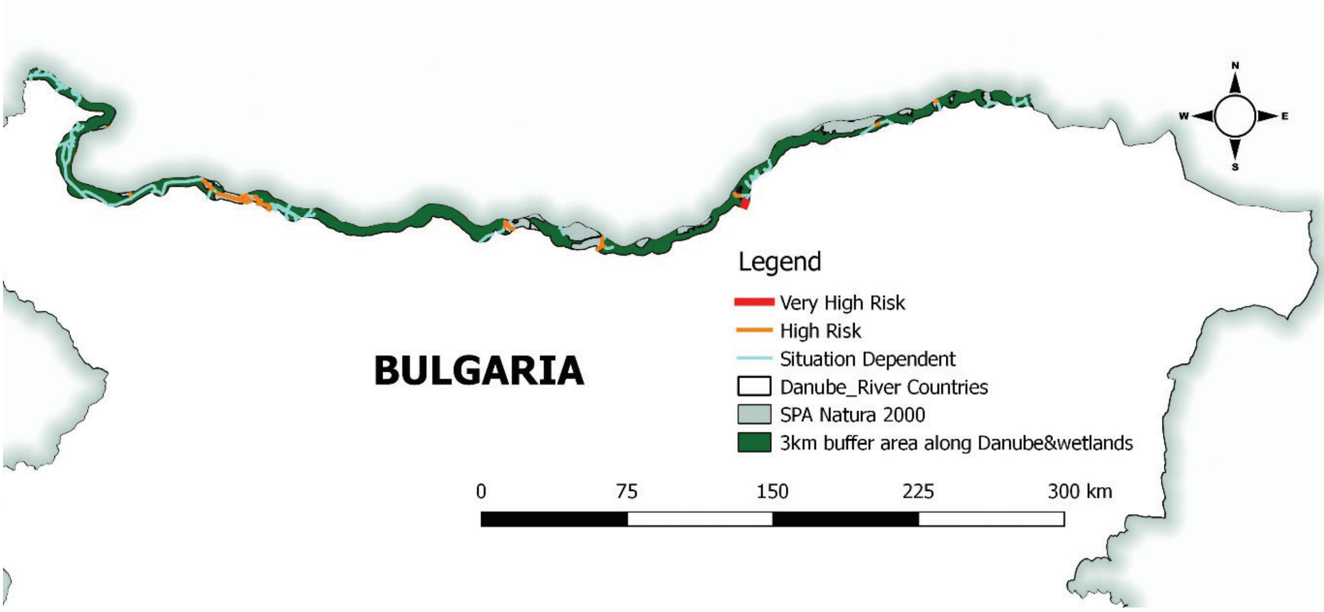


Fig. 13: Need for action map for Bulgaria

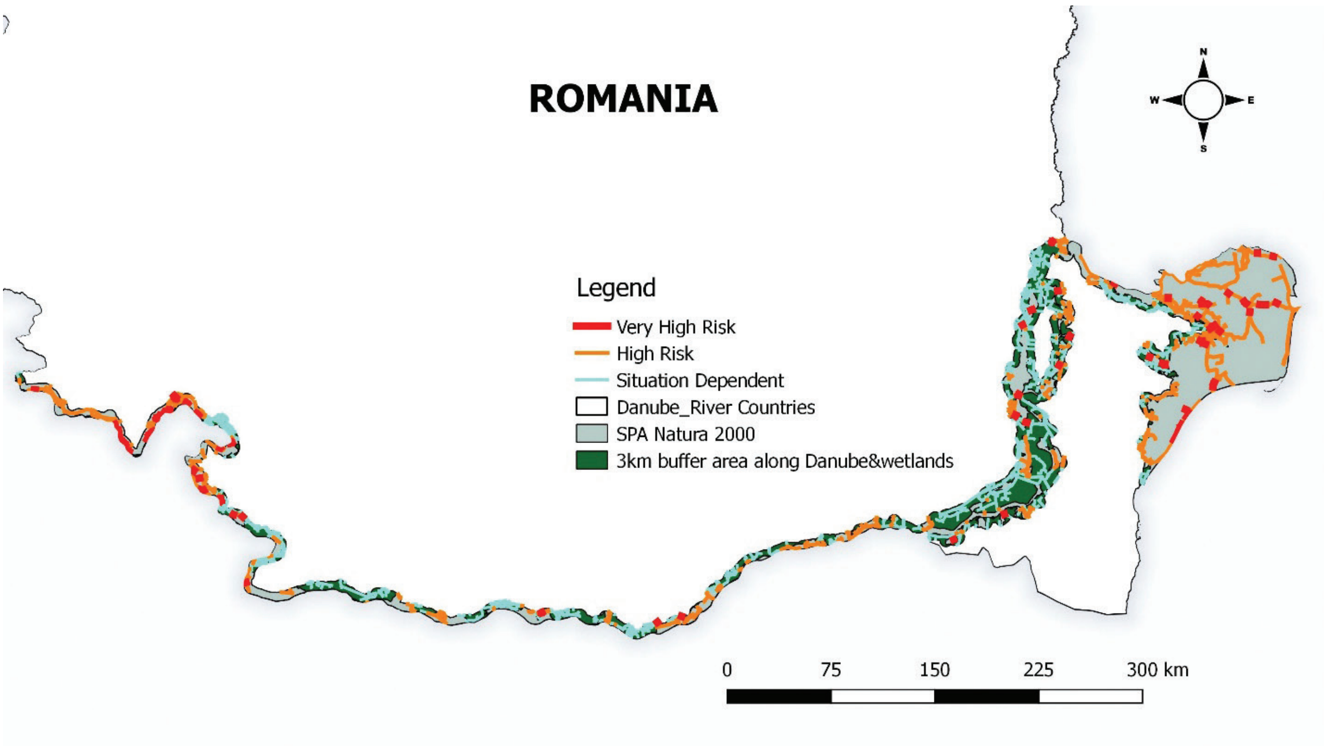


Fig. 14: Need for action map for Romania

4.3. Electrocution

For the prioritisation of the protection measures against electrocution on overhead lines three aspects were taken into consideration: First, particularly valuable bird sanctuaries with a high number of rare species, should be given preference. Second, special attention should be given to high-risk habitats. And third, particularly risky power lines should be defused first. Faced with limited financial and human resources, this approach is supposed to maximise the positive impact on bird conservation. Additionally, high-voltage lines of 110 kV or more are classified as harmless in terms of electrocution. In these constructions, the insulator sections are so long that birds can hardly overcome them. For this reason, no measures need to be undertaken against electrocution in such power lines, only against collision.

With regard to the areas worthy of protection, we have distinguished between Natura 2000 and non-Natura 2000. This makes sense because the most important bird areas along the Danube are integrated in the Natura 2000 network. National parks, nature parks, biosphere reserves and nature reserves are all part of the Natura 2000 protected area network and correspondingly also constitute the most important bird migration, resting and breeding areas. In Serbia, as a non-EU country, the network of Important Bird Areas is taken into consideration.

As far as habitats are concerned, numerous studies show that the risk of electrocution is greater in open countryside than in forests (e.g. DEMERDZHIEV 2014). This is not surprising because in open countryside electricity pylons are often the only perches available. This fact has been taken into account in our priority matrix, with woodland therefore being placed in a lower-risk category.

As far as estimating mortality risk is concerned, we focused mainly on the valuable and long-standing experience in Slovakia ("Project LIFE Energy") and the assessments of a panel of experts. On this basis, we classified electrocution risk into three classes. Illustrative examples can be found in Appendix 1.

High risk: We classify metal cross-arm pylons, in particular, and generally all complex constructions and pylons with combinations of exposed jumper wire locations, mostly when above the console, as high risk.

Medium risk: We classify all kinds of distribution power line consoles with a vertical position of the support insulators, distribution transformers and horizontal switch disconnectors as medium risk.

Low risk: We classify all kinds of distribution power line consoles with a horizontal or hanging position of the support insulators, special constructions with console shapes that prevent birds from perching on the construction, or configurations of support insulators and exposed jumper wires that allow bird individuals to perch safely as low risk.

Prioritisation of conservation measures		Risk of electrocution		
		High	Medium	Low
Worthiness of protection	Open countryside in SPAs	Very High	Very High	High
	Woodland in SPAs	High	Situation-dependent	Situation-dependent
	Open countryside outside of SPAs	High	High	Situation-dependent
	Woodland outside of SPAs	Situation-dependent	Situation-dependent	Low

Fig. 15: Matrix for the prioritisation of conservation measures against electrocution on overhead lines.

Interpretation guide for the matrix:

Very High Risk: An immediate need for action exists!

High Risk: An immediate need for action exists! Only "very high" risk power lines have to be secured with even greater priority.

Situation-dependent: The security measures must be implemented in the medium term. They are to be weighed up according to local distributions and concentrations of birds, resources for implementation etc.

Low Risk: The security measures must be implemented in the long term

Fig. 16: Installations of bird diverters reduce the risk of collision by up to 79% - 91%. Pilot actions within DANUBE FREE SKY found positive response in media and public. (photo: G. Frank/DANUBEPARKS)

5. Bird-friendly solutions

At the beginning of this chapter, it should be noted that starting points differ greatly between the Danube riparian states. These pertain, for example, to the density of the electricity grid, the construction of power lines or the national legal requirements. Therefore, it is not possible to deal with each individual case in the following, but rather a general instruction manual is to be presented. It is a kind of a hierarchical checklist, which should be applied from top to bottom.

5.1. Preliminary examinations and project assessments

Before working on specific technical solutions in bird protection for overhead lines (see 6.2 and 6.3), the following basic questions and project requirements should first be clarified.

5.1.1. Needs analysis and legal background

It should be noted once again that the construction of a power line always represents a substantial encroachment on nature and the landscape. As already explained above, this results in an increased risk of fatalities due to electrocution and collision, but the landscape features are also changed. This structuring and fragmentation can ultimately lead to a different composition of species (changes in habitat, altered competitive conditions, changes in predator/prey ratios, etc.).

From a nature conservation perspective, the so called "zero variant", i.e. abandonment of construction of a power line, is always the best solution. It is imperative, therefore, that the need to upgrade the electricity grid must be proven by the applicants and verified by nature conservation. Appropriate environmental impact assessments must therefore be carried out. If there are still countries in the Danube region with an insufficient right of appeal, the legal situation must first be checked for conformity with EU law and adjusted if necessary. In principle, however, it should be noted that all Danube riparian states have committed themselves to bird protection in international agreements. This can be well illustrated by the example of electrocution (for an overview, see BÖHMER & HAAS 2015), where Resolution 7.4 "Electrocution of Migratory Birds" was signed by more than 80 states at the 7th Conference of the Convention on the Conservation of Migratory Species of Wild Animals (CMS; "Bonn Convention") in 2002. These states also include the Danube countries (http://www.cms.int/en/parties-range-states). In addition, in 2004 the Standing Committee of the Bern Convention in Strasbourg adopted the recommendations presented by NABU and BirdLife. Besides bird protection on medium-voltage pylons, they also include requirements for avoiding collisions on conductor ropes, for underground cabling, for route planning, as well as for systematic data collection and accompanying scientific research. This agreement was signed by 35 European countries. These draft recommendations require the member nations to solve the problem by observing the state of the art in engineering.

5.1.2. Variant check

As a rule, variant tests are carried out prior to the implementation of construction projects on the scale of power lines. Matters of concern are not only the natural heritage, but also the overall appearance of the landscape, project costs and much more. In any case, projects are definitely to be designed to ensure that construction is as environmentally friendly and resource-saving as possible. Numerous studies have shown that high-voltage power lines should not cross main flight routes, as they can have the highest negative impact at bird migration flyways or when built as barriers to feeding grounds. Bird clusters should also be avoided. These factors should be taken into account in variant testing (see e.g. BEVANGER 1994, D'Amico et al. 2018, DREWITT& LANGSTON 2008, JASS 1999, Pérez-García et al. 2018).

In the case of a concrete project, there must always be an individual examination of nature conservation law in accordance with national law, and such a result cannot be prejudiced by a general position paper such as this. As far as ornithology is concerned, the well-known methodological standards (such as those of SÜDBECK et al. 2005) must be adhered to. Only the exact knowledge of the actual avi-faunistic status quo allows a derivation of the degree and the importance of the intervention, and finally of any protective measures.

However, from the point of view of the authors of this position paper, and of all persons and supporting organisations involved, the protected area scenery is of particular importance. As explained in the previous chapters, the protected areas along the Danube are the backbone of biodiversity protection and biodiversity. For this reason, there is a clear demand here that protected areas of all kinds be exempted from planning for power lines. This is particularly true of Natura 2000 sites. These areas are subject to a legal prohibition of deterioration, which we believe will be violated in any case by the construction of a power line. Natura 2000 sites (or analogue areas in Serbia) must therefore be excluded from the construction of all kinds of power lines a priori (unless underground cabling is used)!

5.1.3. New construction or conversion

Before assessing a construction project, it should always be clarified whether it is a new construction or a conversion. Apart from the aspects discussed in 6.1.1 and 6.1.2 with regard to new construction, there are also fundamental differences of a technical nature. In the case of retrofitting existing power lines, it is often necessary to take account of structural aspects (e. g. load capacity) and similar factors. Therefore, secondary protection measures such as bird protection hoods (see 6.3 for details) will usually be the means of choice, though they will never provide complete protection or are maintenance-intensive. Wherever possible, therefore, new constructions or major alterations must be planned, leading to permanent, "constructive" solutions that are completely harmless for birds (note: this applies only to electrocution, and there is always a residual risk of collision).

5.1.4. Construction versus operation phase

It should be emphasised that many protective measures "only" refer to the operating phase. However, the so-called increased mortality risk must also be avoided during the construction stage. This is not necessary for electrocution (because there is no current flowing yet), but it is possible and important with regard to collision.
Before the construction is completed and all protective measures such as warning balls, lamellae etc. have been installed, an increased risk of collision must be avoided even during the construction phase. This could be achieved, for example (like in some projects in Austria), by securing the earth rope immediately with tracer belts and, at most one month later, replacing them with the warning diverters against bird strike. The routing tapes must be at least one metre long, red-white in colour and not further than 30 metres apart from each other. In addition, the unmarked pilot rope required to pull up the earth wire rope must not be attached for longer than two days before the actual earth wire rope is attached and marked. Otherwise, the pilot rope must already be marked every 20 m with 1-metre warning tapes, thus offering immediate protection. In this case, the pilot rope must be replaced by the definitive earth wire rope within 14 days.

Furthermore, it goes without saying that power lines which are not (or no longer) active pose the same potential risk of collision as power lines in operation. They are to be deconstructed as soon as possible.

5.2. Technical solutions against collision

5.2.1 Underground cabling

Underground electricity cables are used in almost all European countries, mainly for parts of the electric transmission and distribution networks in urban areas, as well as in the countryside wherever ecological or historical interests need to be preserved.

The cost of underground cables at voltages of up to 90 kV are estimated to be around double the cost of overhead lines; at voltages of 225 kV the estimate is around three times the cost, while at 400 kV the estimates are around ten times the cost of overhead lines (a current project in Denmark, however, shows that the cost of burying 400 kV lines is only 3–4 times higher than overhead line).

Good practice projects (e.g. for Great Bustard) show the efficiency of underground cabling for bird conservation. For core populations and in core areas (e.g. in high risk areas in the Danube Delta Biosphere Reserve) ground cabling has to be considered as an option and sometimes as a priority solution, also in the Danube region.

In Germany, according to the Energiewirtschaftsgesetz (EnWG § 43h), underground cabling is obligatory for 110-kV lines (but not for highest voltage power lines), with exception of sections where the total costs for the installation would increase the errection the overhead power lines by a factor of 2.75 (W. Böhmer, NABU Deutschland, pers. Comm.). This factor is often reached e.g. in mountainus areas.

5.2.2. Marking of power lines with bird diverters

Collision hazards can be greatly reduced through modifications to existing design standards. Beside underground cabling (which is a permanent solution for both electrocution and collision), the line markers represent the best available alternative.

Power line modification is the process where steps are taken to make a power line more visible to birds in flight. Marking the conductors and/or ground wires is the most common power line modification response by electric utility companies (ALONSO et al. 1994, APLIC 1994). On transmission lines, marking the ground wire has received particular focus because it appears to be the wire most often struck by birds in flight (SCOTT et al. 1972, WILLARD & WILLARD 1978, FAANES 1987). ALONSO et al (1994) found that both collisions and flight intensity decreased by 60% after shield wires were marked. BEAULAURIER (1981) summarised the results from 18 studies and found that, on average, marking the shield wires or conductors resulted in collisions decreasing by 45%. In Schleswig-Holstein, the installation of bird diverters on the ground wire resulted in a reduction of bird collision by 79% - 91%, depending on the species (JÖDICKE et al. 2018).

There are numerous types and variations of markers available on the market. There has been a tremendous amount of research conducted on marking power lines and the effectiveness of marking power lines, although few studies have been able to verify the actual effect of certain devices (e.g. BEVANGER & BRØSETH 2001). Marking with the wrong colour or wrong type of device may not be effective at solving the problem, and may become a maintenance problem for the power company or even cause lines to go down in extreme cases (BRIDGES & ANDERSON 2002). Therefore, it is imperative that effective devices are used to mark power lines.

A number of devices have shown good success and are recommended for the Danube climate: FireFly Bird Flapper / Flight Diverter (“Firefly”), Birdmark Afterglow, Bird Flight Diverter (BFD) and Bird Flappers (RIBE type) (Figure 14) https://birddiverter.eu/; http://www.hammarprodukter.com/; http://preformed.com/; https://www.ribe.de/en

Thanks to their ability to reflect UV light, bird diverters with a so-called afterglow effect have the advantage of being visible in low light conditions, when collisions are most common. The devices also glow at night for up to 10 hours and can therefore provide a visual cue to night migrants and other birds that are active at night.

Fig. 17: A wide range of bird diverters are available on the market to reduce bird collision with overhead power lines. Afterglow effects make them visible even during the night. © Clydesdale Ltd and Lucia Deutschová Raptor

All bird diverters presented provide a visual stimulus that helps birds to avoid collisions with power lines. Guidelines for the installation of bird diverters are available (e.g. VDE/FNN, 2014). Their maximum effect is achieved if they are installed every 10 metres.

Markers should be installed every 10 meters on the overhead ground wire(s). If more than one ground wire is present (or is a medium-voltage line), then markers are placed at 10-metre intervals, on alternating wires (FERRER M. & G. F. E. JANSS (1999; eds.).

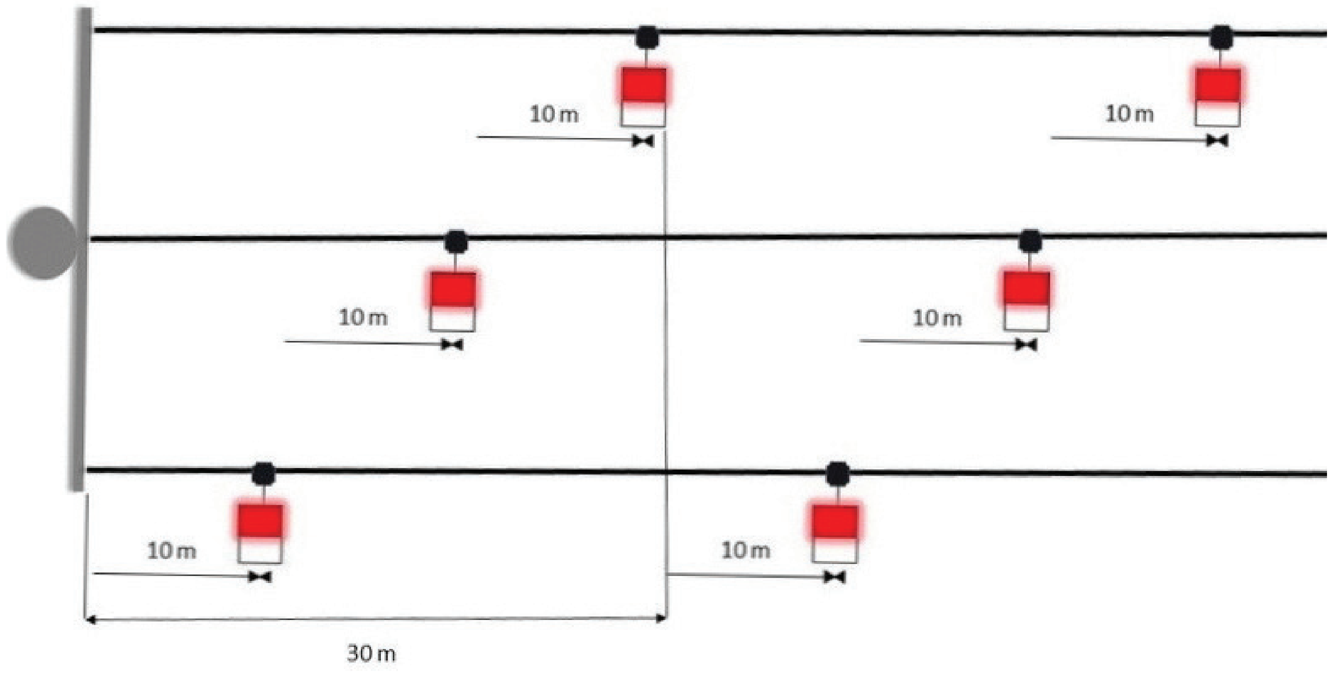


Fig. 18: Recommended placement method (10-metre intervals on alternating wires) for high effectiveness in reducing risk of bird collision with overhead electric lines.

Research is also under way to develop an affordable Bird Strike Indicator (BSI) and Bird Activity Monitoring (BAM) system to remotely detect and record collisions and electrocutions on a large scale. The Bird Strike Indicator (BSI) is an automated vibration-sensing and recording tool designed to detect bird strikes on overhead cables such as power lines and guy wires. It provides system operators the ability to affordably identify the most dangerous line segments and determine the effectiveness of line marking devices. The BSI uses accelerometers to record stress waves and vibrations caused by a bird strike. The BSI sensors are installed on the monitored wires and transmit strike activity wirelessly to a nearby base station, where the data is recorded.

Bird Activity Monitor (BAM) is an intelligent image-based sensing and recording tool to assist with detailed study of wildlife interactions with various types of structures. This device is able to capture, store, and transmit video images of the interaction of birds with power lines, communication lines, and other human made structures. BAMs can also efficiently monitor the impact of retrofitted power lines (HARNESS R., PANDEY A. , PHILLIPS G. 2003).

5.2.3. Deconstruction of power lines and removal of the ground wire

The removal of the ground wire for some transmission lines may be another possible mitigation option. In some situations, up to 90% of collisions with transmission lines may occur on the overhead ground wire because its smaller diameter makes it difficult to see in low light, fog and other poor visibility conditions. A study by BEVANGER & BRØSETH (2001) found that when the ground wire was removed, collisions decreased by half. Although a viable option for reducing collisions, ground wire removal will render the power line more susceptible to lightning damage (KURTZ & SHOEMAKER 1986). Therefore, removal of this wire is not always a viable option, especially in areas where lightning is common. Knowledge and cooperation are essential components in the search for viable solutions fully adapted to local situations.

5.2.4. Habitat modifications to minimise risk of collision

Habitat modification is an environmental management initiative that could be used in certain circumstances to reduce collision risks. There are two land modification options that can be considered:

1. Modify habitat near power lines to determine birds' flight paths. For example, plant trees that will grow close to or above the height of the power lines. This will cause birds to gain altitude to clear the treeline and subsequently also clear the power line.
2. Modify land use to reduce birds' activity around the power line. For example, create feeding habitat on the same side of the power line as roosting or nesting habitats so that birds have less reason to cross the power line.

However, habitat modification may not always be feasible. There could be legal, economic or conservation arguments against such modification. For example, it may not be desirable to modify habitat in areas with rare, sensitive or significant native habitats.

5.3. Technical solutions against electrocution

Apart from the possibility of abstaining completely from constructing a power line, as already discussed in 6.1.1, the following measures can be taken to protect birds against electrocution. These measures are listed in sequence according to their nature conservation value, i.e. measures mentioned first are to be given priority whenever possible!

5.3.1. Underground cabling

Underground cabling is the ultimate method of choice, as it completely and permanently excludes both electrocution and collision. However, this protective measure is expensive and difficult to implement in rocky terrain. The estimated cost is about 50–60 thousand Euro per kilometre for a 22 kV power line (M. Gális, pers. comm.). Nevertheless, in the interest of a permanent solution, underground cabling should always be considered and implemented as a matter of priority!

5.3.2. Primary surface solutions

We understand these solutions to be those that provide long-term and almost 100-percent protection. In practice, it has been shown that these protective fittings do not increase the maintenance work required by the system operator. Such solutions can either be (1) attached to the power cable itself or (2) to the pole construction.

In the first case, power line cables themselves can be completely insulated. These are then called aerial cables and do not pose any danger of electrocution to birds. However, aerial cables are relatively heavy and can therefore change the static requirements, so that a decision for this measure must be made early on in the planning phase.

In the second case, pylon heads can be redesigned or planned in such a way that they do not pose any danger of electrocution due to their dimensions. There are many publications addressing the distances even large birds can no longer overcome. These have also been incorporated into the VDE application rule (VDE/FNN 2014) from which we quote the following minimum dimensions and recommendations: Whenever possible, pylon constructions with suspension (hanging) insulators are to be carried out. In order to avoid (a) conductor-earth-contacts, perches for birds on earthed parts must be at least 0.6 m away from active parts that are not protected against direct contact. This minimum distance also applies to perches on active parts regarding earthed parts. In the case of earthed perches for birds below active parts not protected against direct contact, an additional vertical distance of 1.0 m must be maintained (i.e. 1.6 m in total). In order to avoid (b) conductor-conductor-contacts, the horizontal distance must be not less than 2.4 m for bird perches between the conductors (on overhead lines between parts not protected against direct contact).

5.3.3. Secondary surface solutions

Secondary solutions differ from primary solutions in that they require increased maintenance and are not 100-percent safe, at least over time. For example, extreme weather conditions or material fatigue can make the valves involved unusable and assembly errors can never be completely ruled out. However, protective measures such as bird protection hoods are a good means of making pylons safe by retrofitting.

In principle, the same safety distances must be observed as with primary measures (cf. 6.3.2). This means that there must be no potential perch below the bird protection cover in a vertical distance of 1.6 m.

However, bird protection hoods of at least 1.4 m in length are required (as 1.2 m turned out to be too short in some cases; W. Böhmer, NABU, pers. comm.), and they must be attached to the support insulators on medium-voltage lines.

Finally, completeness of the security measures must also be ensured. For example, it is not enough to install bird protection hoods only on a power line accompanying a railway power line. The upper cantilever tube must also be secured against electrocution of birds (if this is not already guaranteed by its construction, e.g. with a long rod insulator).

It is not possible to list all the options in this position paper, but it should be kept in mind that such measures can be highly complex. Bird protection hoods, hoses, cylinders, long rod insulators, ring grids, etc. are used for this purpose (one extreme example is the securing of a complex transformer). These must be planned for each individual case and reviewed by an expert!

5.3.4. Missing or unsuitable solutions

In principle we assume that, in a modern society, the negligent killing of birds and other animal species through human infrastructure is no longer acceptable. For this reason, there are already legal frameworks or voluntary agreements between operators and nature conservation organisations in many countries. Only absolutely safe solutions should be chosen in new constructions, and retrofitting must be carried out at least at "hotspots" within a reasonable and feasible period of time (< 5 years).

However, sometimes well-intended measures can prove to be ineffective or even counterproductive ("bad engineering"). We cannot deal with all eventualities here, but would like to illustrate this topic with two frequently occurring examples.

Example 1 concerns the Animal Guard, a deflector based on an electrostatic system. The mode of operation, a light electric shock, is not uncontroversial. While some authors do not expect any negative consequences for the bird's body due to the application of the Animal Guard for animal physiological reasons (IVIS 2015), NABU Germany has not been able to rule out secondary effects on the nervous system of bird individuals. In order to clarify this technical dispute, an experiment will be carried out in 2019 (W. Böhmer, pers. comm.). We cannot recommend a potentially dangerous deflector until this final clarification has been made.

Example 2 concerns technically provided perches. Repeatedly, supposedly more attractive bird perches are attached by the operators on pylon heads, which are either not accepted by the birds at all, or continue to bear a very high residual risk of electrocution. HAAS & SCHÜRENBERG (2008) give numerous examples where constructions of this type did not achieve the desired effect. It should be stated clearly here that solutions such as these can only be used in an emergency situation or in addition to others, and that they cannot replace safe insulation or, even better, a permanently safe conversion. Incidentally, the same thing can also happen in the opposite case, if an attempt is made to prevent landing by so-called spike deflectors. The latter are often ignored by birds and electrocution still occurs (see fig. 2 in BÖHMER & HAAS 2015).

6. DANUBE FREE SKY – a model for bird conservation at large rivers in Europe

In addition to national nature conservation laws, the Habitats Directive (92/43/EEC) ensures the conservation of a wide range of rare, threatened or endemic animal and plant species, and an additional approx. 200 infrequent and characteristic habitat types (http://ec.europa.eu/environment/nature/legislation/habitatsdirective). The Birds Directive (09/147/EEC) aims to protect all of the approx. 500 wild bird species naturally occurring in the European Union (http://ec.europa.eu/environment/nature/legislation/birdsdirective). An important part of these directives is the designation of Natura 2000 sites in order to ensure the conservation of Europe's natural heritage in this network of protected areas. Danube countries that are not yet members in the EU, such as Serbia, have adopted comparable legislation of their own.

The large number of Natura 2000 sites along the Danube river course is a clear commitment to the conservation of Europe's natural treasures on a continental scale.

The macro-regional strategy now provides a relatively new policy framework for the Danube region. The Danube Region Strategy addresses, within the Priority Areas 2 and 6, the topics of Sustainable Energy and Biodiversity & Landscapes, respectively. The energy Priority Area takes a three-fold approach, including the coordination of regional energy policies in order to exploit the full potential of an integrated energy market, the integration of the energy markets of the non-EU countries, and to launch cutting-edge technology developments, to increase the energy efficiency of the region and enhance the use of renewable energy sources. The targets of Priority Area 6 are four-fold: to achieve a significant and measurable improvement, adapted to the special needs of the species and habitats covered by the EU nature legislation in the Danube Region, to enhance the work on establishing green infrastructure and the process of restoration of at least 15% of degraded ecosystems by 2020, to identify and prioritise invasive alien species and their pathways in order to control or eradicate priority species, and to continue the ongoing work and efforts to securing viable populations of Danube sturgeon species and other indigenous fish species (https://www.danube-nature.eu).

DANUBE FREE SKY is supported by the EU Strategy for the Danube Region. Both Priority Area 2 "Sustainable Energy" and Priority Area 6 "Biodiversity and Landscape" consider this initiative as a good example for cross-sector cooperation and as a concrete contribution to bird conservation along power lines through innovative technical solutions.
Furthermore, DANUBE FREE SKY aims to contribute to raise awareness for this issue and to contribute with concrete actions to the Bonn and Bern Conventions and the Biodiversity Strategy 2020.
Despite the clear indication that large rivers are priority areas for bird conservation along power lines, DANUBE FREE SKY is a first unique initiative on a river-wide scale.
The awareness raised across borders and across sectors initiated a strategic approach and resulted in harmonised and step-by-step implementation of conservation actions.
At the DANUBE FREE SKY conference in Tulcea (September 2019), possible future cooperations were developed together with BirdLife International.
The DANUBE FREE SKY position paper is now an appeal for full implementation of bird conservation on power lines along the Danube river and should set standards for all other large rivers in Europe.

7. Acknowledgements

We are grateful to have been given the opportunity to write this position paper, within the framework of the DANUBEparksCONNECTED project, funded by the Interreg Danube Transnational Programme. M. Gális was part of the expert team for the assessment of the dangerousness of power pylons. D. Mašić was responsible for the GIS analysis, R. Prinz provided illustrative maps. However, it would have been impossible to produce this strategic document without the input of many experts from the Danube countries, and we would like to thank them most sincerely (and in alphabetical order): S. Aberle, S. Blutaumüller, W. Böhmer, Gy. Bíró, J. Chavko, S. Cheshmedjiev, G. Cretu, A. Fersch, A. Froncova, S. Geißler, L. Deutschová, D. Dobrev, V. Ečimović, E. Hapl, H. Herzig, Z. Hegyi, D. Hulea, V. Josipović, R. Kazi, Gy. Kiss, J. Klarić, Z. Kovács, M. Malenica, G. Morozov, T. Mikuška, I. Munteanu, E. Neuling, T. Papp, T. Parrag, E. Petkova, M. Popić, J. Rašić, V. Rožac, M. Ružić, T. Schneider, A.Tomik, B. Tóth, M. Tucakov, J. Šmíd, H. Stotz, S. Rakic, D.Varga , O. Wieding and M. Zec. Finally, we are grateful to B. Seaman for the proofreading.

In particular, our acknowledgements refer to all experts in the energy sector. The fruitful cooperation with numerous transmission system operators, and their efforts to plan, to prepare and to implement the many different pilot actions within the framework of DANUBE FREE SKY, were the main source of experiences gained.

8. Literature

ALLAN J. D. & A. S. FLECKER (1993): Biodiversity conservation in running waters. Bioscience 43: 32-43.

ALONSO, J.C., ALONSO, J.A. and MUÑOZ-PULIDO, R. 1994. Mitigation of bird collisions through groundwire marking. Biological Conservation 67:129 – 134.

ANDREWS A. (1990): Fragmentation of habitat by roads and utility corridors: a review. Austral. Zoologist 26: 130-141.

APLIC (Avian Power Line Interaction Committee; 1994): Mitigating Bird Collisions with Power Lines: The State of the Art in 1994. Edison Electric Institute (EEI). Washington, D.C. 78p.

APLIC (Avian Power Line Interaction Committee; 2006): Suggested practices for avian protection on power lines: the state of the art 2006. Edison Electric Institute, APLIC, and the California Energy Commission, Washington, DC and California, CA U.S.A.

BEAULAURIER, D. 1981. Mitigation of bird collisions with transmission lines. Bonneville Power Administration, US Department of Energy, Boulder, Colorado. 83p.

BENÍTEZ-LÓPEZ, A., Alkemade R. and Verweij P. A. (2010): The impacts of reoads and other infrastructure on mammal and bird populations: A meta-analysis. Biological Conservation 143: 1.307-1.316.

BEVANGER K. (1994): Bird interactions with utility structures: collisions and electrocution, causes and mitigating measures. Ibis 136: 412-425.

BEVANGER K. (1997): Biological and conservation aspects of bird mortality caused by electricity power lines: a review. Biological Conservation 86: 67-76.

BEVANGER, K. and BRØSETH, H. 2001. Bird Collisions with power lines - an experiment with ptarmigan (Lagopus spp.). Biological Conservation 99: 341 – 346.

BÖHMER W. & D. HAAS (2015): Stromtod von Vögeln – Lösungsansätze auf nationalem und internationalem Niveau. Orn. Mitt. 67: 287-290.

BRIDGES, J.M. and ANDERSON, T.R. 2002. Mitigating the impacts of electric facilities to birds. Environmental Concerns in Rights-of-Way Management: Seventh International Symposium. © 2002 Elsevier Science Ltd. pp. 389 – 393.

D'Amico M., Catry I., Martins R. C., Ascensão F., Barrientos R. & Morieira F. (2018): Bird on the wire: Landscape planning considering costs and benefits for bird populations coexisting with power lines. Ambio, https://doi.org/10.1007/s13280-018-1025-z und Pérez-García J. M., DeVault T., Botella F. & Sánchez-Zapata J. A. (2018): Using risk prediction models and species sensitivity maps for large-scale identification of infrastructure-related wildlife protected areas: The case of bird electrocution. Biological Conservation 210, 334-342.

DAVIS P. M. (2010): Climate change implications for river restoration in global biodiversity hotspots. Restoration Ecol. 18: 261-268.

DEMERDZHIEV D. A. (2014): Factors influencing bird mortality caused by power lines within special protected areas and undertaken conservation efforts. Acta zool. Bulg. 66: 411-423.

Demeter I., Horváth M., Nagy K., Görögh Z., Tóth P., Bagyura J., Solt S., Kovács A., Dwyer J. F. & R. E. Harness (2018): Documenting and reducing avian electrocutions in Hungary: a conservation contribution from citizen scientists. The Wilson Journal of Ornithology 130, 600-614.

DREWITT A. L. & R. H. W. LANGSTON (2008): Collision effects of wind-power generators and other obstacles on birds. New York Academy of Science 1.134: 233-266.

DUDGEON D., ARTHINGTON A. H., GESSNER M. O., KAWABATA Z-I., KNOWLER D. J., LÉVÊQUE C., NAIMAN R. J., PRIEURRICHARD A.-H., SOTO D., STIASSNY M. L. J. & C. A. SULLIVAN (2006): Freshwater biodiversity: importance, threats, status and conservation challenges. Biol. Rev. 81: 163-182.

ELLIOTT A., CHRISTIE D. A., JUTGLAR F., GARCIA E. F. J. & G. M. KIRWAN (2018a). Great White Pelican (Pelecanusonocrotalus). In: DELHOYOJ., ELLIOTTA., SARGATALJ., CHRISTIED. A. & E.DEJUANA (eds.): Handbook of the Birds of the World Alive. Lynx Edicions, Barcelona. (retrievedfrom https://www.hbw.com/node/52610 on 17 January 2018).

ELLIOTT A., CHRISTIE D. A., JUTGLAR F., KIRWAN G. M. & C. J. SHARPE (2018b). Dalmatian Pelican (Pelecanuscrispus). In:DELHOYOJ., ELLIOTTA., SARGATALJ., CHRISTIED. A. & E.DEJUANA (eds.):Handbook of the Birds of the World Alive. Lynx Edicions, Barcelona. (retrievedfrom https://www.hbw.com/node/52613 on 17 January 2018).

FAANES, C.A. 1987. Bird behavior and mortality in relation to power lines in prairie habitats. Fish and Wildlife Technical Report 7. United States Department of the Interior Fish and Wildlife Service. 24p.

FERRER M. & G. F. E. JANSS (1999; eds.): Birds and power lines. Collision, electrocution and breeding. Quercus, Madrid, 240 pp.

FERRER M. (2012): Birds and power lines. From conflict to solution. ENDESA S.A and Fundacion MIGRES, Sevilla, 182 pp.

Fidlóczky J., Bagyura J., Nagy K., Tóth P., Szitta T. & L. Haraszthy (2014): Bird conservation on electric-power lines in Hungary: Nest boxes for saker falcon and avian protection against electrocutions. Projects' report. Slovak Raptor Journal 8: 87-95.

GÁLIS M., DEUTSCHOVÁ L., ŠMÍDT J., HAPL E. & J. CHAVKO (2016): Vysoká cena za pohodlie alebo rizikovosť elektrických vedení pre voľne žijúce druhy vtákov In: KRUMPÁLOVÁ Z., ZIGOVÁ M. & F. TULIS (eds.): Zoológia 2016. Zborník príspevkov z vedeckého kongresu, Nitra. 24.-26. November 2016.

GÁLIS M., DEUTSCHOVÁ L., ŠMÍDT J., HAPL E. & J. CHAVKO (2017): Vplyv konštrukčného prevedenia konzolystĺpu 22 kV a jej ošetrenia na úmrtnosť vtákov. In: BRYJA J., HORSÁK M., HORSÁKOVÁ V., ŘEHÁK Z. & J.ZUKAL (eds.): Zoologické dny Brno 2017. Sborník abstraktů z konference 9.-10. února 2017.

Gerdzhikov G. P. & D. A. Demerdzhiev (2009): Data on bird mortakity in „Sakar" IBA (BG021), caused be hazardous power lines. Ecologia Balkanica 1: 67-77.

GORIUP P., BABOIANU G. & J. CHERNICHKO (2007): The Danube Delta: Europe's remarkable wetland. British Birds 100: 194-213.

Guil F., Colomer M. Á. Moreno-Opo R. & A. Margalida (2015): Space-time trends in Spanish bird electrocution rates from alternative information sources. Global Ecology and Conservation 3: 379-388.

HAAS D. & B. SCHÜRENBERG (2008; Hrsg.): Stromtod von Vögeln. Grundlagen und Standards zum Vogelschutz an Freileitungen. Stand der Erkenntnisse, Gesetzliche Vorgaben, Internationale Abkommen,Weltweiter Handlungsbedarf. Ökologie der Vögel, Band 26, 304 S.

HARNESS R., PANDEY A. , PHILLIPS G. (2003): Bird Strike Indicator/Bird Activity Monitor and

Field Assessment of Avian Fatalities, EPRI, Palo Alto, CA, Audubon National Wildlife Refuge, Coleharbor, ND, Edison Electric Institute, Washington, DC, Bonneville Power Administration, Portland, OR, California Energy Commission, Sacramento CA, NorthWestern Energy, Butte, MT, Otter Tail Power Company, Fergus Falls, MN, Southern California Edison, Rosemead, CA, Western Area Power Administration, Lakewood, CO: 2003.

HECK, N. S. (2007): Firefly bird flight diverter: durability testing. Unpublished study. AltaLink Management Ltd.

HOHENEGGER J. A. (2014): Anthropogen verursachte, kollisions- und elektrokutionsbedingte Verluste bei Vögeln (Aves). Am Beispiel einer Bahnstrecke im nördlichen Niederösterreich. Fachbereichsar-beit aus Biologie und Umweltkunde, Bundesgymnasium Horn, 48 Seiten und zusätzliche Tab.-Blätter.

ICPDR (2016): Sturgeon 2020. A program for the protection and rehabilitation of Danube sturgeons. ICPDR, Danube Sturgeon Task Force & Danube Region strategy, Vienna International Centre, 24 pp.

IVIS (2015): Verifizierung und Berechnung des Animal Guard für 15 kV und 16,7 Hz. – Gutachten des Instituts für Verkehrsinfrastruktur im Auftrag der ÖBB-Infrastruktur AG, Luzern, 33 S.

JANSS G.E.F. (1999): Avian mortality from power lines: a morphologic approach of a species-specific mortality. Biological Conservation 95: 353-359.

Jödicke K., Lemke H. & M. Mercker (2018): Wirksamkeit von Vogelschutzmarkierungen an Erdseilen von Höchstspannungsleitungen. Naturschutz und Landschaftsplanung 50, 286-294.

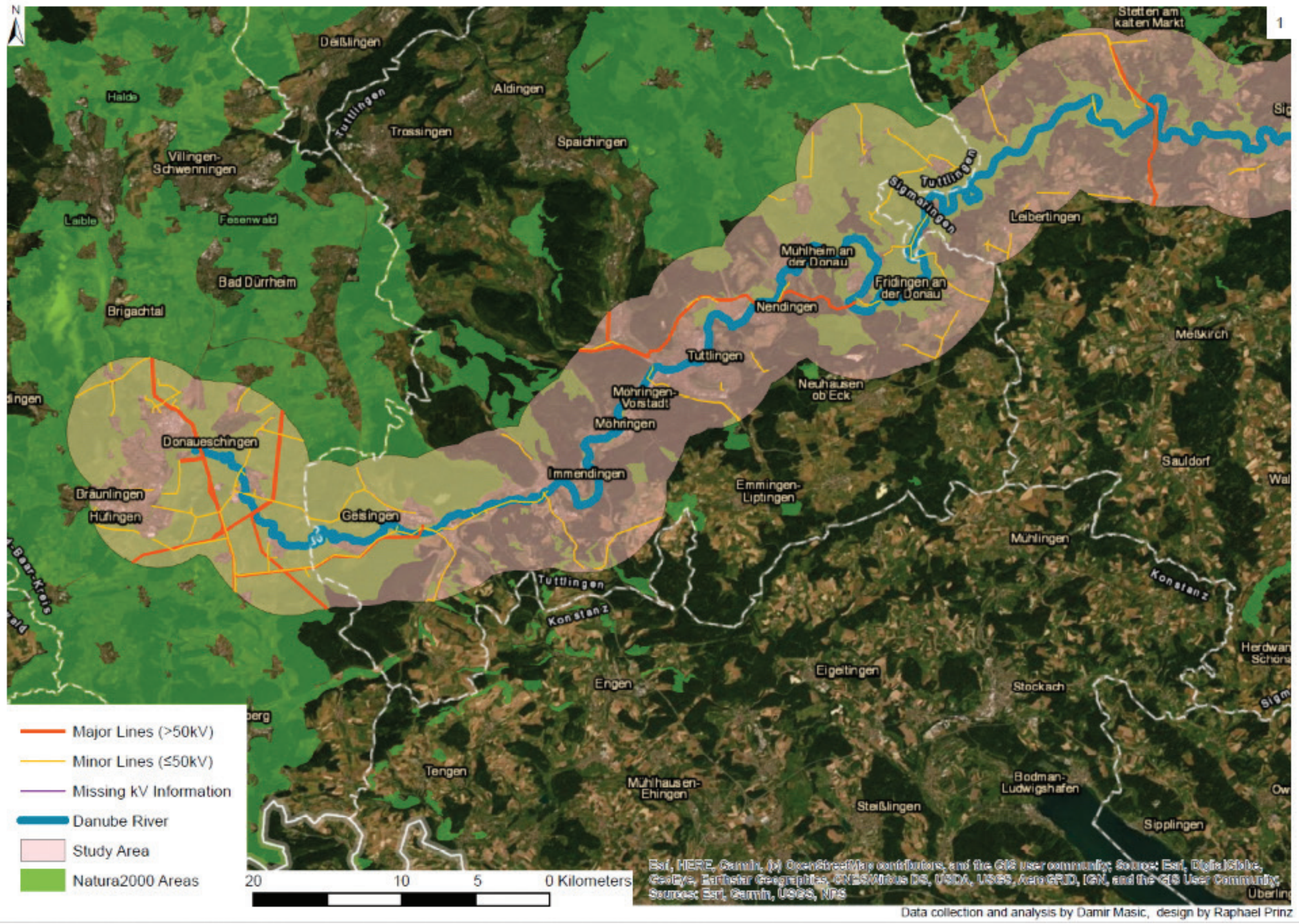
KARYAKIN I. V. (2012): Birds of prey and power lines in Northern Eurasia: What are the prospects of survival? Raptors Conservation 24: 69-85.

KISS J.B. & MARINOV M. (1977): Vagelunfalle an Telefonleitungen.Vogel der Heimat. vol.48 no.9, pp.196-197.
Kear, J. (2005; ed.): Ducks, Geese and Swans.Oxford University Press, Oxford.
KURTZ, E.B. & SHOEMAKER, T.M. (1986): The Lineman's and Cableman's handbook. 7th Edition. McGraw Hill, Inc.
LOSS S. R., WILL T. & MARRA P. P. (2014): Refining estimates of bird collision and electrocution mortality at power lines in the United States. https://doi.org/10.1371/journal.pone.0101565
MARINOV M., POGAN T., DOROŞENCU A., NICHERSU I, ALEXE V., TRIFANOV C., BOZAGIEVICI R., TOŠIĆ K. & J. B. KISS (2016a): Monitoring the Great White Pelican (Pelecanus onocratolus Linnaeus, 1758) breeding population using drones in 2016 – the Danube Delta (Romania). Scientific Annals of the Danube Delta Institute 22: 41-52.
MARINOV M., DOROŞENCU A., ALEXE V., NANU C. & J. B. KISS (2016b): New nesting site for Dalmatian Pelican (Pelecanus crispus) in a polyspecific colony of aquatic birds on Taşaul Lake (Romania). Scientific Annals of the Danube Delta Institute 22: 53-60.
MIKUSKA J. & T. MIKUSKA (1994): Birds of the Danube valley in Croatia. Anali Zavoda za znanstveni rad u Osijeku, HAZU 10: 1-181.
MYERS N., MITTERMEIER R. A., MITTERMEIER C. G., DA FONSECA G. A. B. & J. KENT (2000): Biodiversity hotspots for conservation priorities. Nature 403: 453-458.
NEMESHÁZI E., KÖVÉR S., ZACHOS F. E., HORVÁTH Z., TIHANYI G., MÓROCZ A., MIKUSKA T., HÁM I., LITERÁK I., PONNIKAS S., MIZERA T. & K. SZABÓ (2016): Natural and anthropogenic influences on the populationstructure of white-tailed eagles in the Carpathian Basin and central Europe. J. Avian Biol. 47: 1-11.
NEWTON I. (2010): The migration ecology of birds. Academic Press, London, 598 pp.
Pérez-García J. M., DeVault T., Botella F. & Sánchez-Zapata J. A. (2018): Using risk prediction models and species sensitivity maps for large-scale identification of infrastructure-related wildlife protected areas: The case of bird electrocution. Biological Conservation 210, 334-342.
PRINSEN H. A. M., BOERE G. C., PÍRES N & J. J. SMALLIE J. J. (2011): Review of the conflict between migratory birds and electricity power grids in the African-Eurasian region. CMS & AEWA Technical Series, Bonn, 115 pp.
PROBST R., BODEGA L., BANDACU D. S. , BOHUŠ M., CHESHMEDZHIEV S., GÁBORIK Á., GEISSLER S., HODOR C. V., IONESCU D. T., KOEV V., MIKUSKA T., NAGY Z., PARRAG T., ROŽAC V., SCHMIDT M., SCHNEIDER T.,ŠĆIBAN M., TATAI S., TODOROV E., TUCAKOV M., VÁCZI M. & G. FRANK (2014): The first comprehensive estimate of winter population of the White-tailed Eagle Haliaeetus albicilla along the Danube. Acrocephalus 35: 115-123.
Rioux, S., J.-P. L. Savard, and A. A. Gerick (2013): Avian mortalities due to transmission line collisions: a review of current estimates and field methods with an emphasis on applications to the Canadian electric network. Avian Conservation and Ecology 8(2): 7.
SÁNDOR A. D., MĂRCUȚAN D. I., D'AMICO G., GHERMAN C. M., DUMITRACHE M. O. & A. D. MIHALCA (2014): Do the ticks of birds an important migration hotspot reflect the seasonal dynamics of Ixodus ricinus at the migration initiation site? A case study in the Danube Delta. PLoS ONE 9(2): e89378. https://doi.org/10.1371/journal.pone.0089378.
SCOTT, R.E., L.J. ROBERS, and C.J. CADBURY. 1972. Bird deaths from power lines at Dungeness. British Birds 65: 273 - 286.
SERGIO F., MARCHESI L., PEDRINI P., FERRER M. & V. PENTERIANI (2004): Electrocution alters the distribution and density of a top predator, the eagle owl Bubo bubo. J. Applied Ecol. 41: 836-845.
SOULÉ M. E. (1991): Conservation: tactics for a constant crisis. Science 253: 744-750.
STANČIK A. & S. JOVANOVIČ (1988; eds.): Hydrology of the river Danube. Publishing House Pritoda, Bratislava, 272 pp.
SÜDBECK P., ANDRETZKE H., FISCHER S., GEDEON K., SCHIKORE T., SCHRÖDER K. & C. SUDFELDT (2005): Methodenstandards zur Erfassung der Brutvögel Deutschlands. Radolfzell, 792 S.
TNL UMWELTPLANUNG (2014): Vogel-Kollisionsopfer an Hoch- und Höchstspannungsfreileitungen in

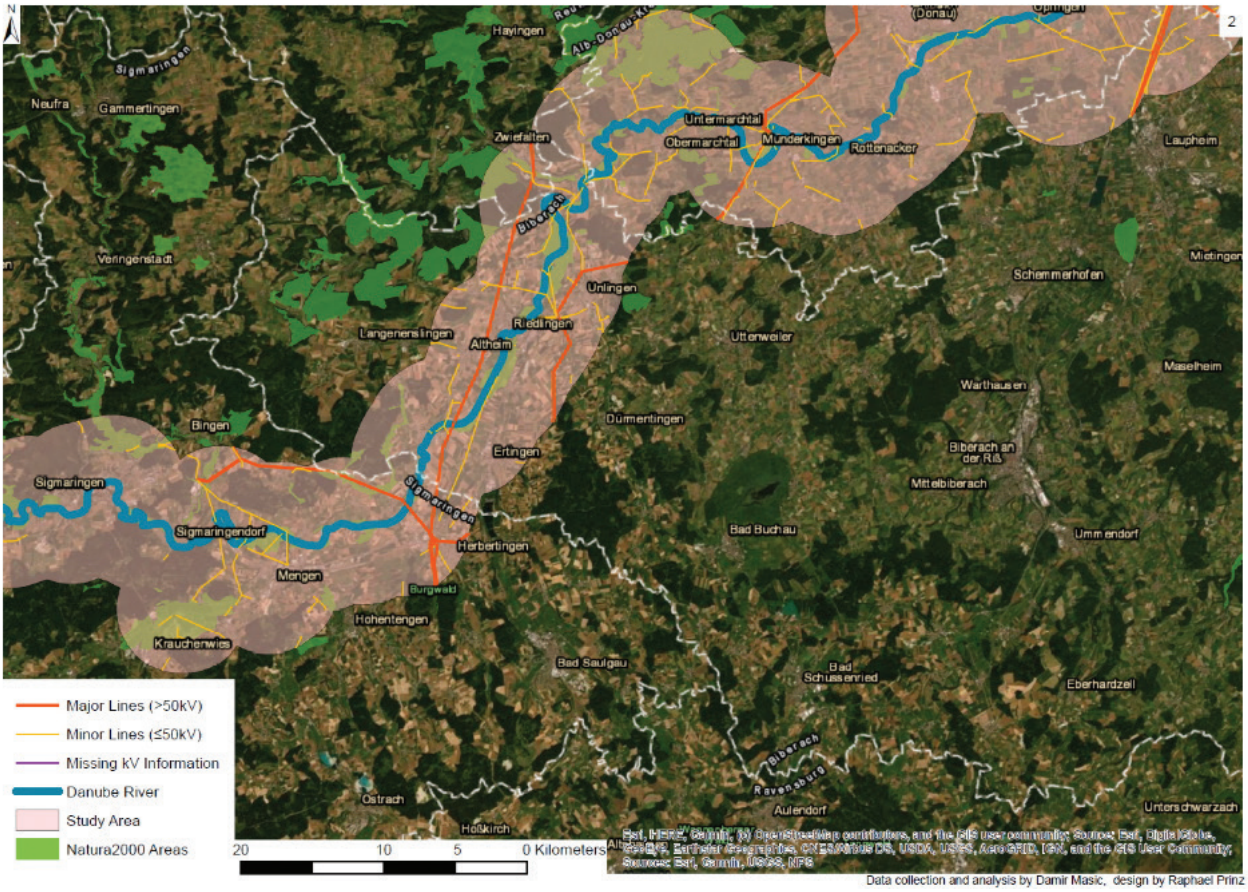
Deutschland – ein Abschätzung. Bericht von TNL Umweltplanung an den NABU – Naturschutzbund Deutschland e. V., Hungen, 34 S.
TUCAKOV M., KALOCSA B., MIKUSKA T., TAMAS E. A., ŽULJEVIĆ A., ERG B. & T. DEME (2006): The Black stork Ciconia nigra between the Sio and the Drava River in the central Danube floodplain: Transboundary monitoring and protection plan. Biota 7: 109-118.
VASIĆ V. (1997): Hiljade lica Dunava. Futura 1: 62-88.
VDE/FNN (2014): Vogelschutzmarkierungen an Hoch- und Höchstspannungsleitungen. Forum Netztechnik/Netzbetrieb im VDE, Berlin, 39 S.
WARD J. V., TOCKNER K. & F. SCHIEMER (1999): Biodiversity of floodplain river ecosystems: ecotones and connectivity. Regul. Rivers: Res. Mgmt. 15: 125-139.
WILLARD, D. E. & WILLIARD, B. J. (1978): The interaction between some human obstacles and birds. Environmental Management 2 (4): 331 – 340.
Zec M. & I. Katanović (in prep.): Mitigation of bird electrocution in Croatia – a pragmaic approach.

Annex 1

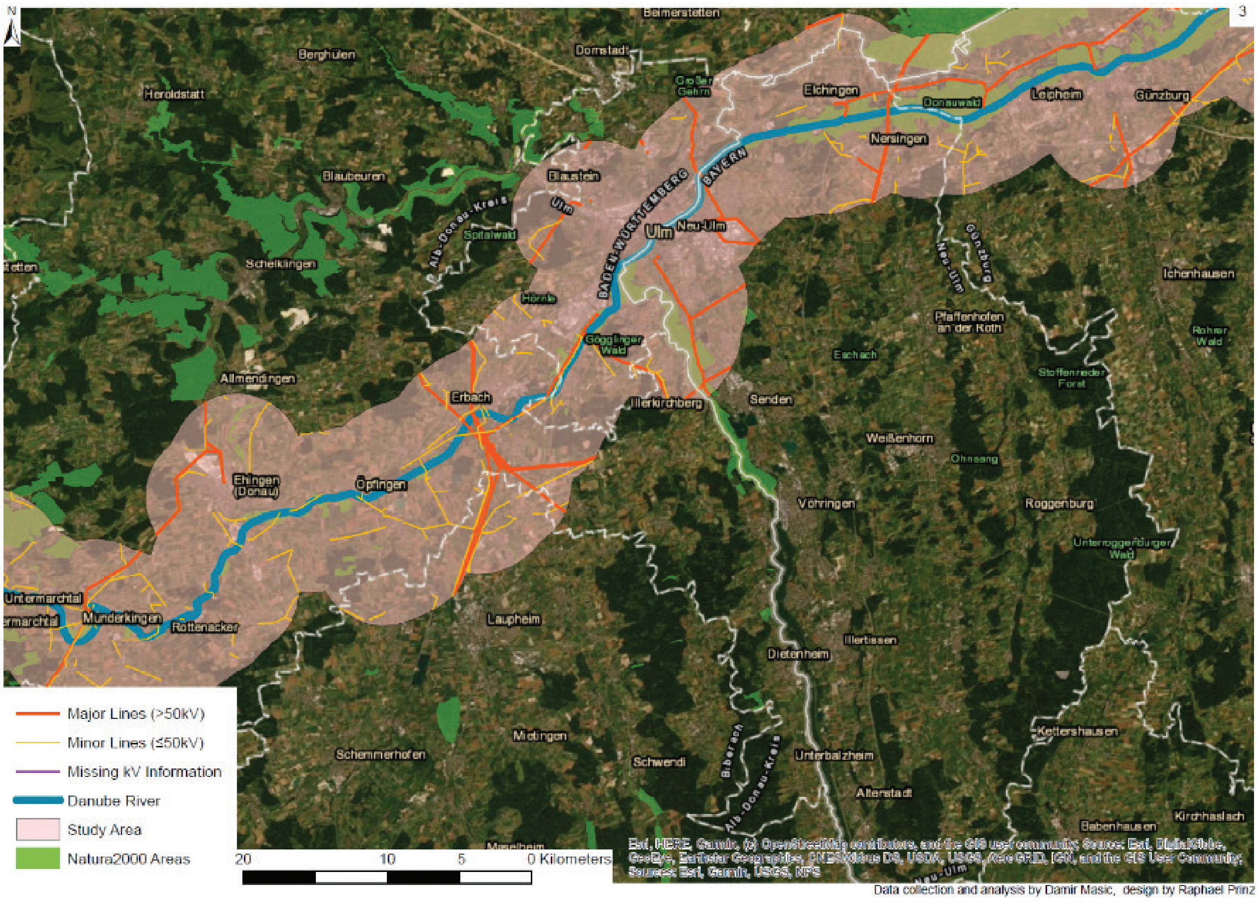
Danube-wide inventory of power lines along the Danube river



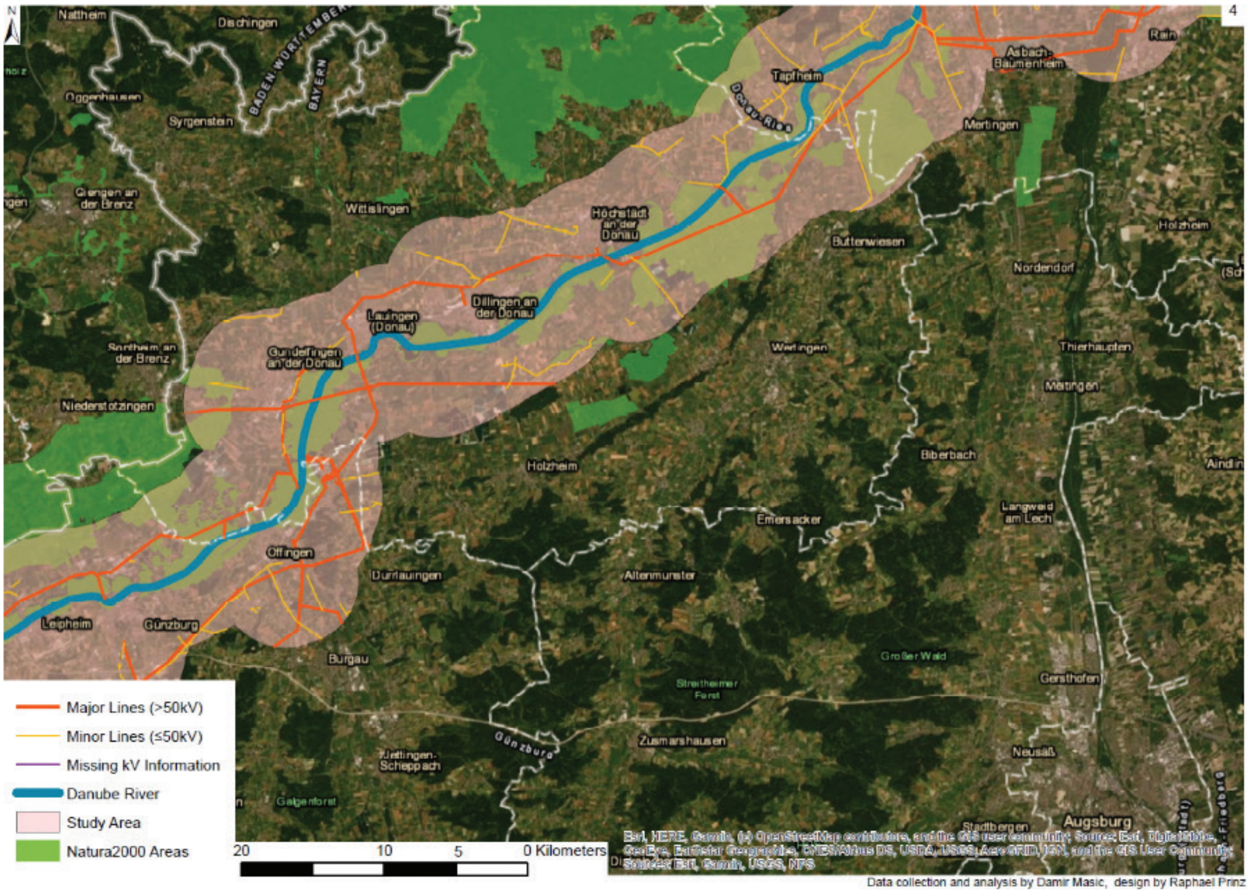
Map 1 (Germany): Donaueschingen – Sigmaringen



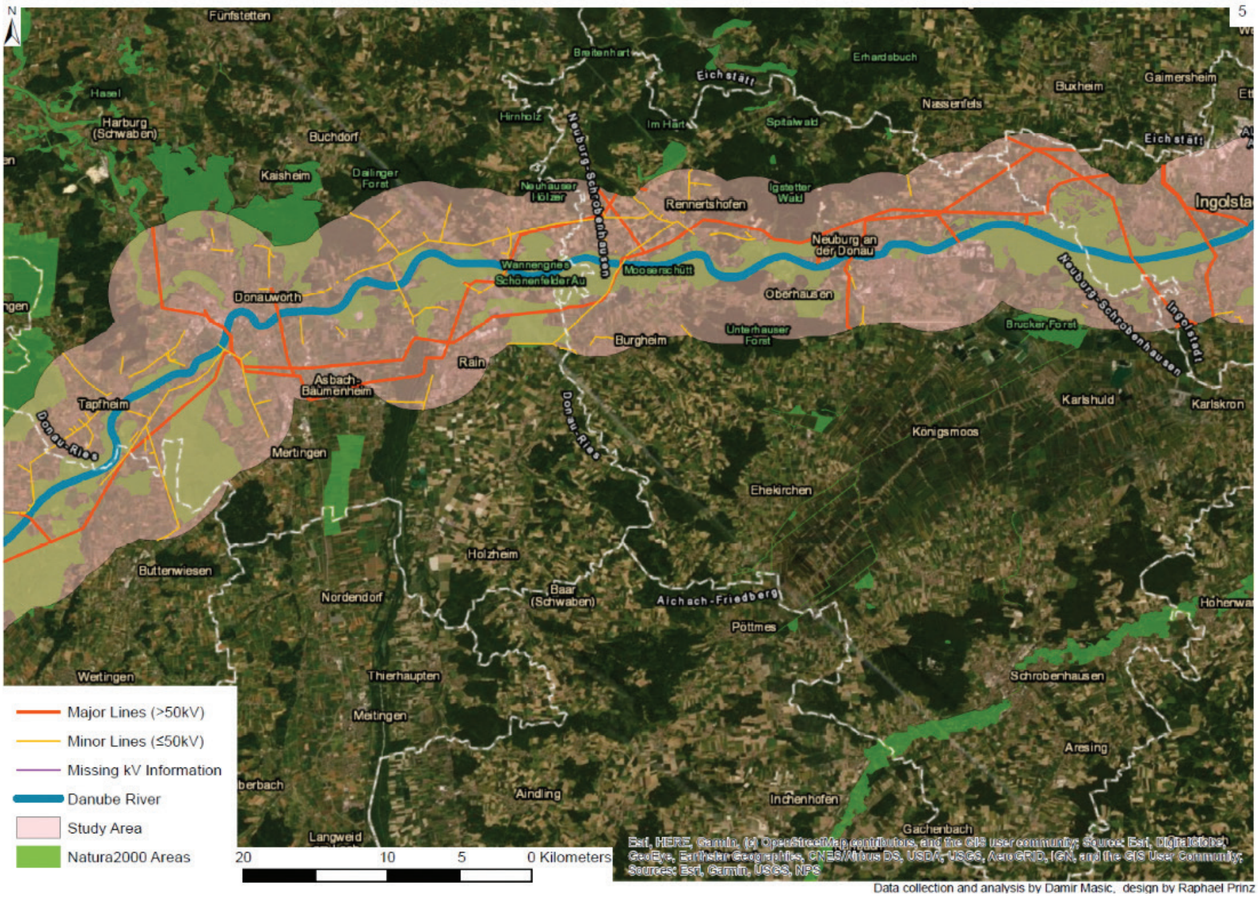
Map 2 (Germany): Sigmaringen - Ehingen



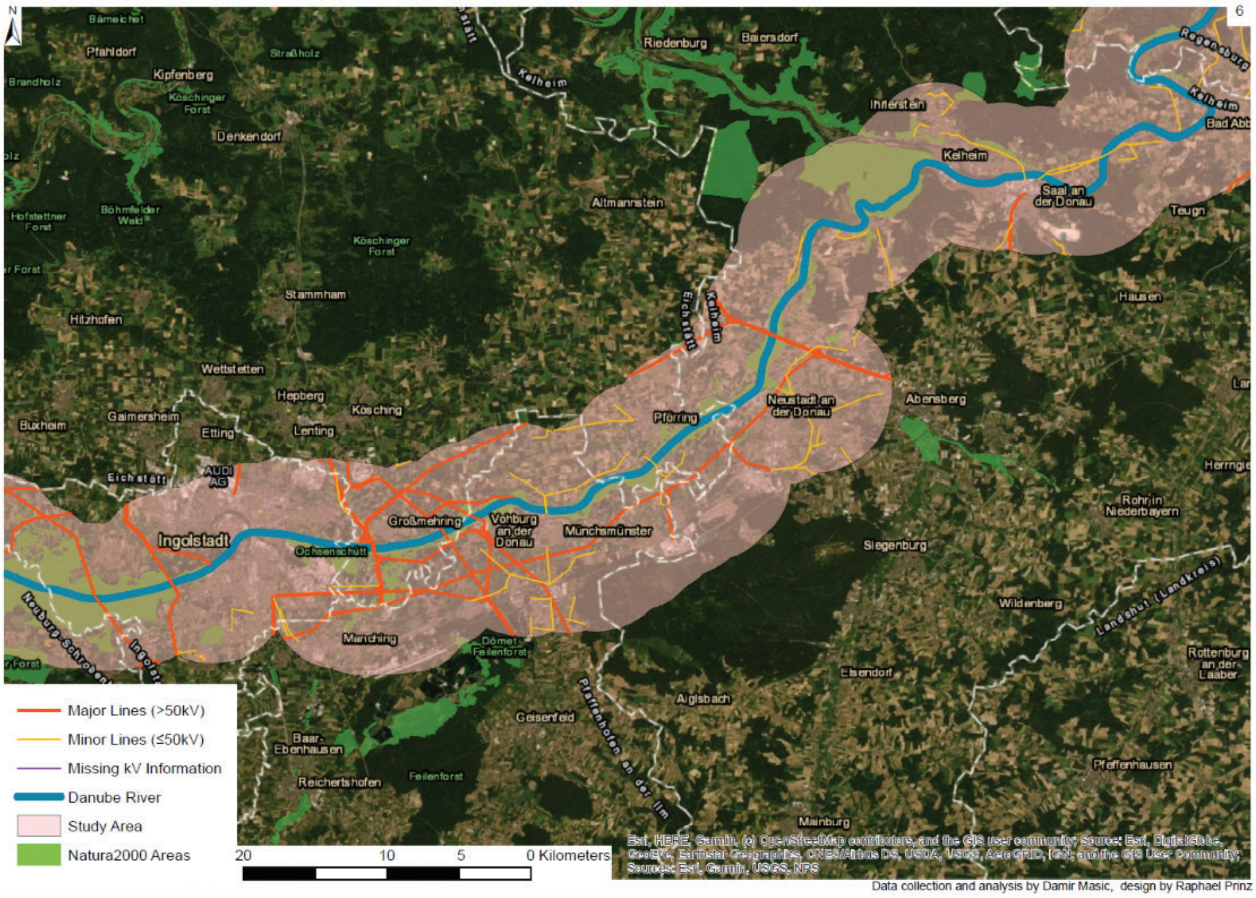
Map 3 (Germany): Ulm



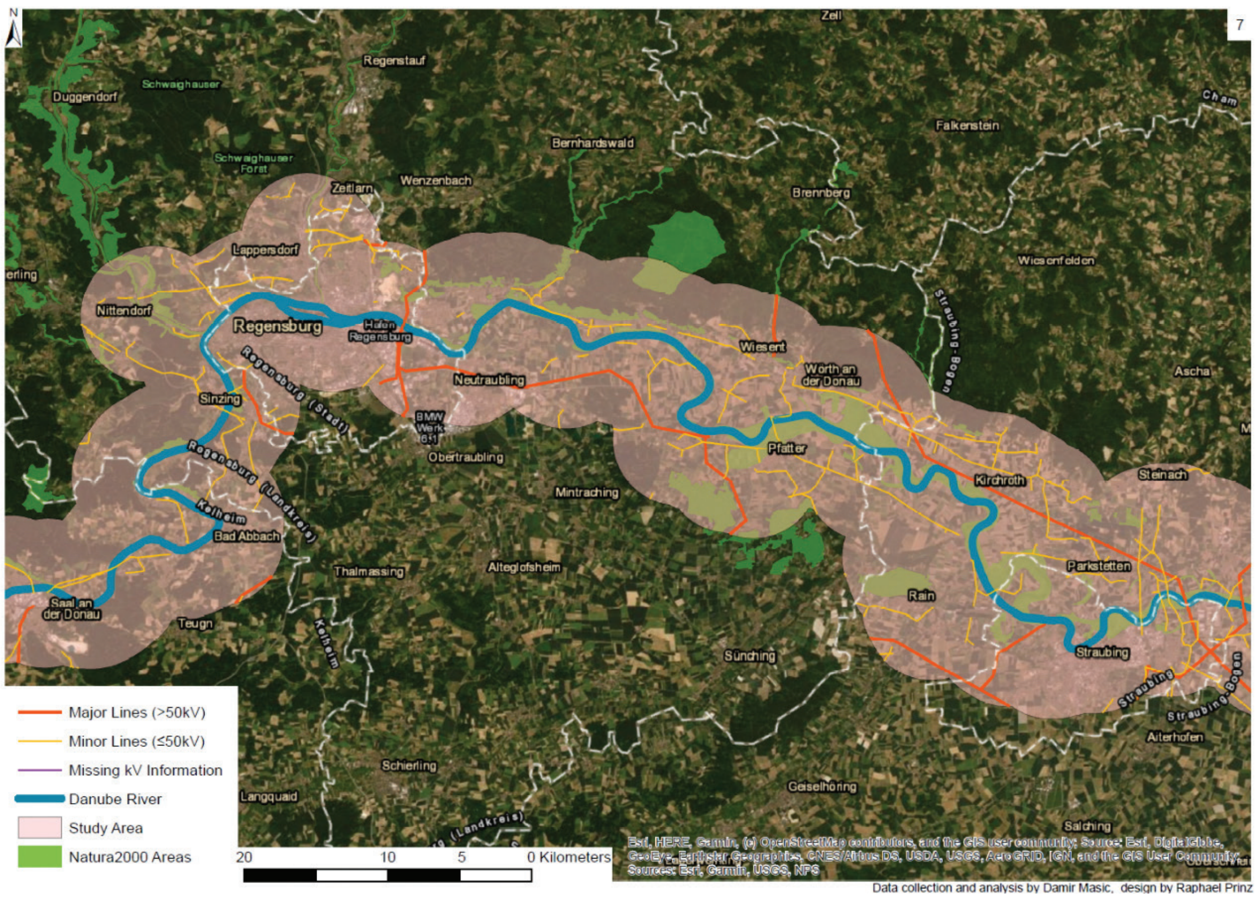
Map 4 (Germany): Leipheim – Tapfheim



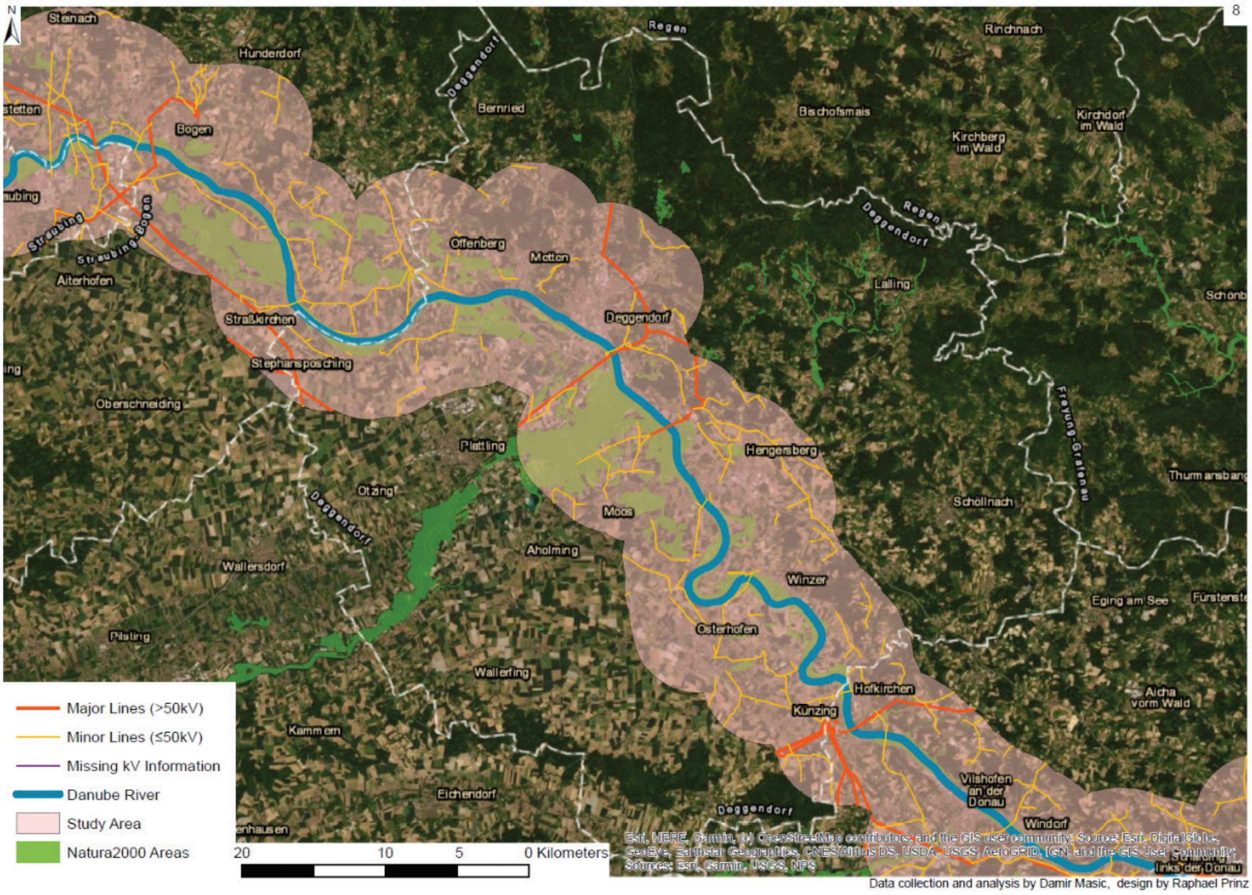
Map 5 (Germany): Donauwörth – Neuburg – Ingolstadt



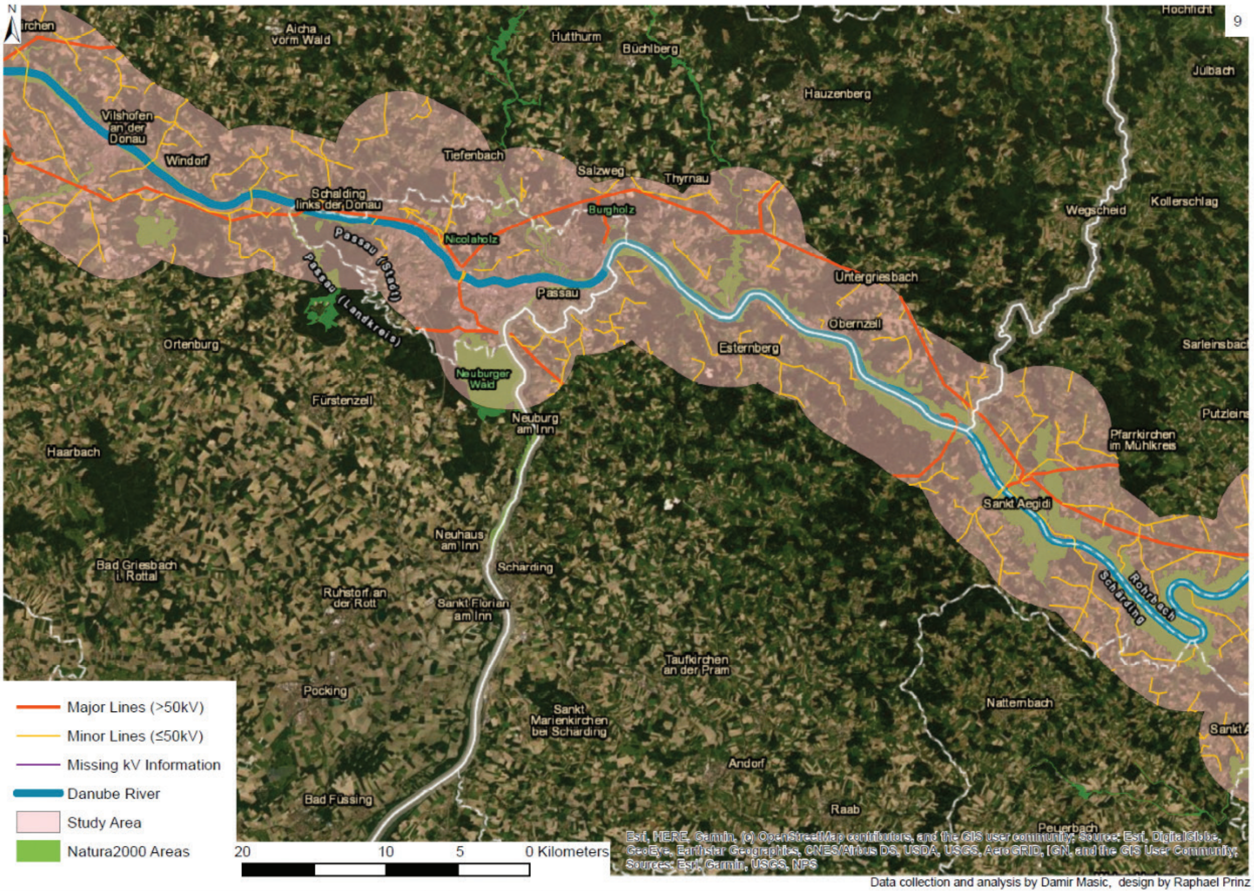
Map 6 (Germany): Ingolstadt – Saal an der Donau



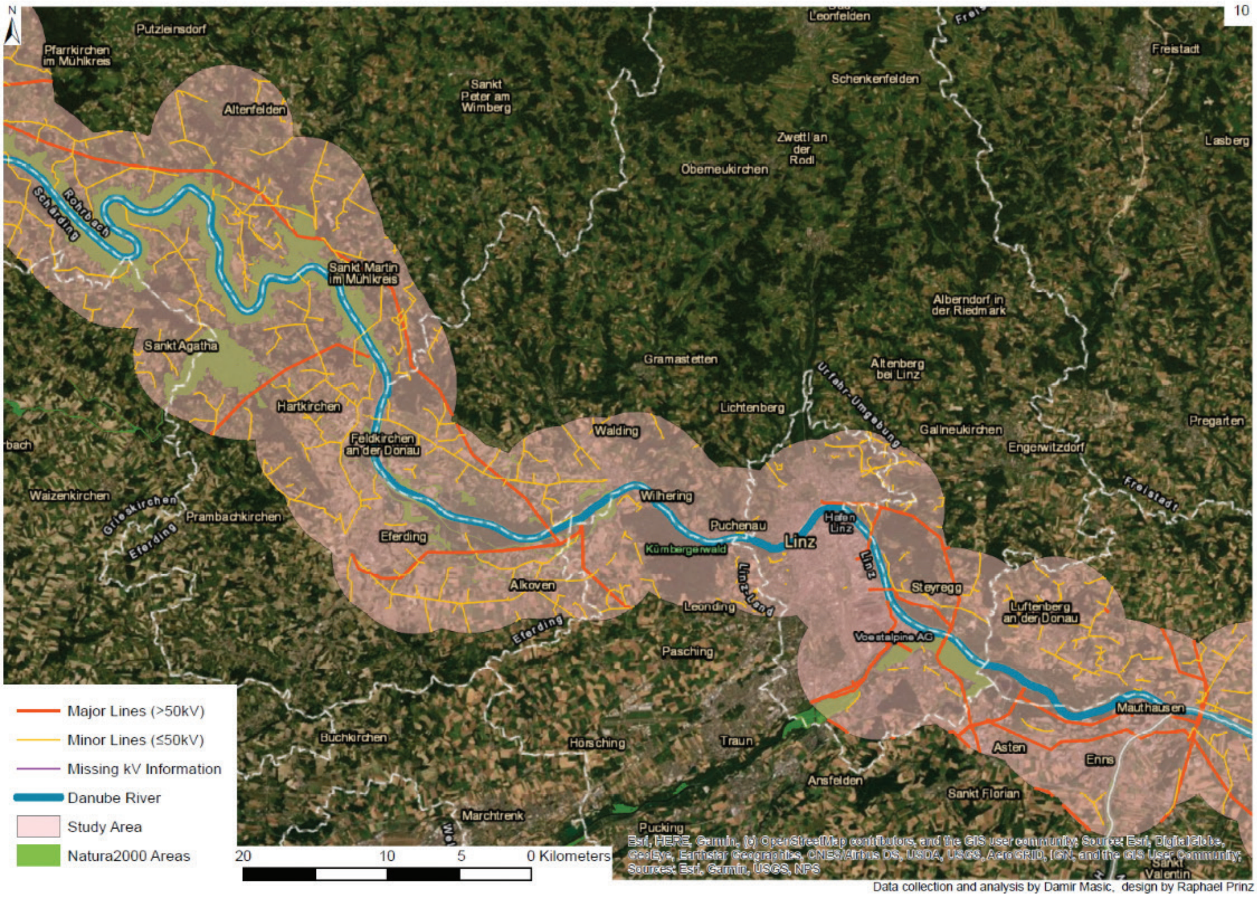
Map 7 (Germany): Saal an der Donau - Regensburg – Straubing



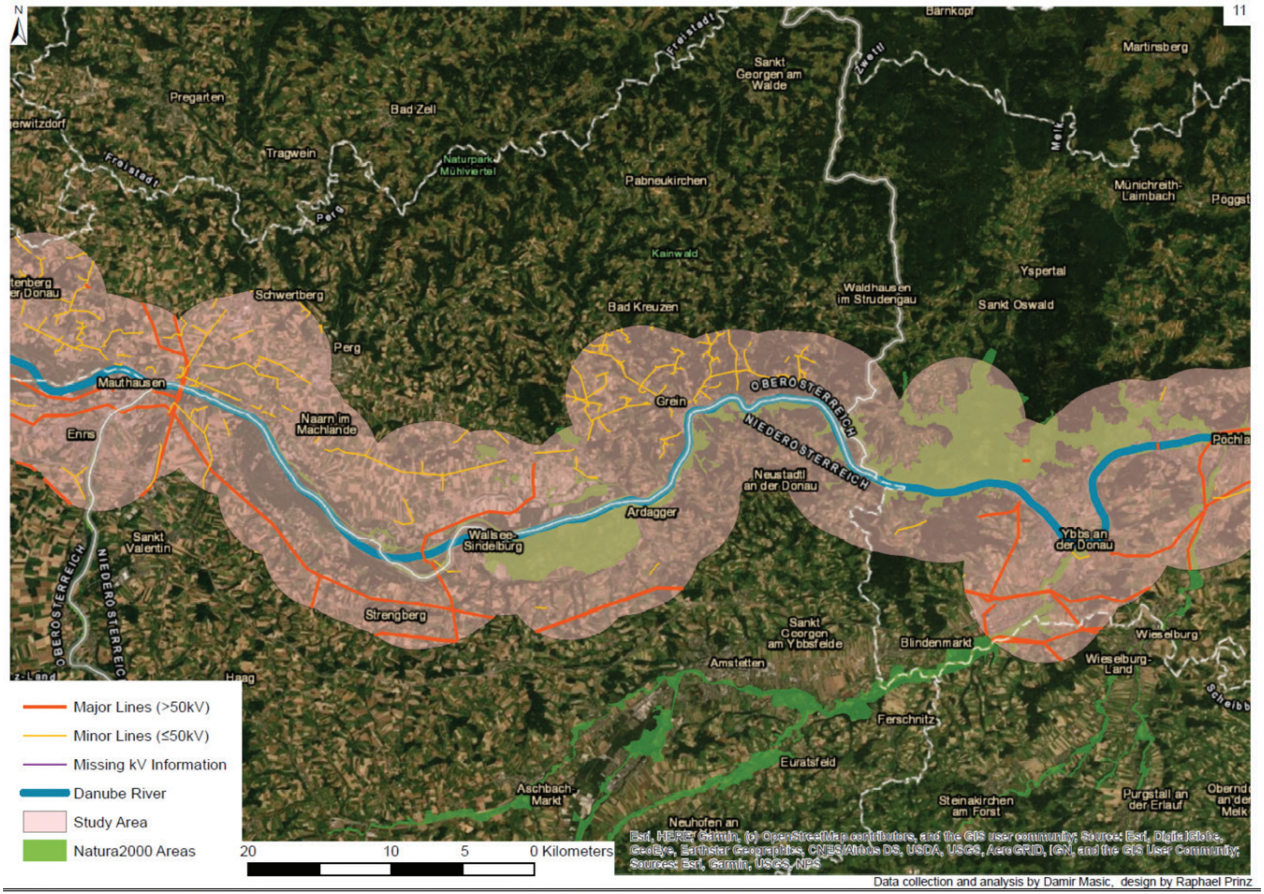
Map 8 (Germany): Straubing - Vilshofen



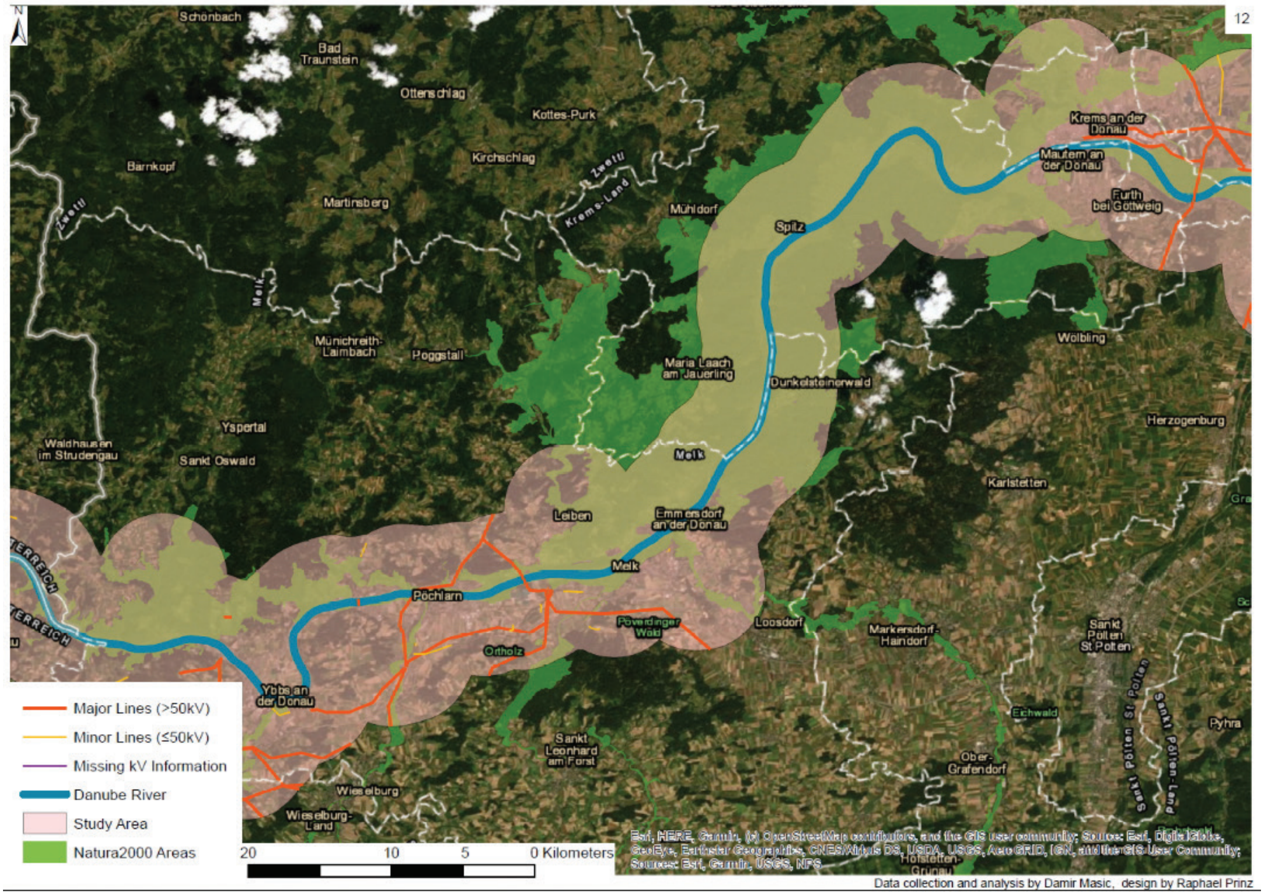
Map 9 (Germany): Vilshofen - Passau



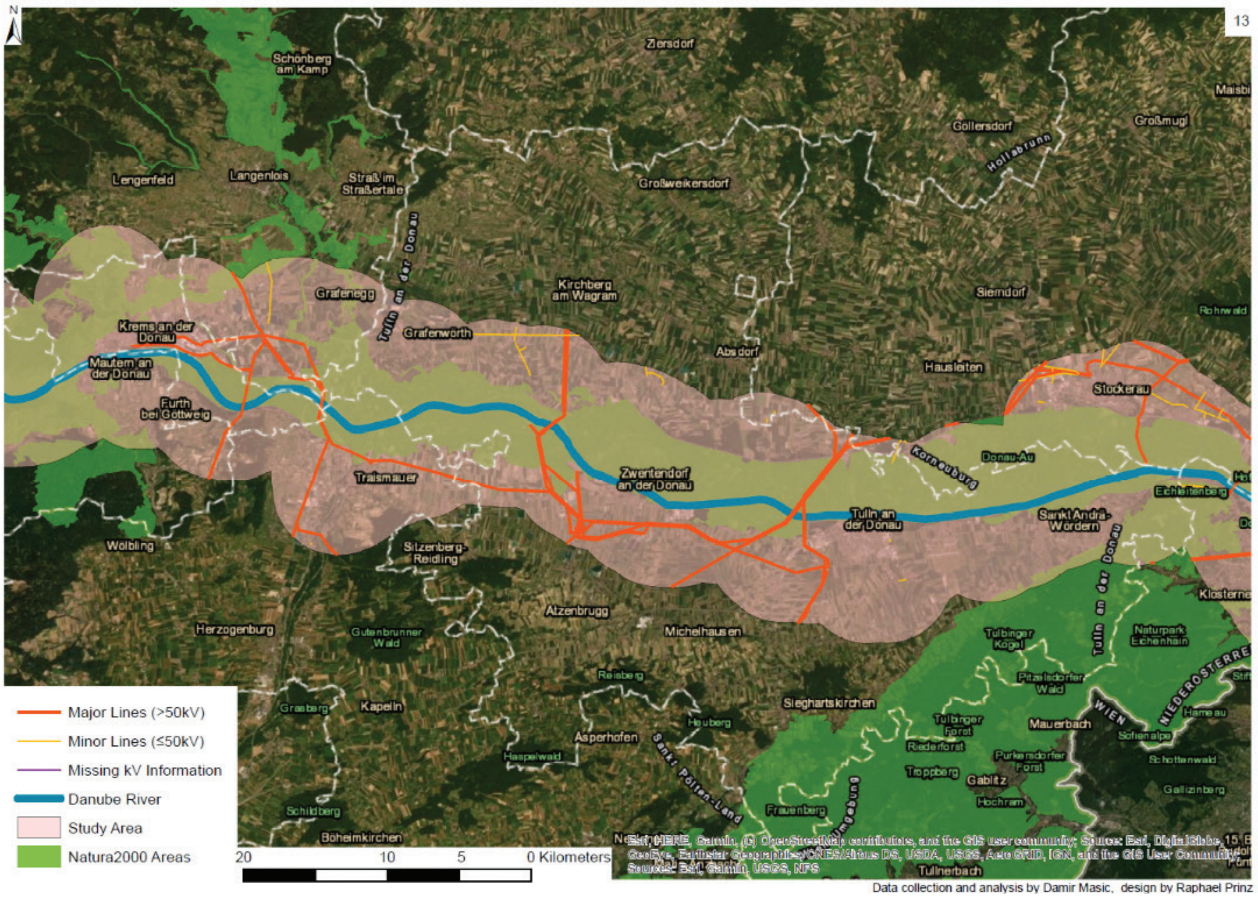
Map 10 (Germany/Austria): Passau – Linz - Mauthausen



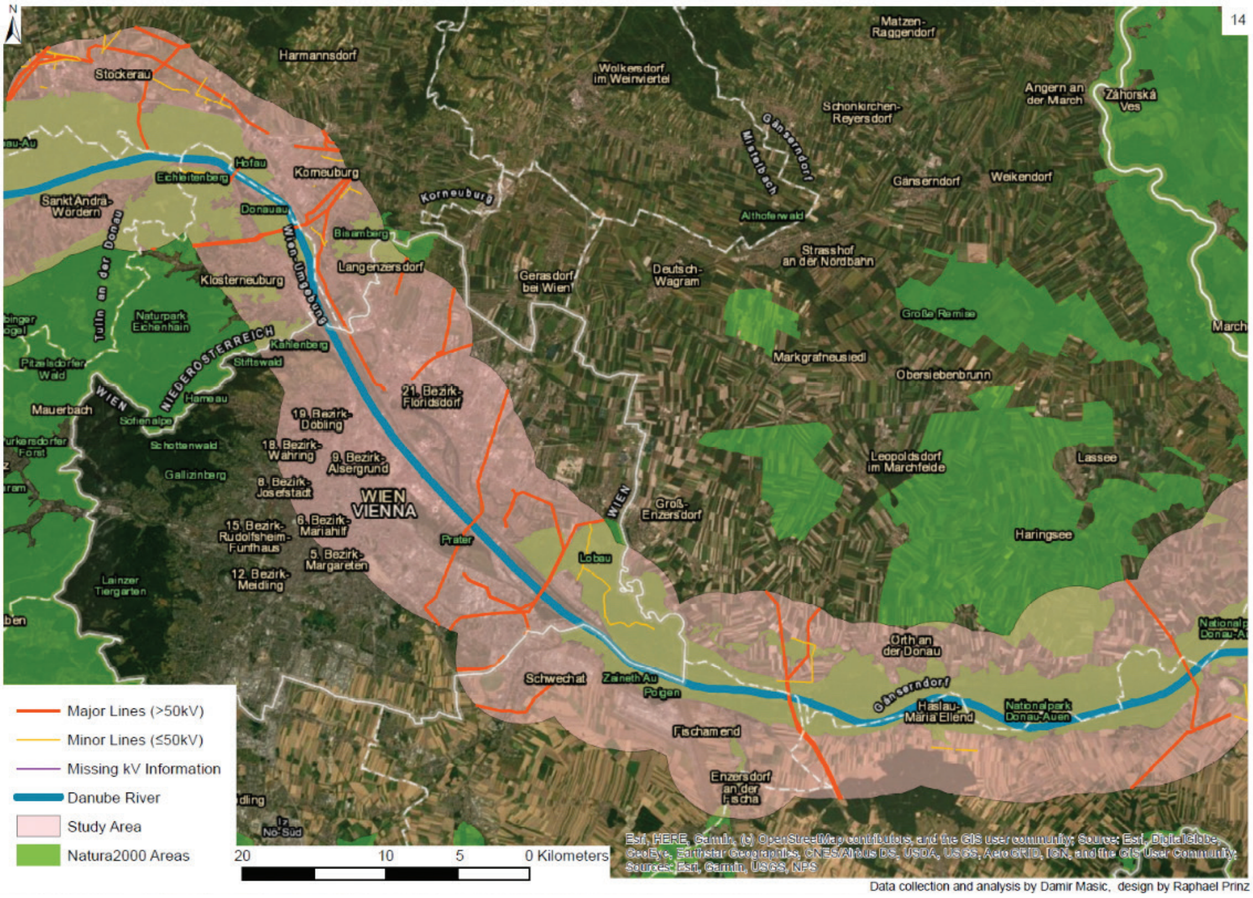
Map 11 (Austria): Mauthausen – Pöchlarn



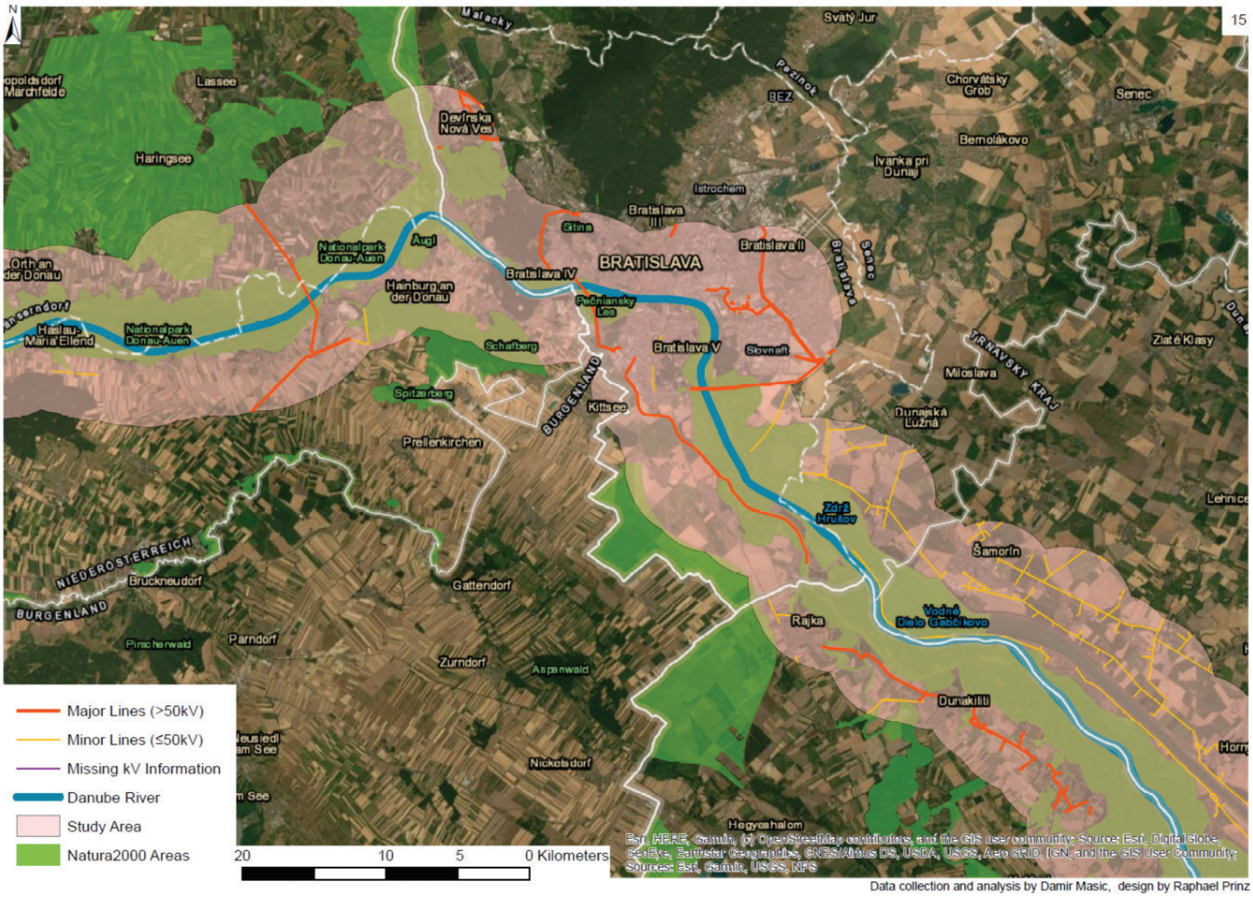
Map 12 (Austria): Pöchlarn – Krems



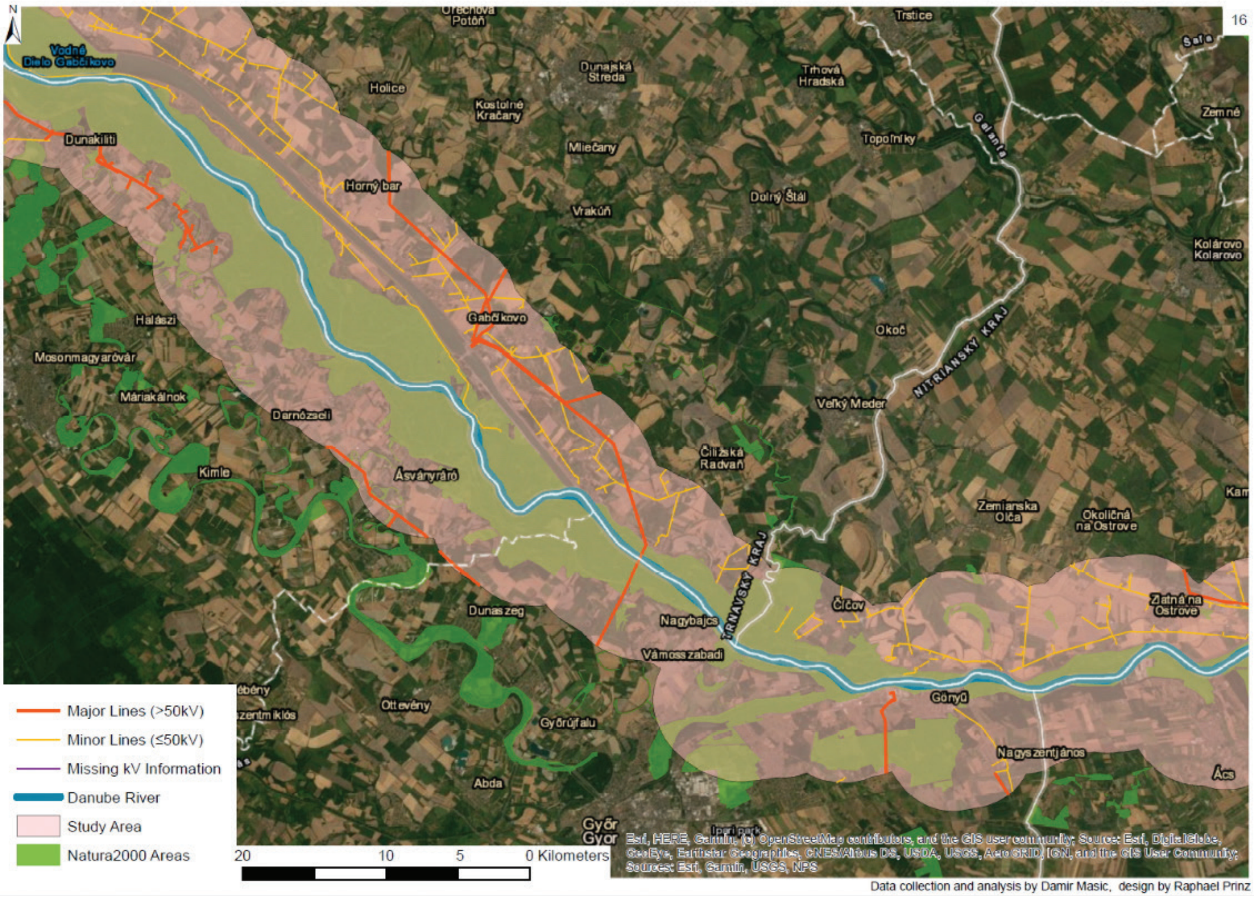
Map 13 (Austria): Krems – Klosterneuburg



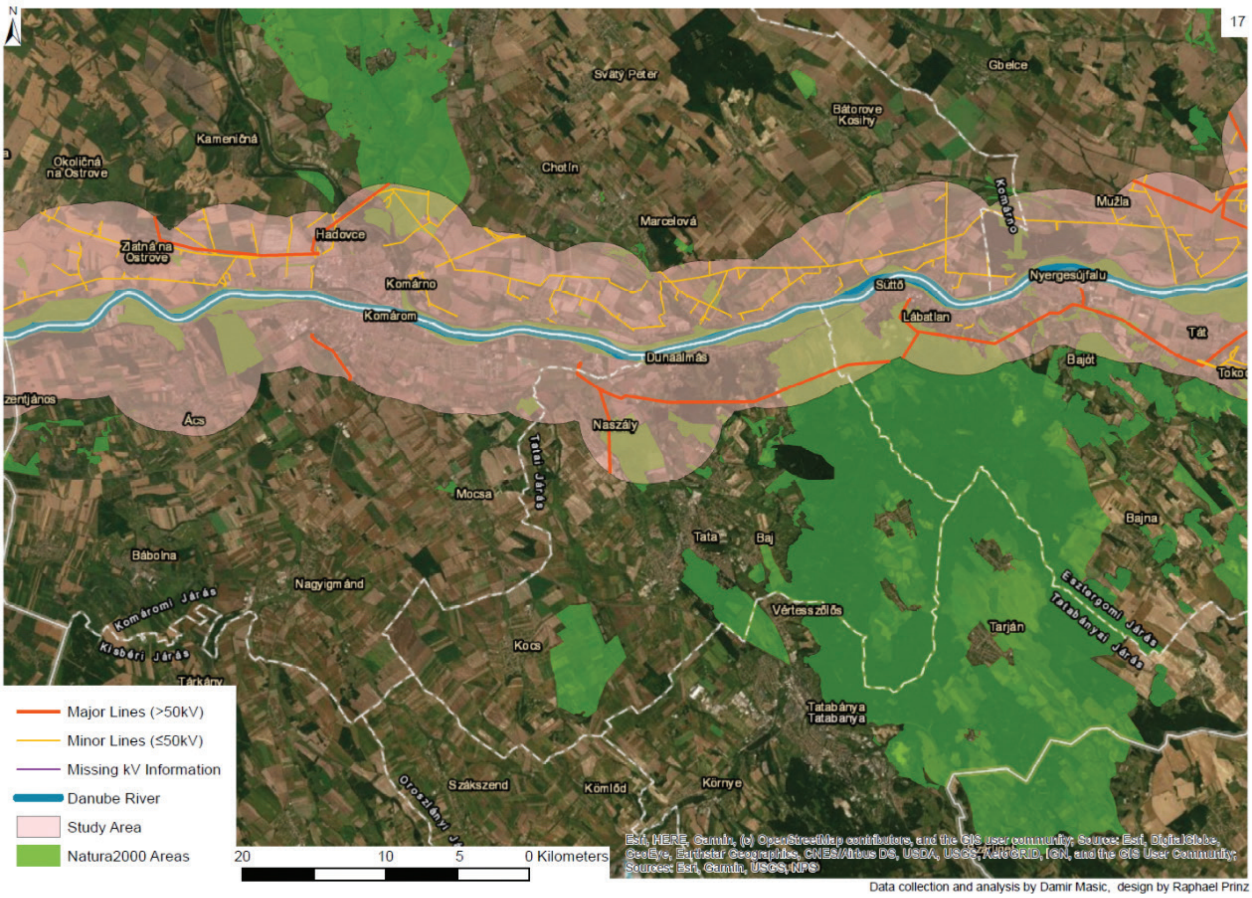
Map 14 (Austria): Klosterneuburg – Wien – Orth an der Donau



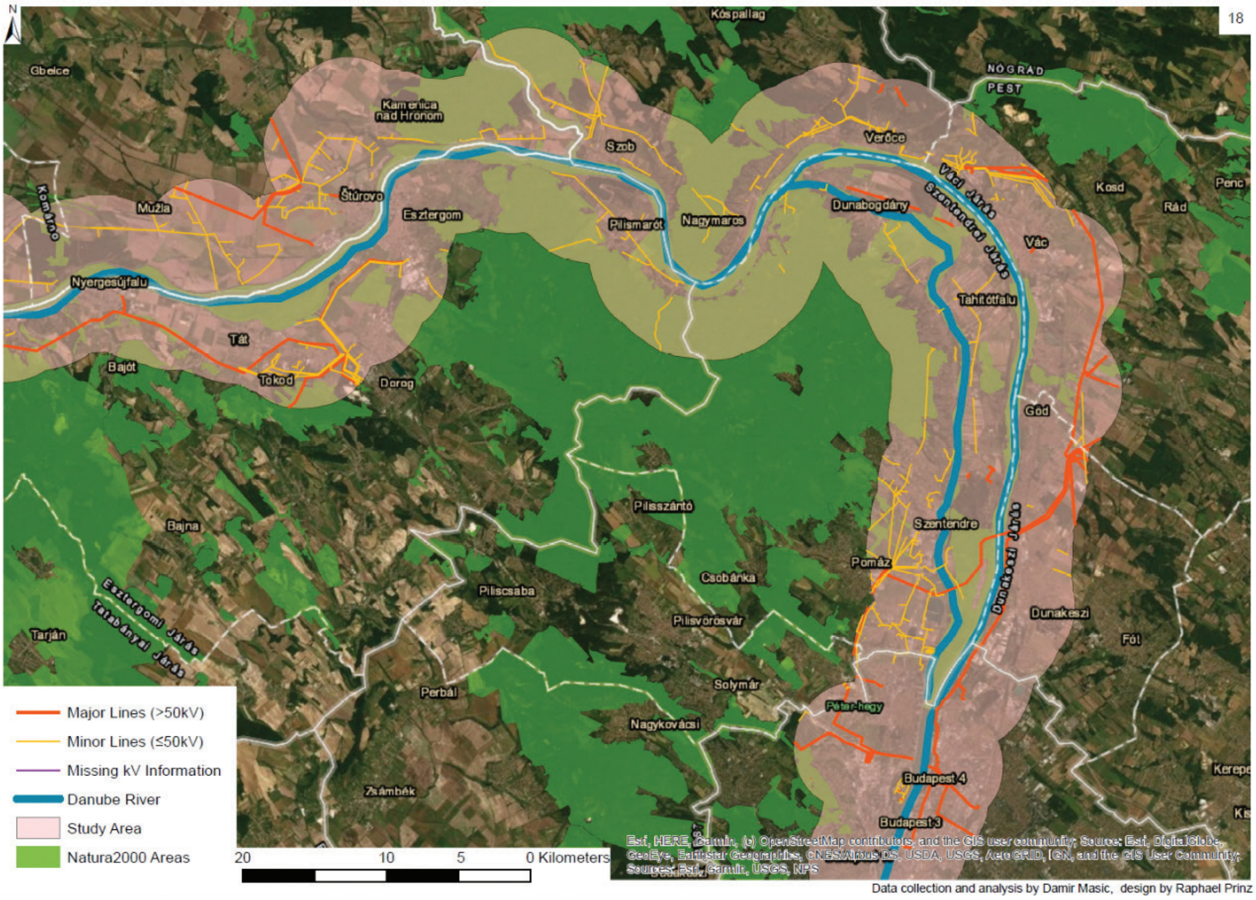
Map 15 (Austria/Slovakia/Hungary): Orth an der Donau – Samorin – Dunakiliti



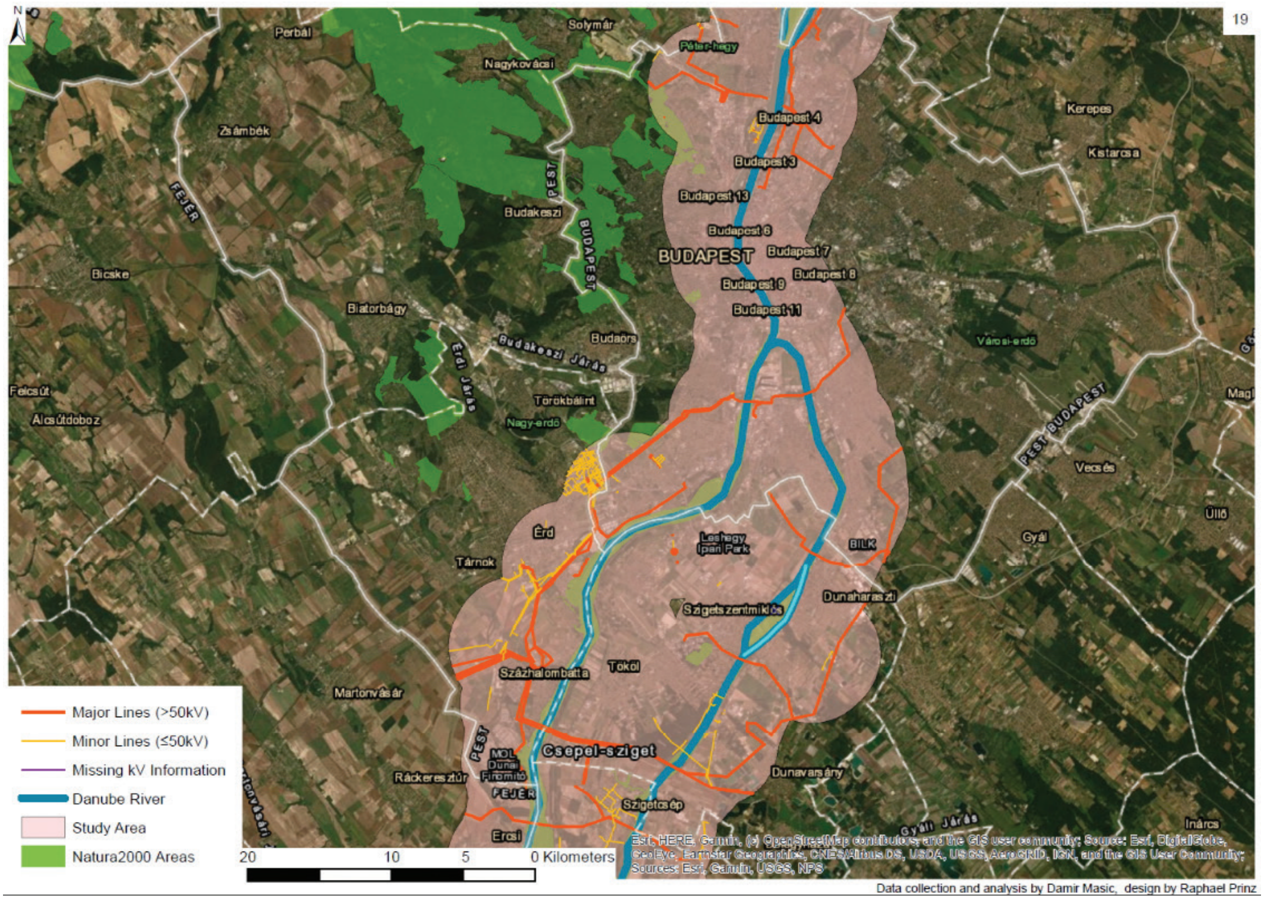
Map 16 (Slovakia/Hungary): Dunakiliti – Zlatná na Ostrove



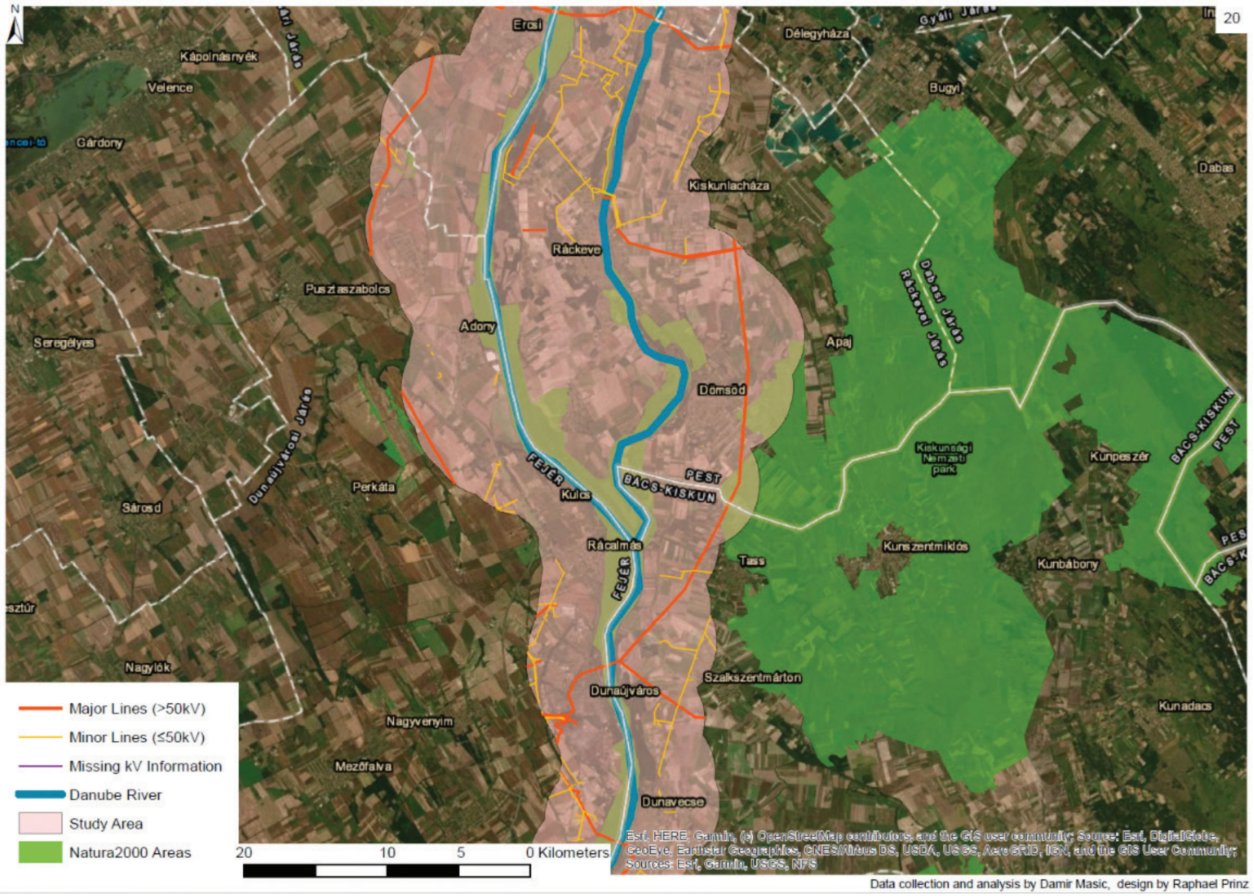
Map 17 (Slovakia/Hungary): Zlatná na Ostrove – Tát



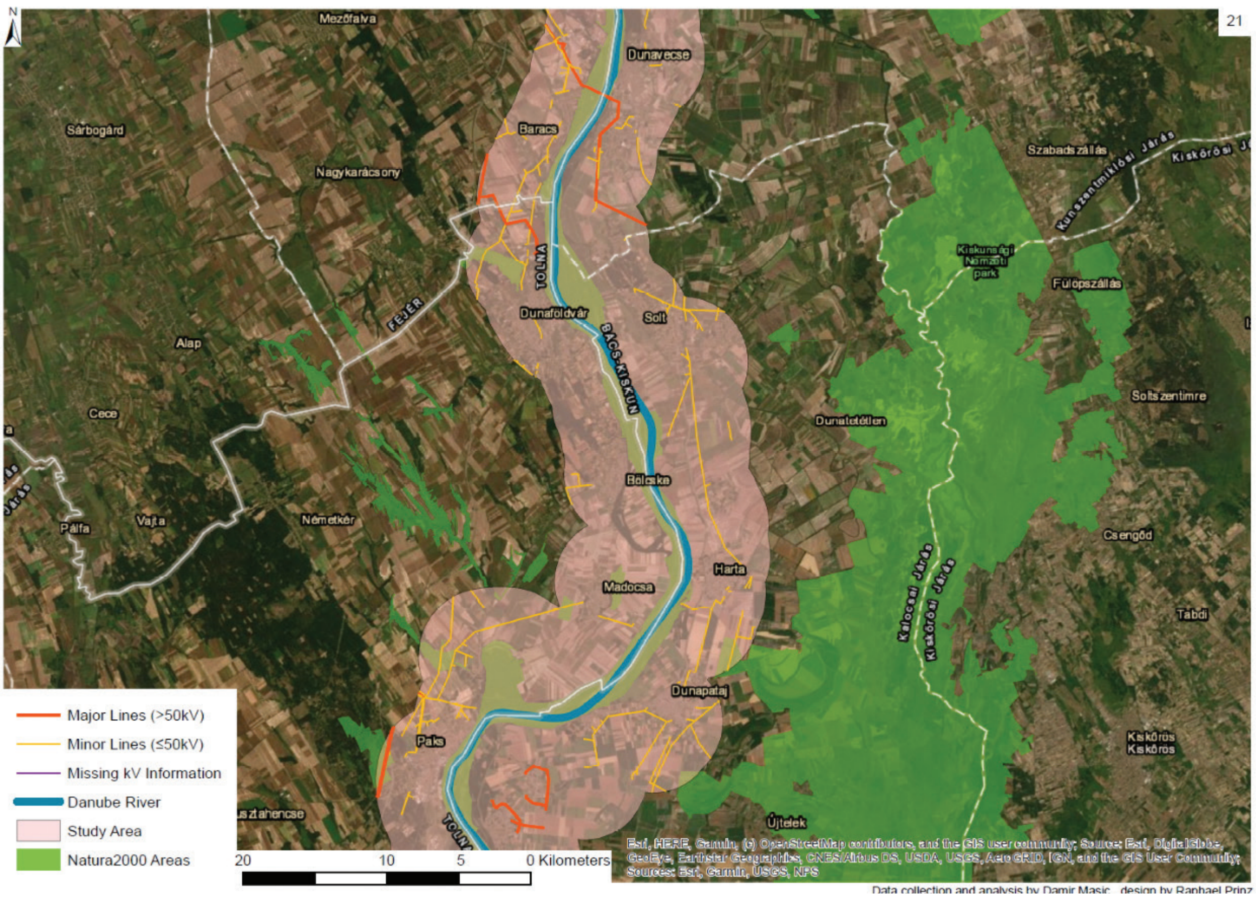
Map 18 (Slovakia/Hungary): Mužla – Budapest



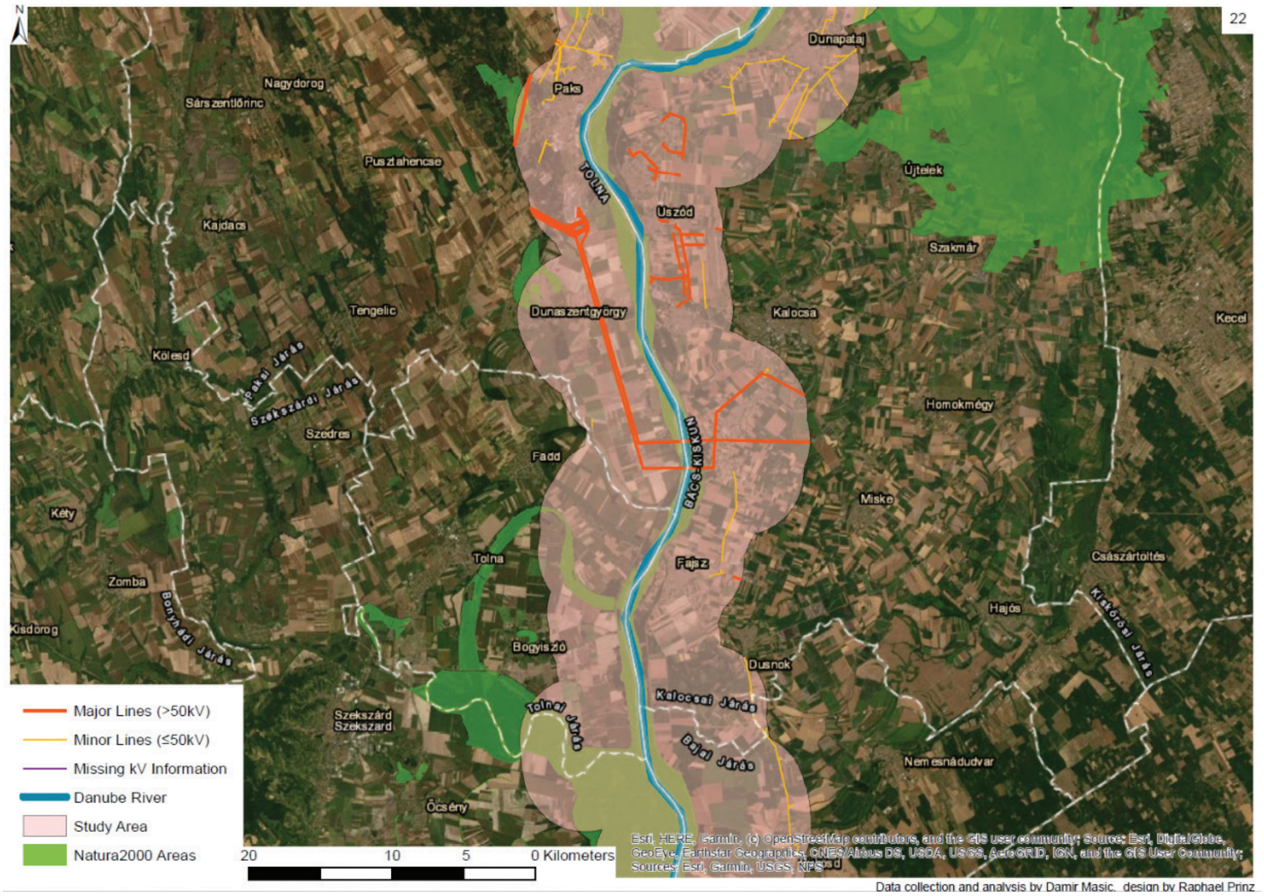
Map 19 (Hungary): Budapest – Ercsi



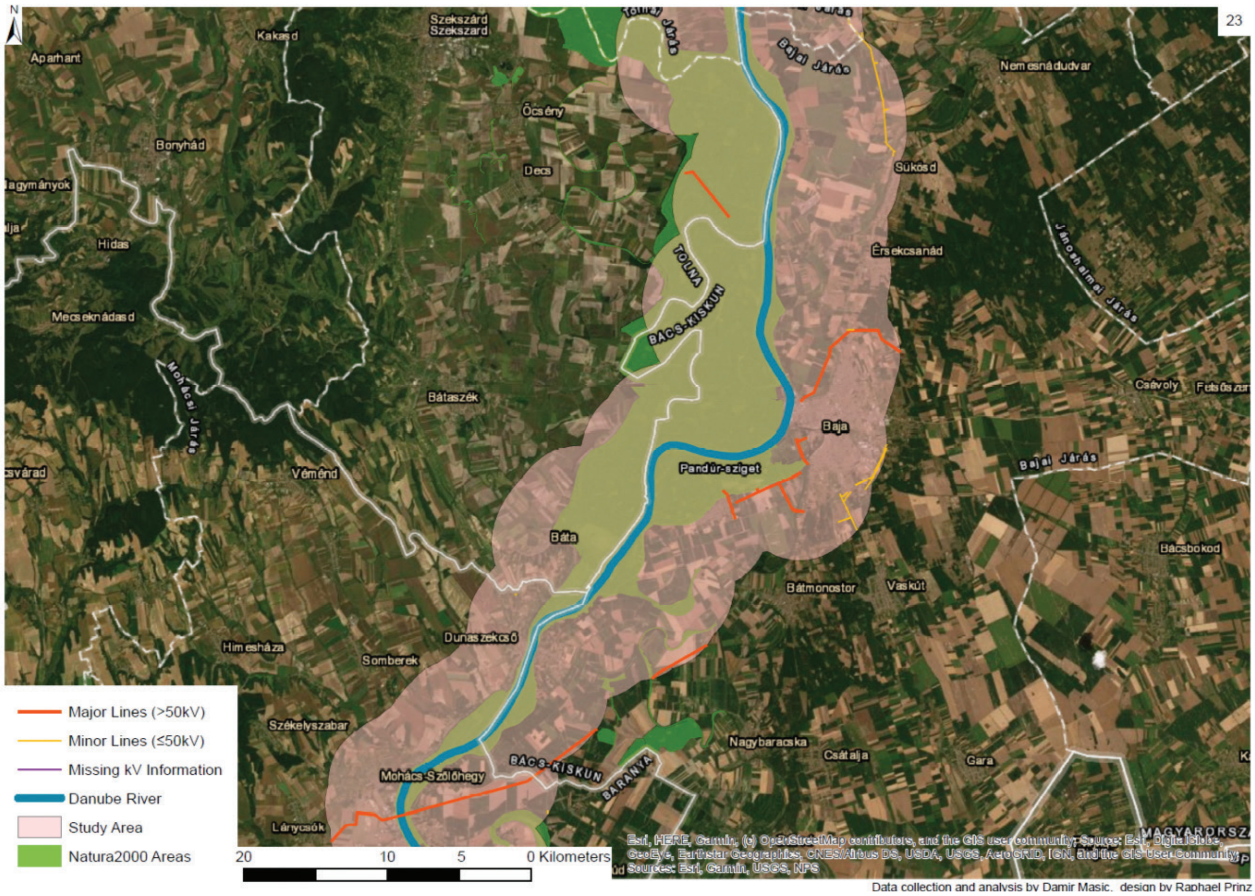
Map 20 (Hungary): Ercsi - Dunaújváros



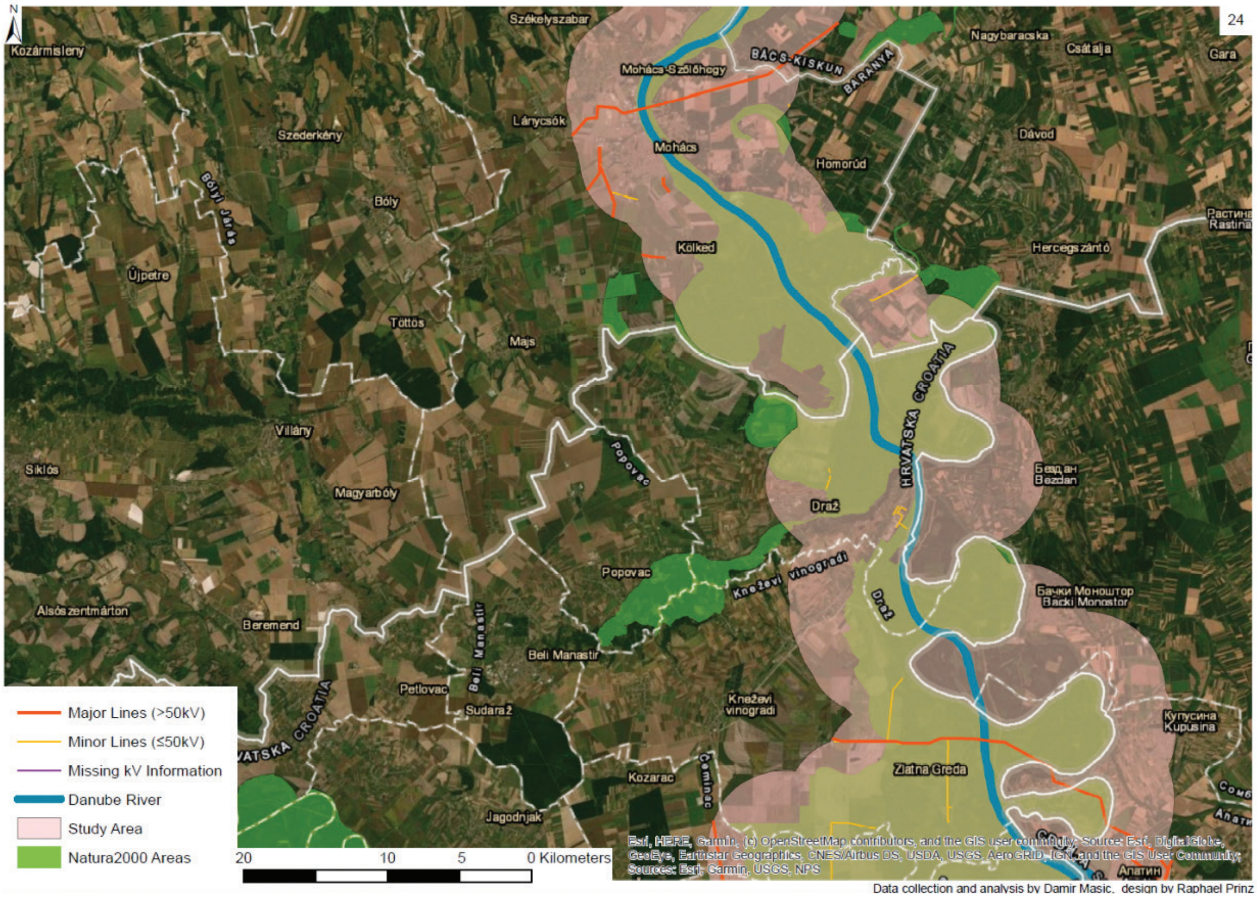
Map 21 (Hungary): Budapest – Paks



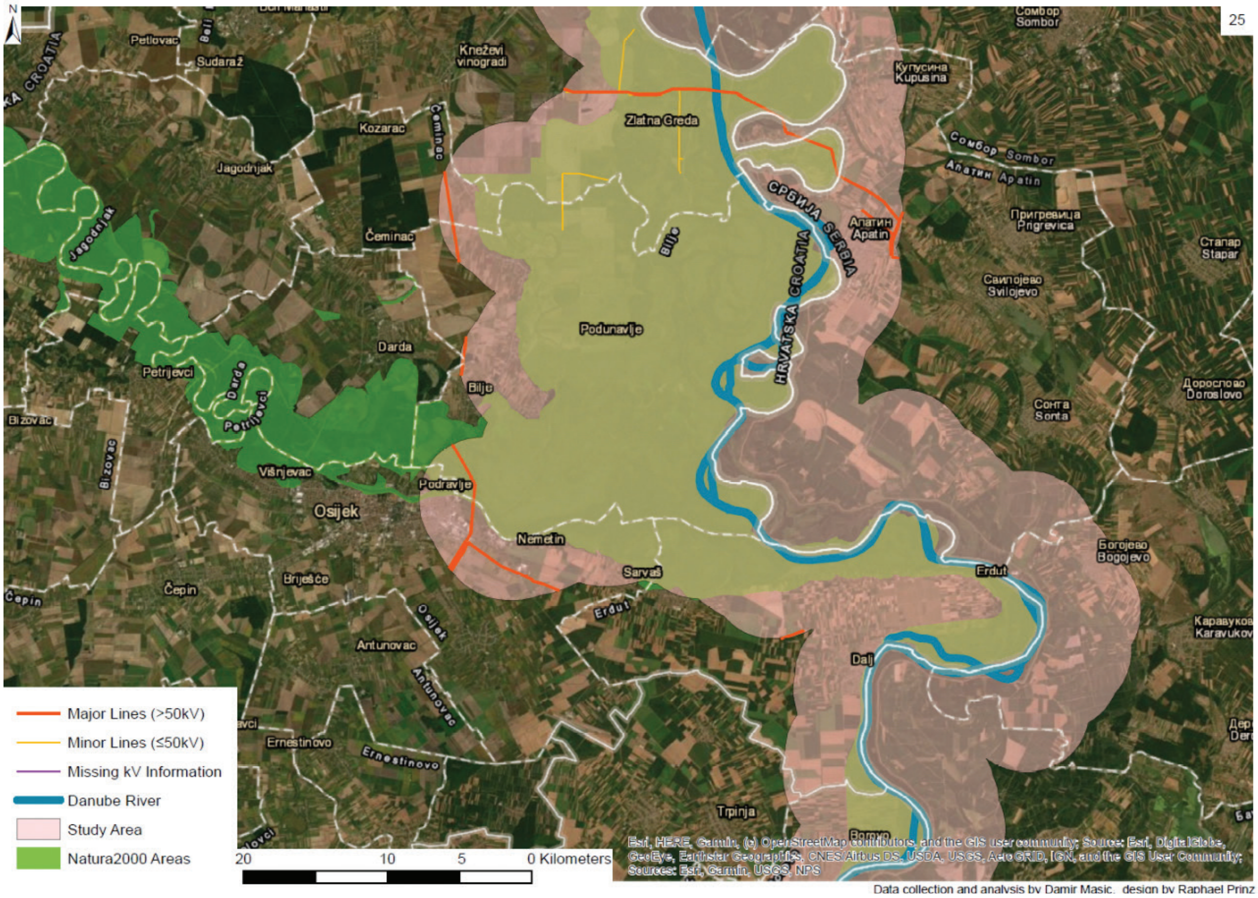
Map 22 (Hungary): Paks – Szekszárd



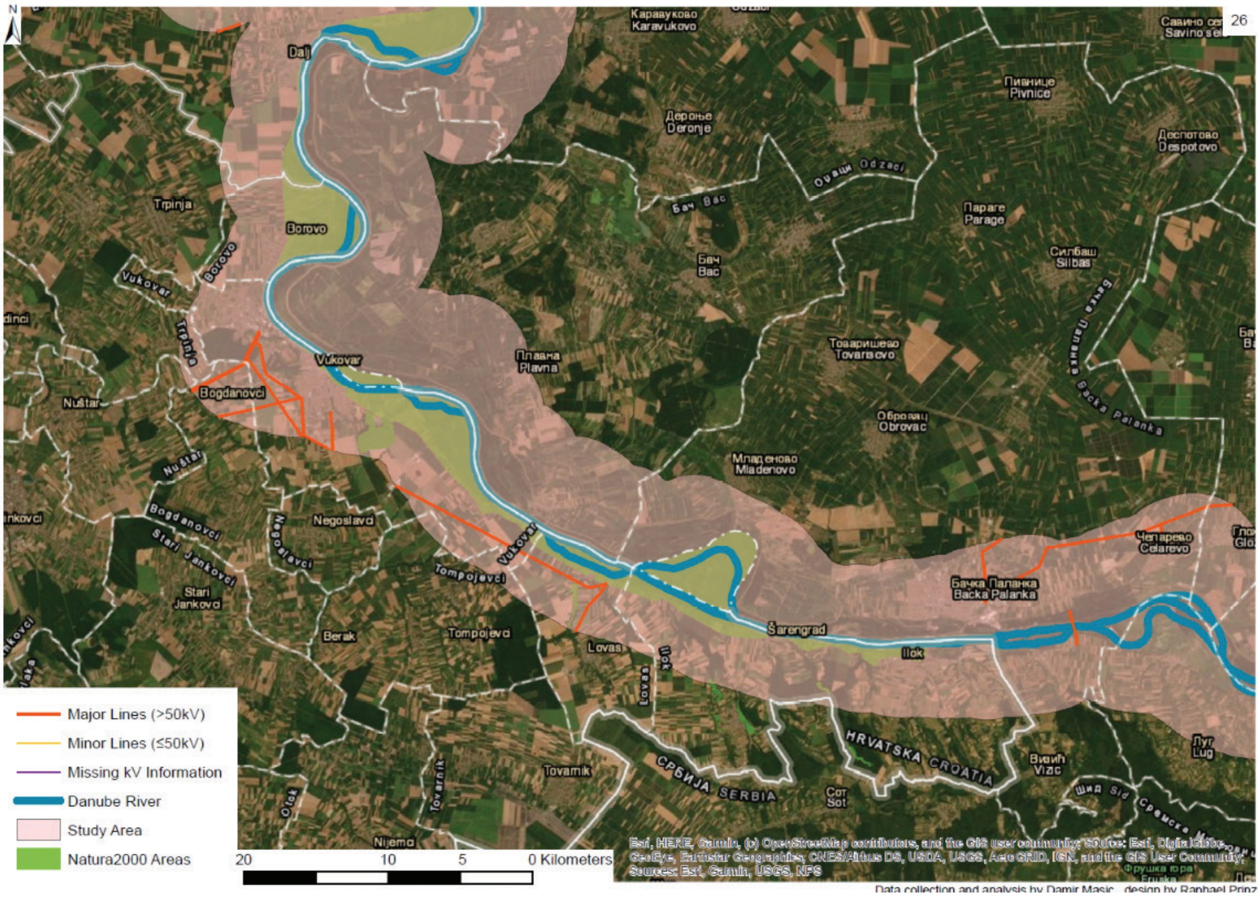
Map 23 (Hungary): Paks – Mohács



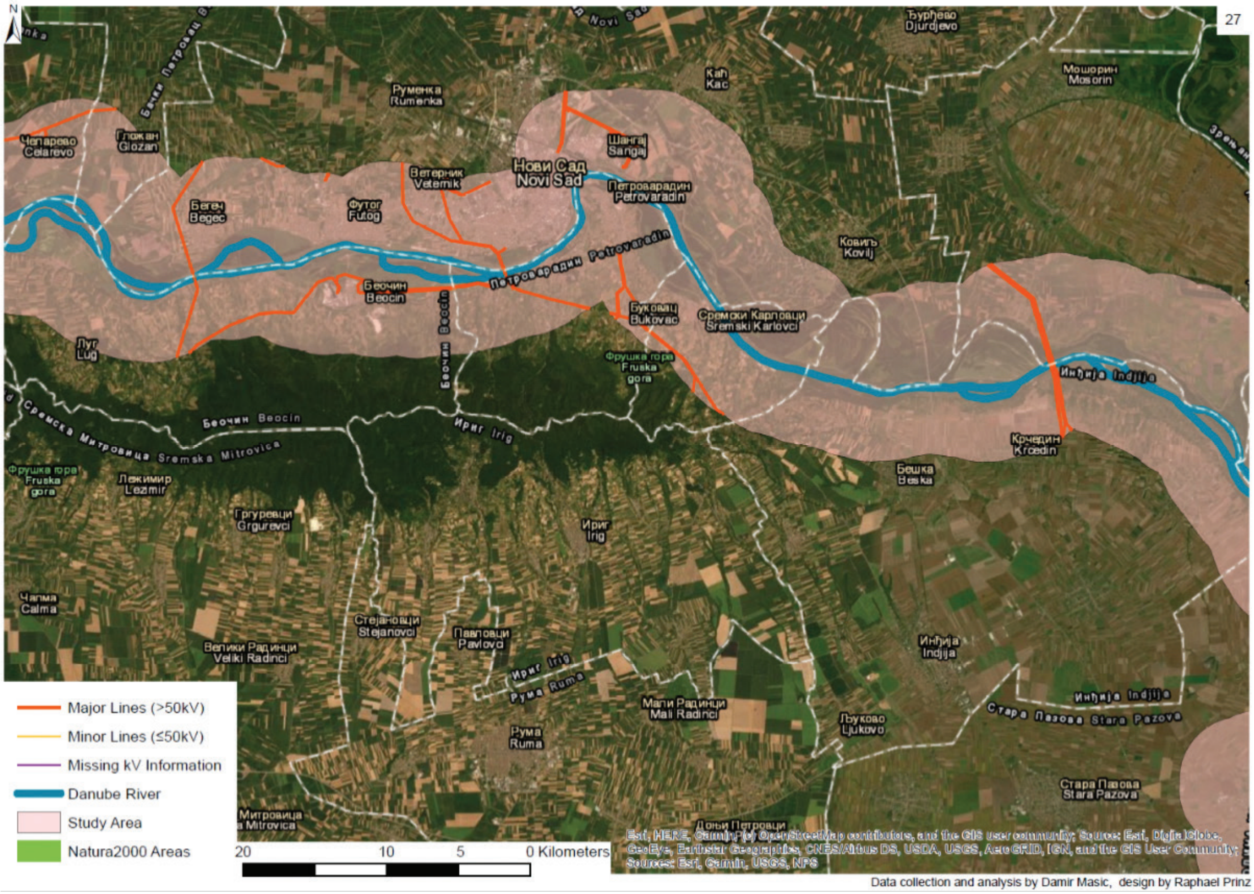
Map 24 (Hungary/Croatia/Serbia): Mohács – Apatin



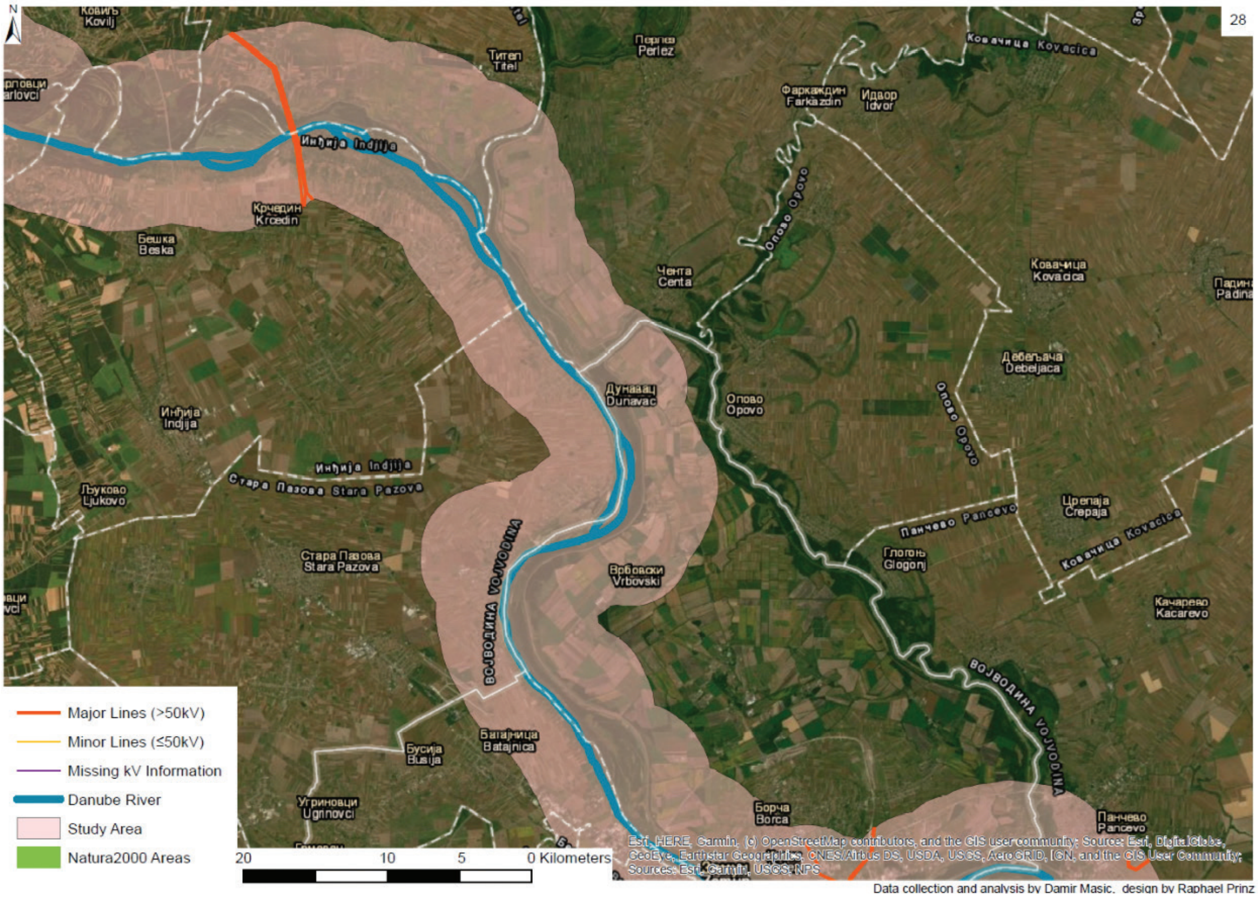
Map 25 (Croatia/Serbia): Apatin – Dalj



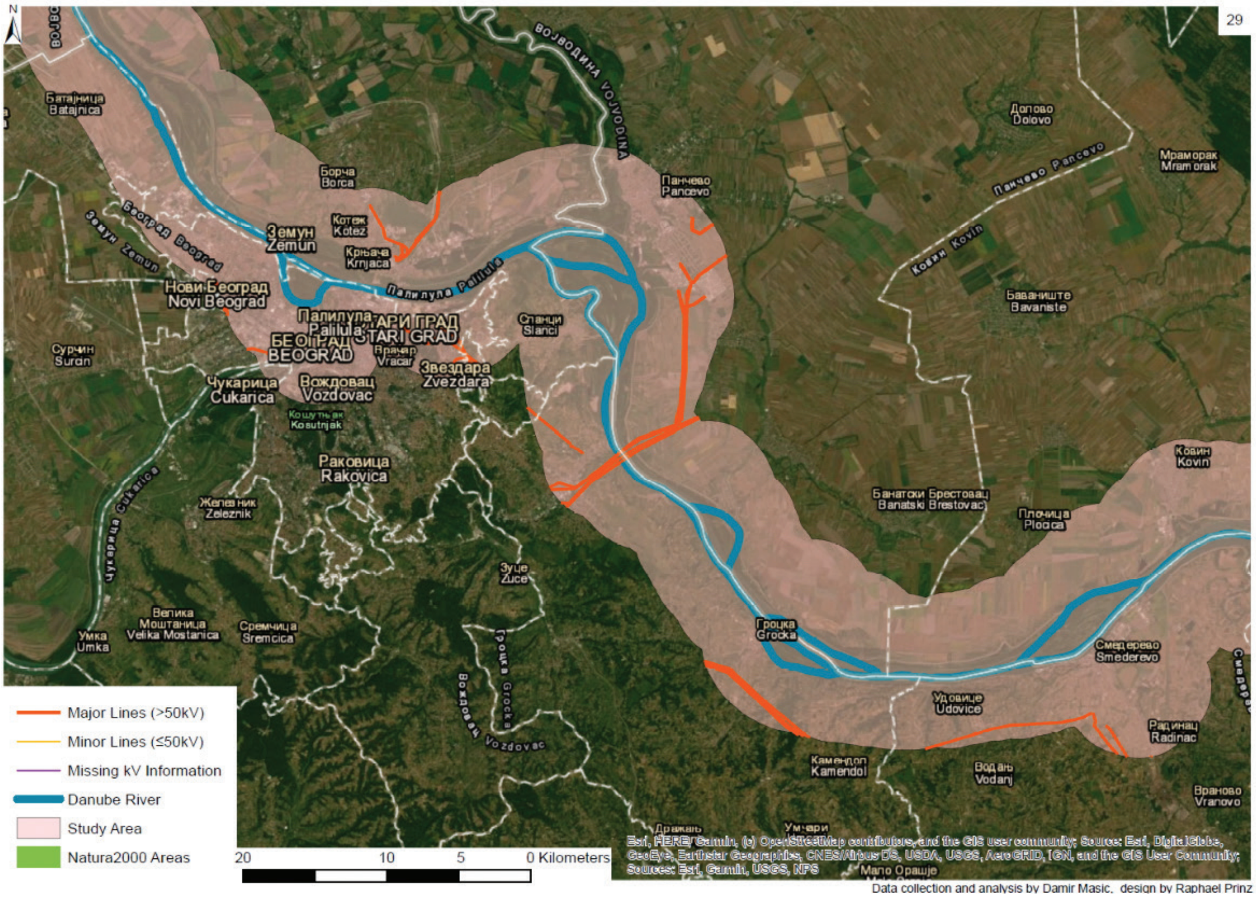
Map 26 (Croatia/Serbia): Dalj – Vukovar - Celarevo



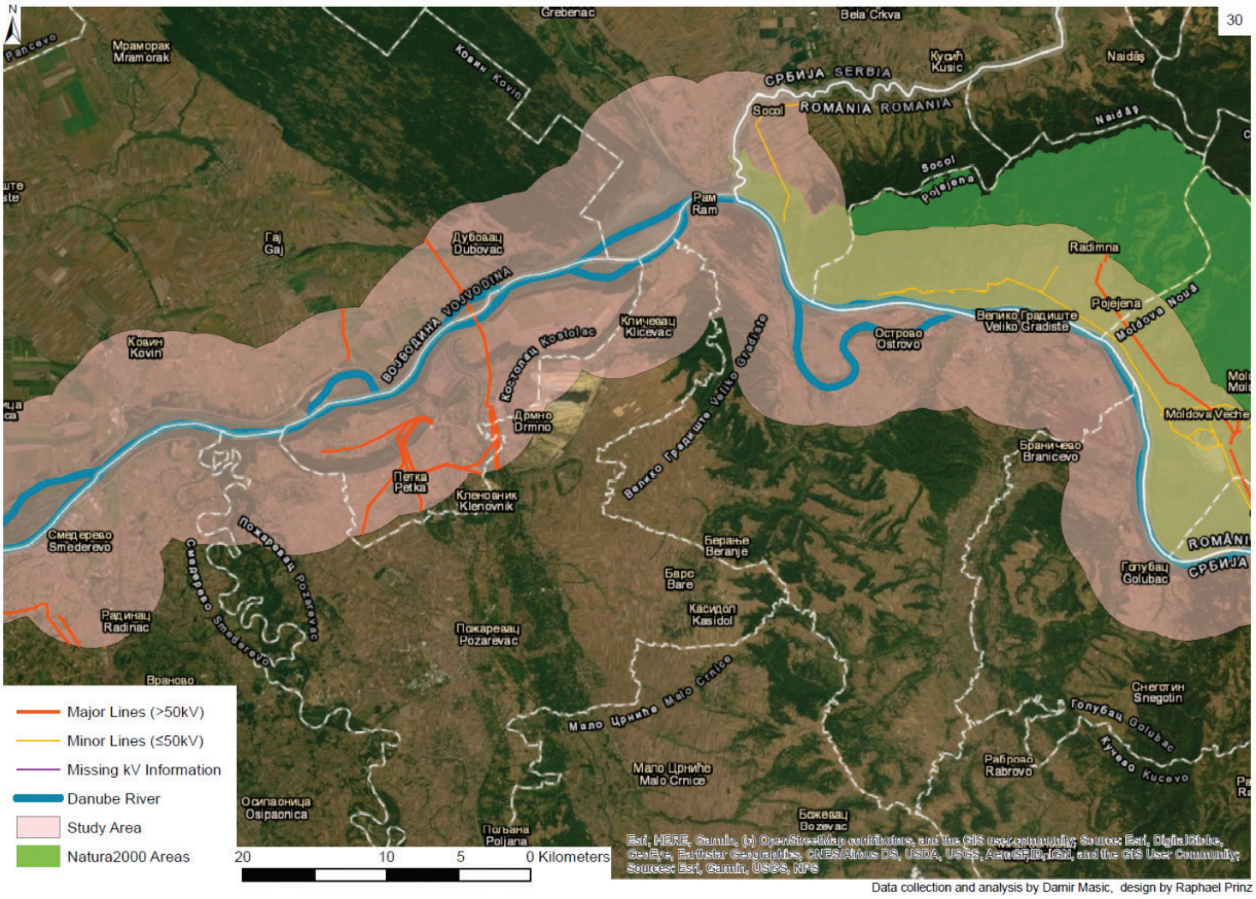
Map 27 (Serbia): Celarevo – Novi Sad



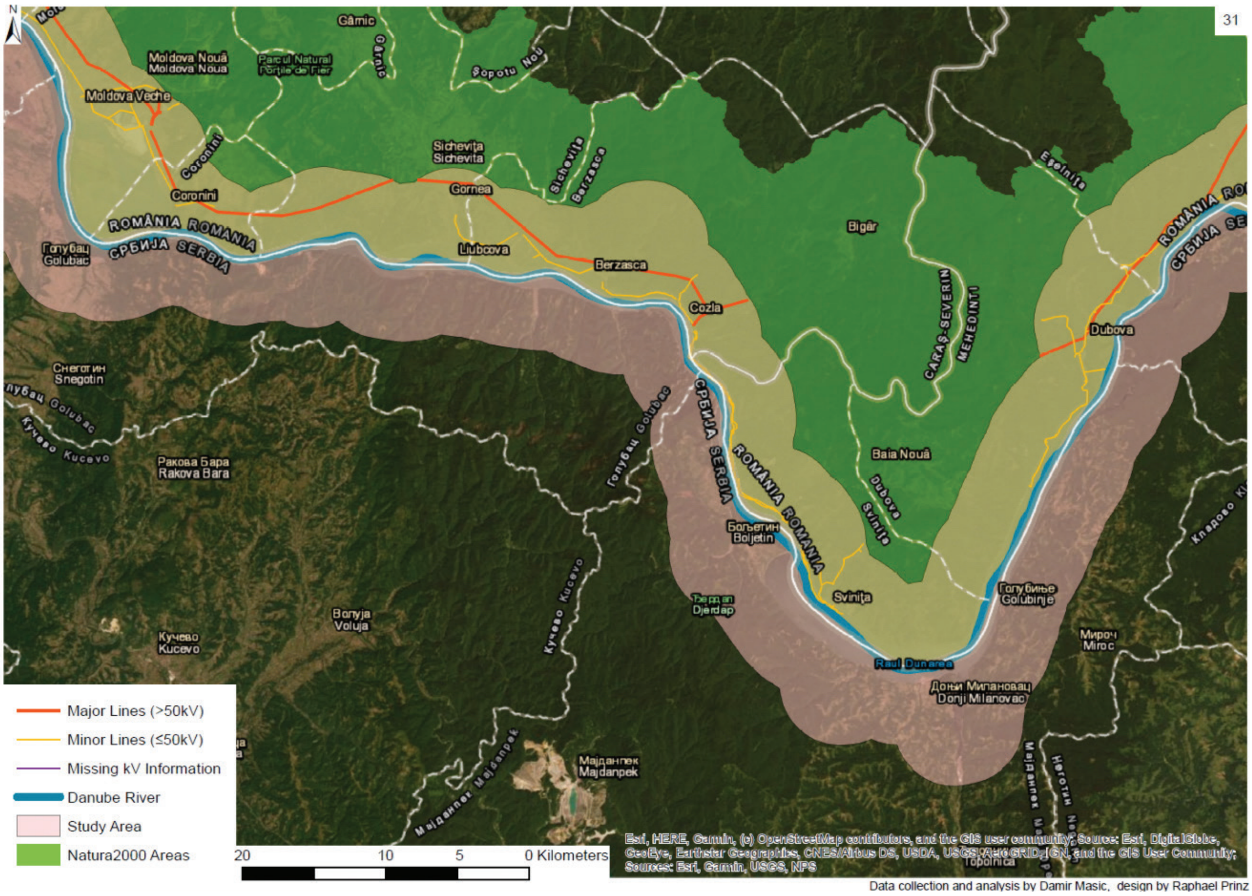
Map 28 (Serbia): Karlovci – Pančevo



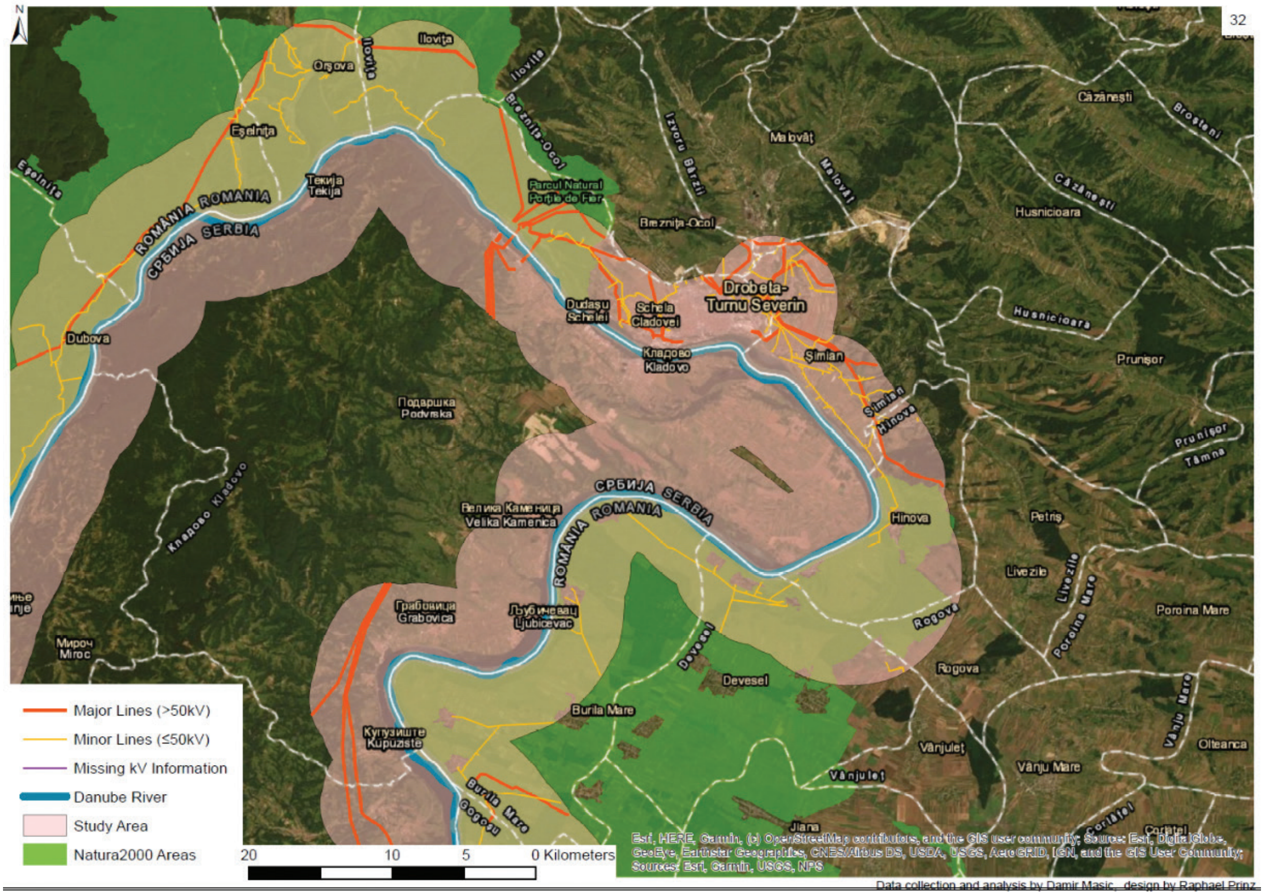
Map 29 (Serbia): Pančevo – Belgrad – Smederevo



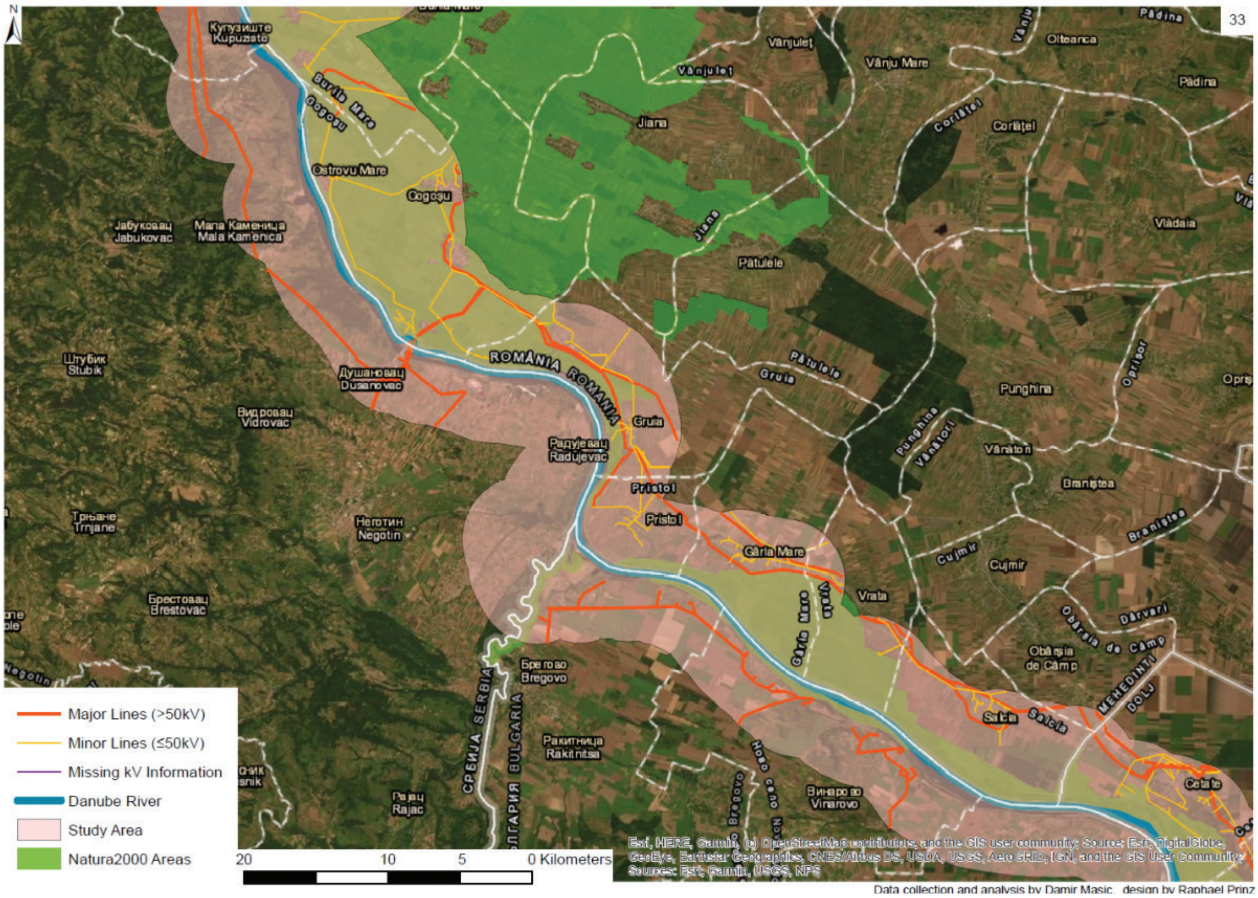
Map 30 (Serbia/Romania): Smederevo – Golubac



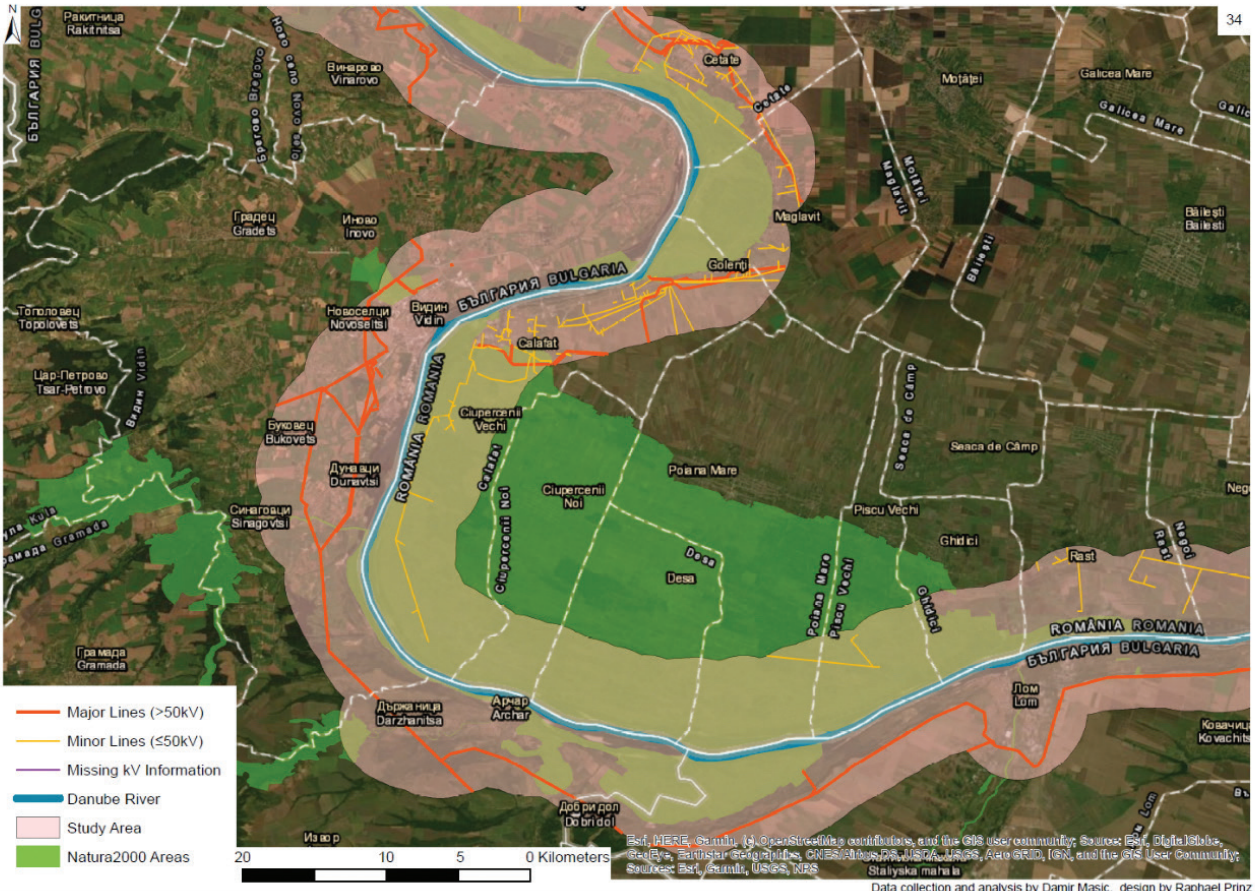
Map 31 (Serbia/Romania): Golubac – Donji Milanovac



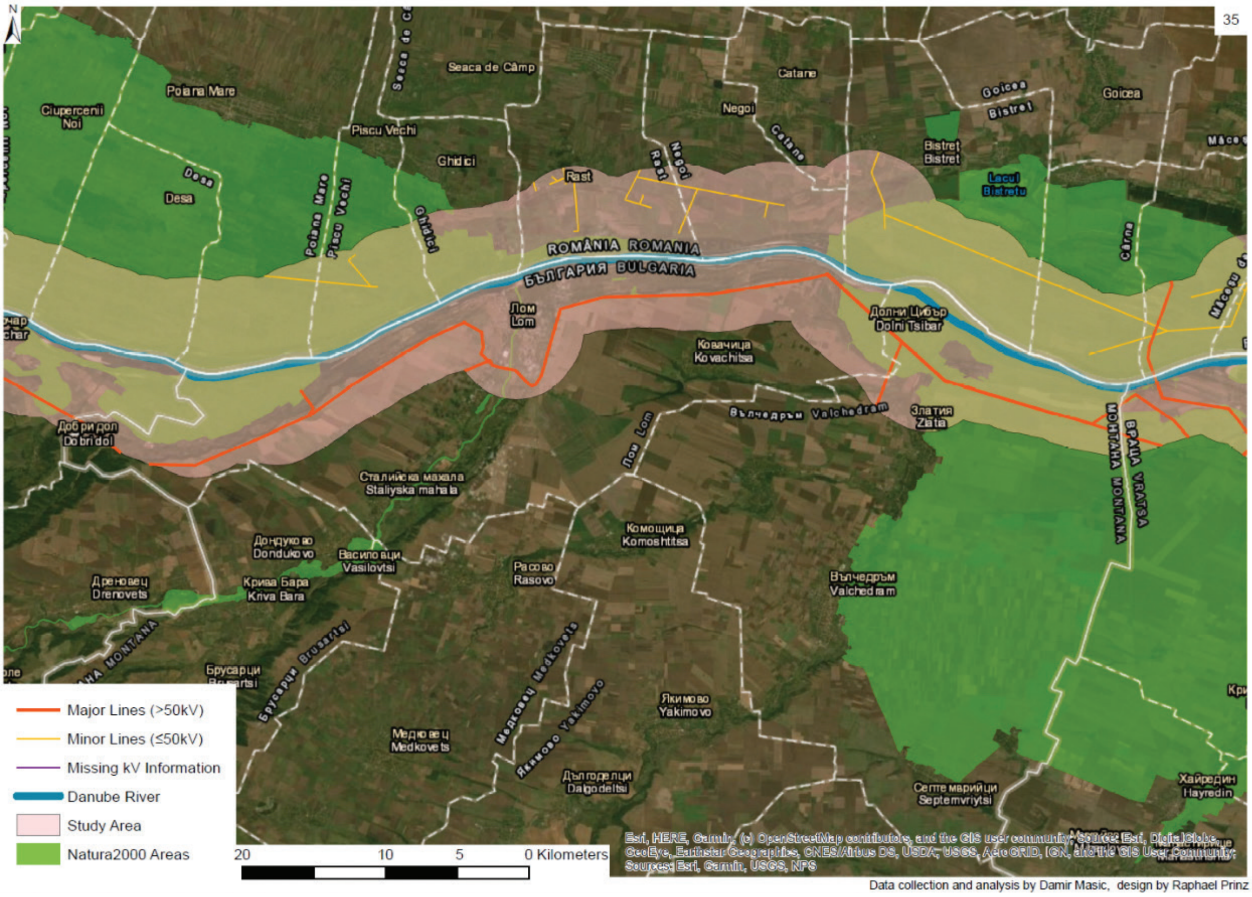
Map 32 (Serbia/Romania): Donji Milanovac – Dobreta-Turnu Severin



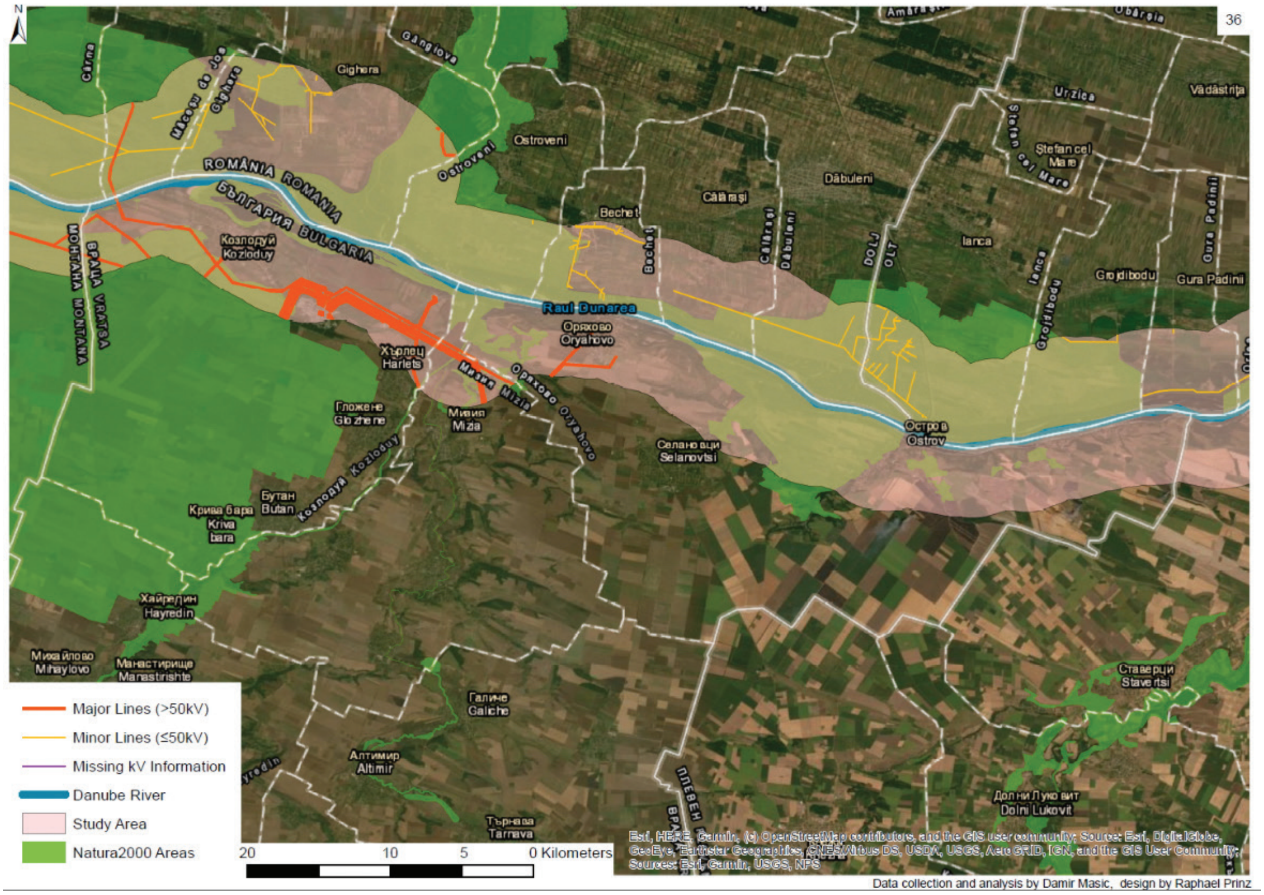
Map 33 (Serbia/Romania/Bulgaria): Dobreta-Turnu Severin - Vinarovo



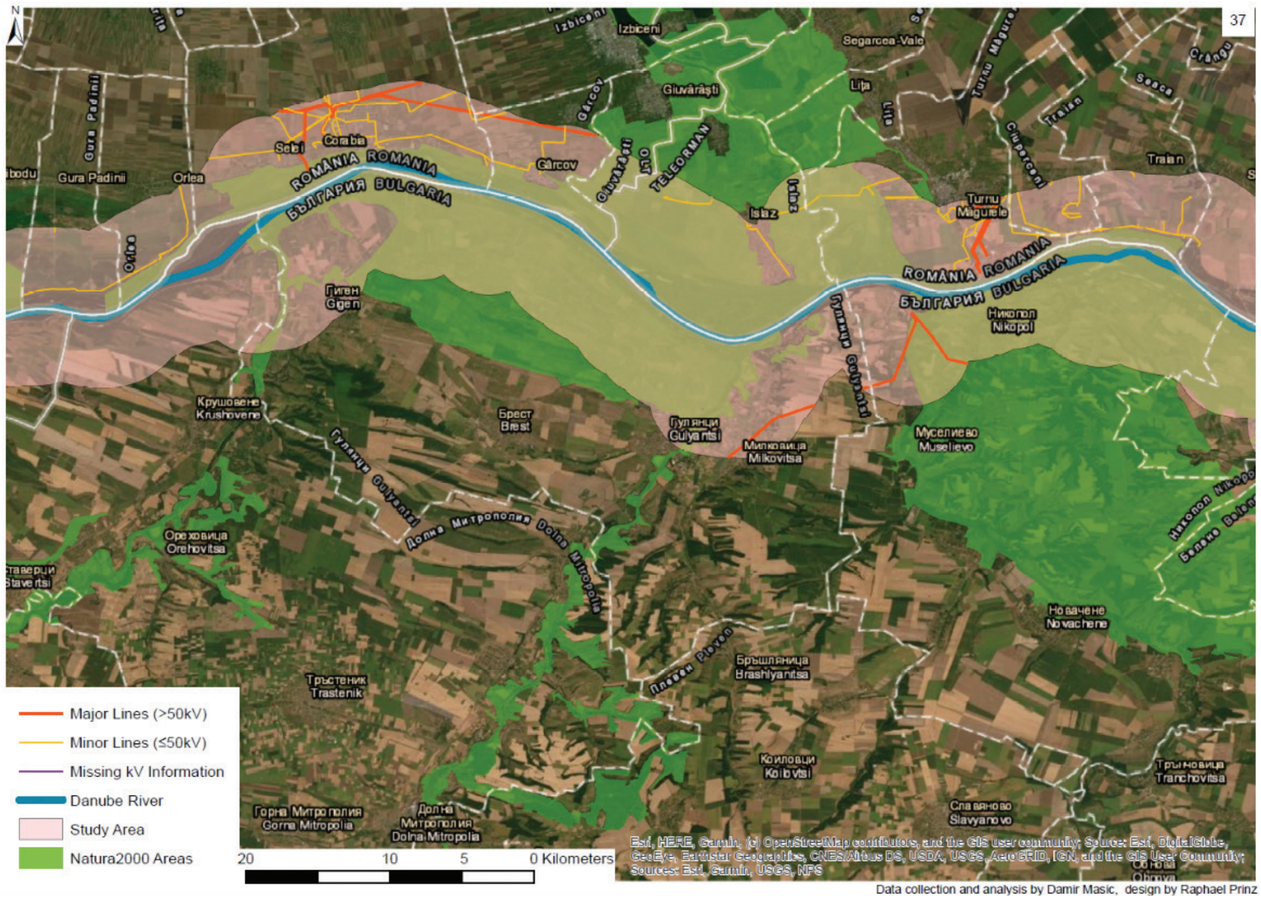
Map 34 (Bulgaria/Romani): Vinarovo - Lom



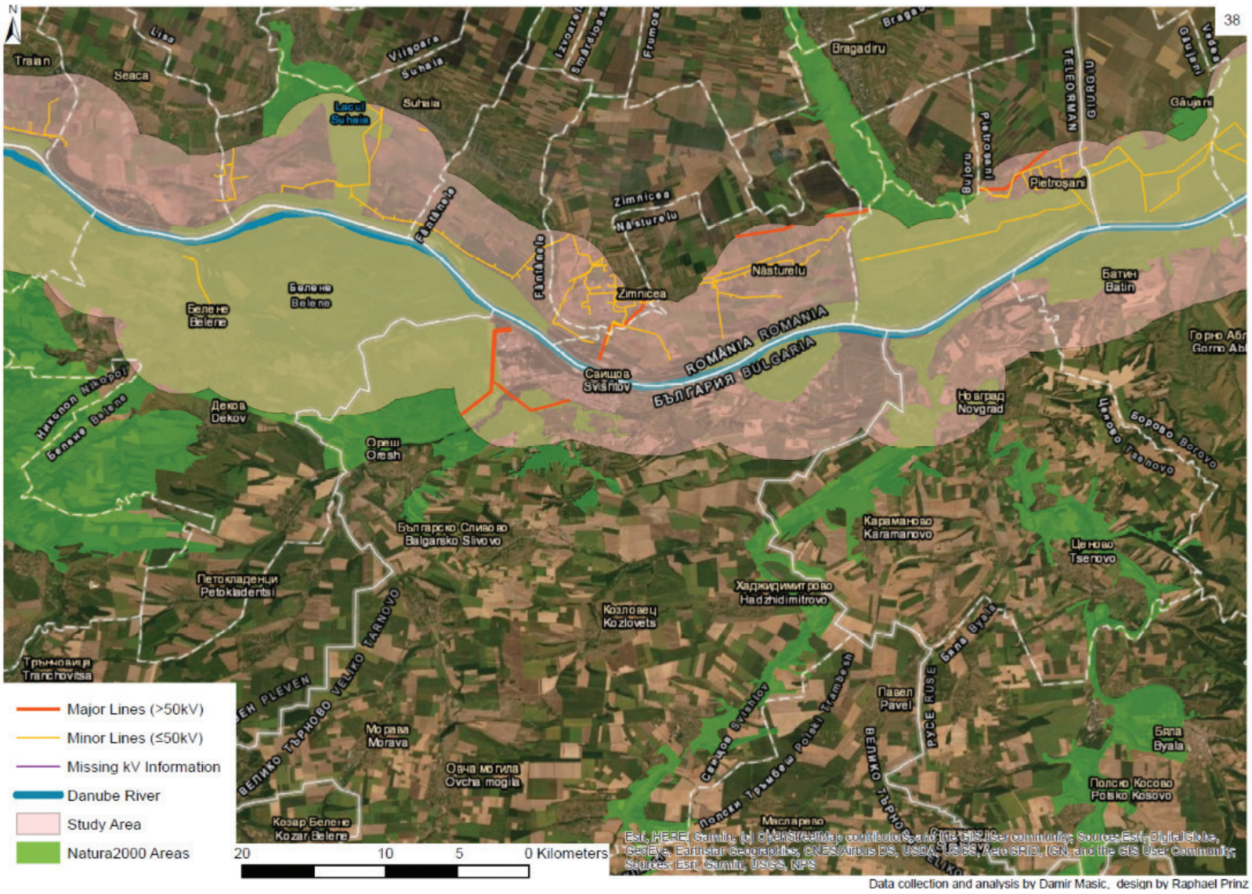
Map 35 (Bulgaria/Romania): Lom - Kozloduy



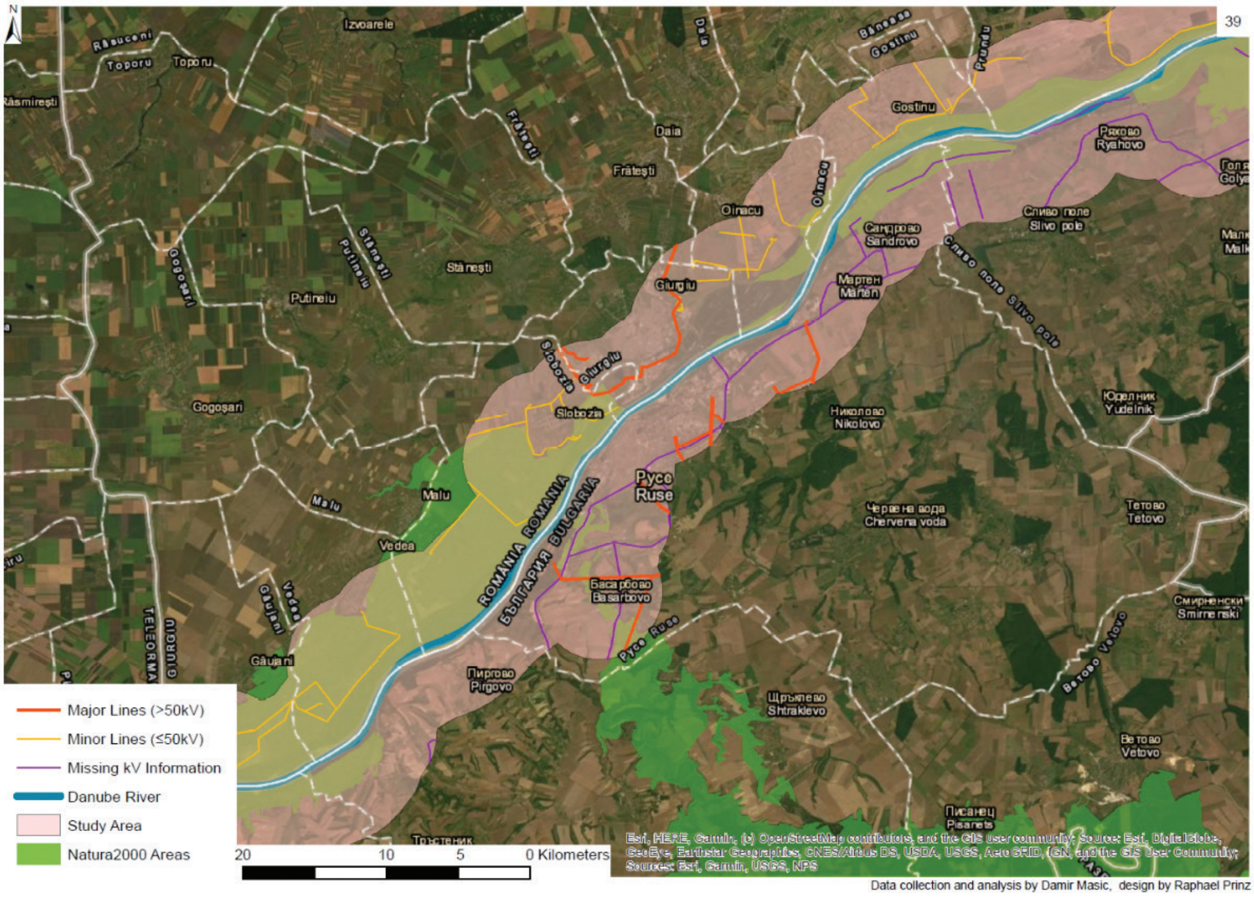
Map 36 (Bulgaria/Romania): Kozloduy - Ostrov



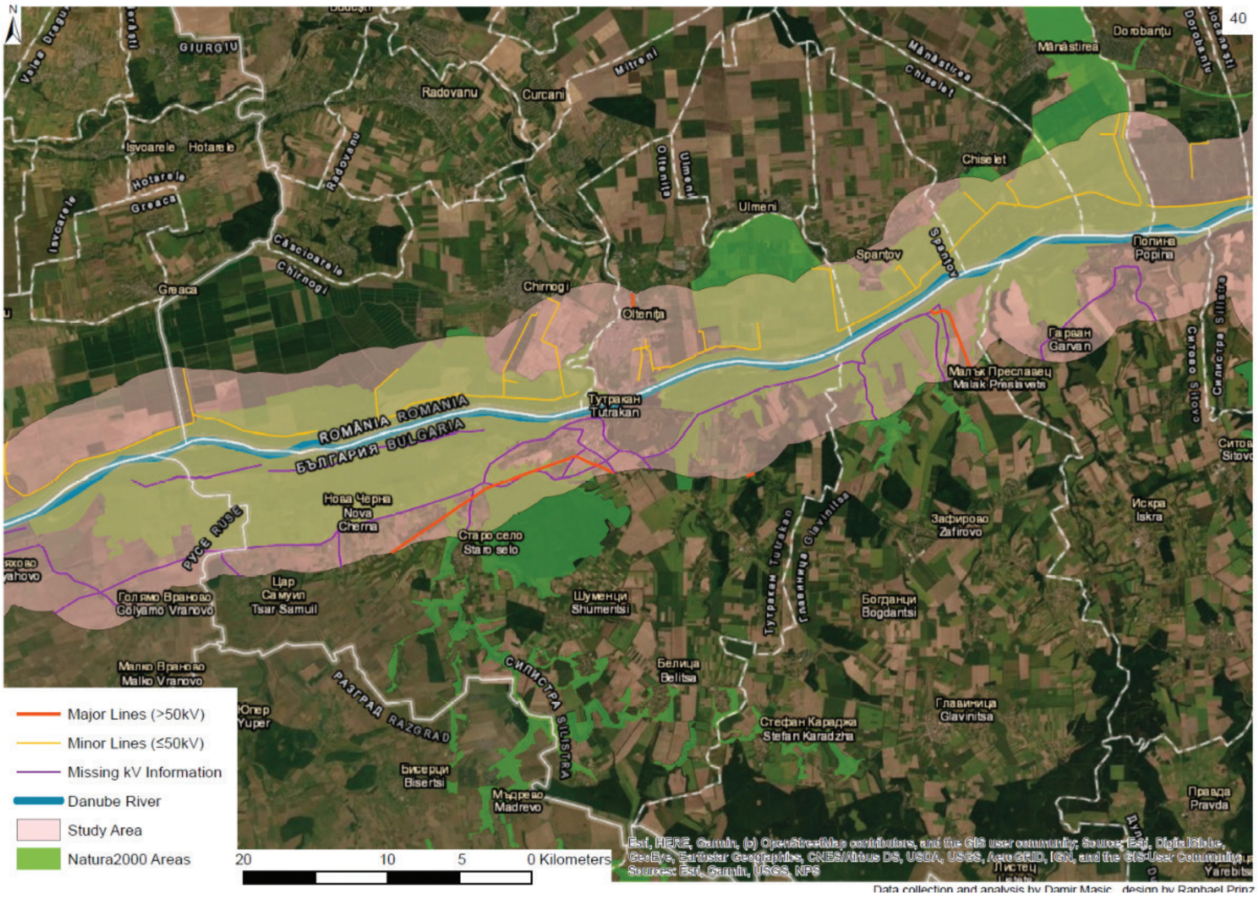
Map 37 (Bulgaria/Romania): Ostrov – Turnu Magurele



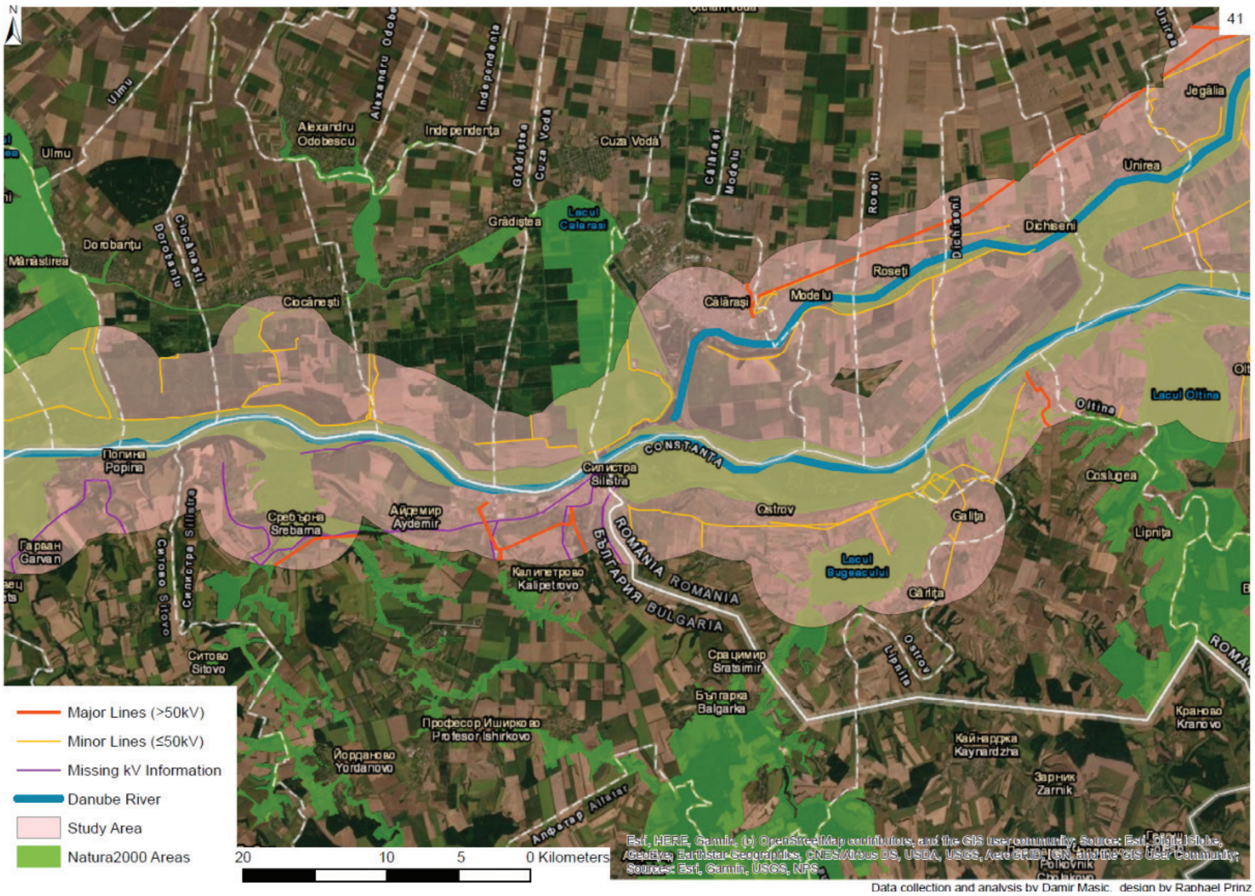
Map 38 (Bulgaria/Romania): Turnu Magurele – Svistov



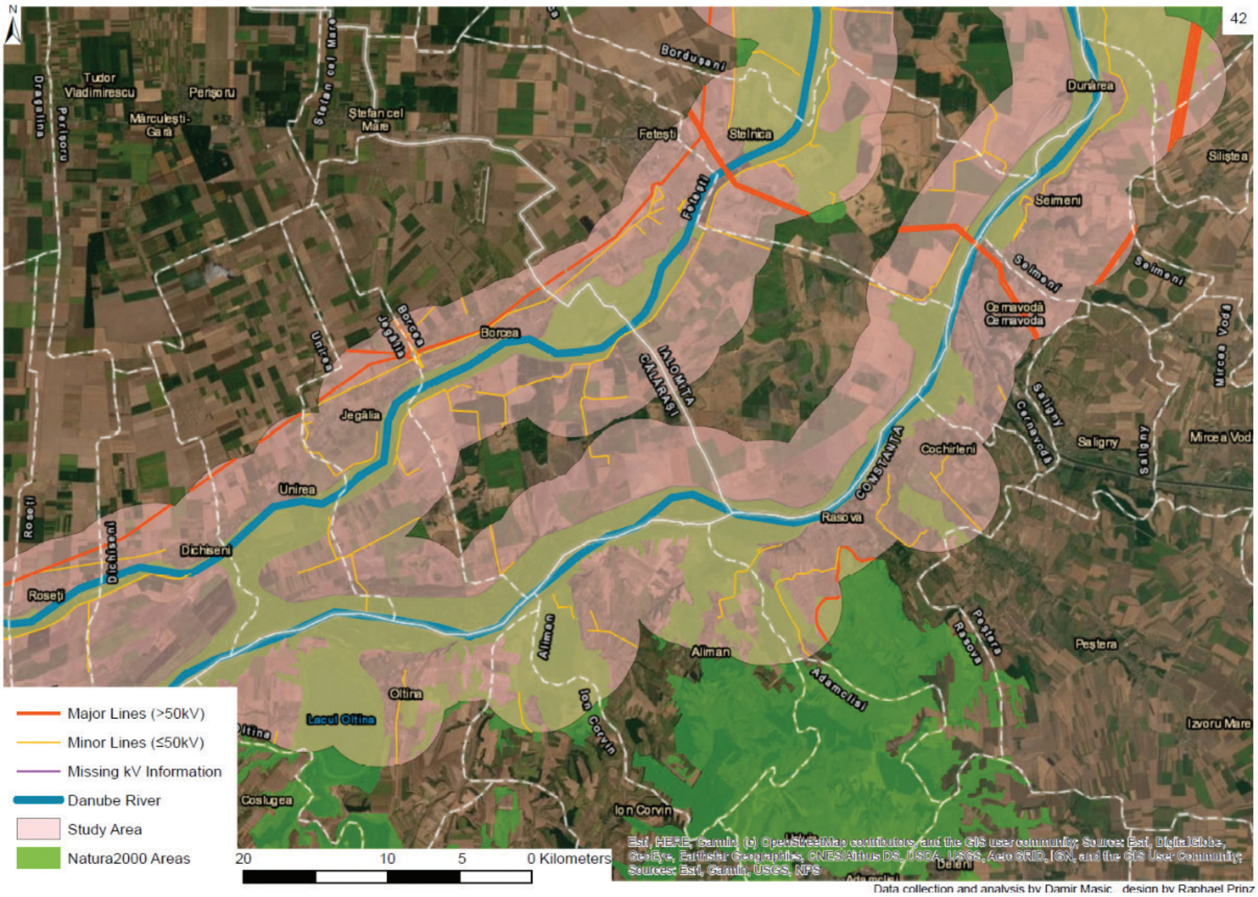
Map 39 (Bulgaria/Romania): Ruse – Giurgiu – Gostinu



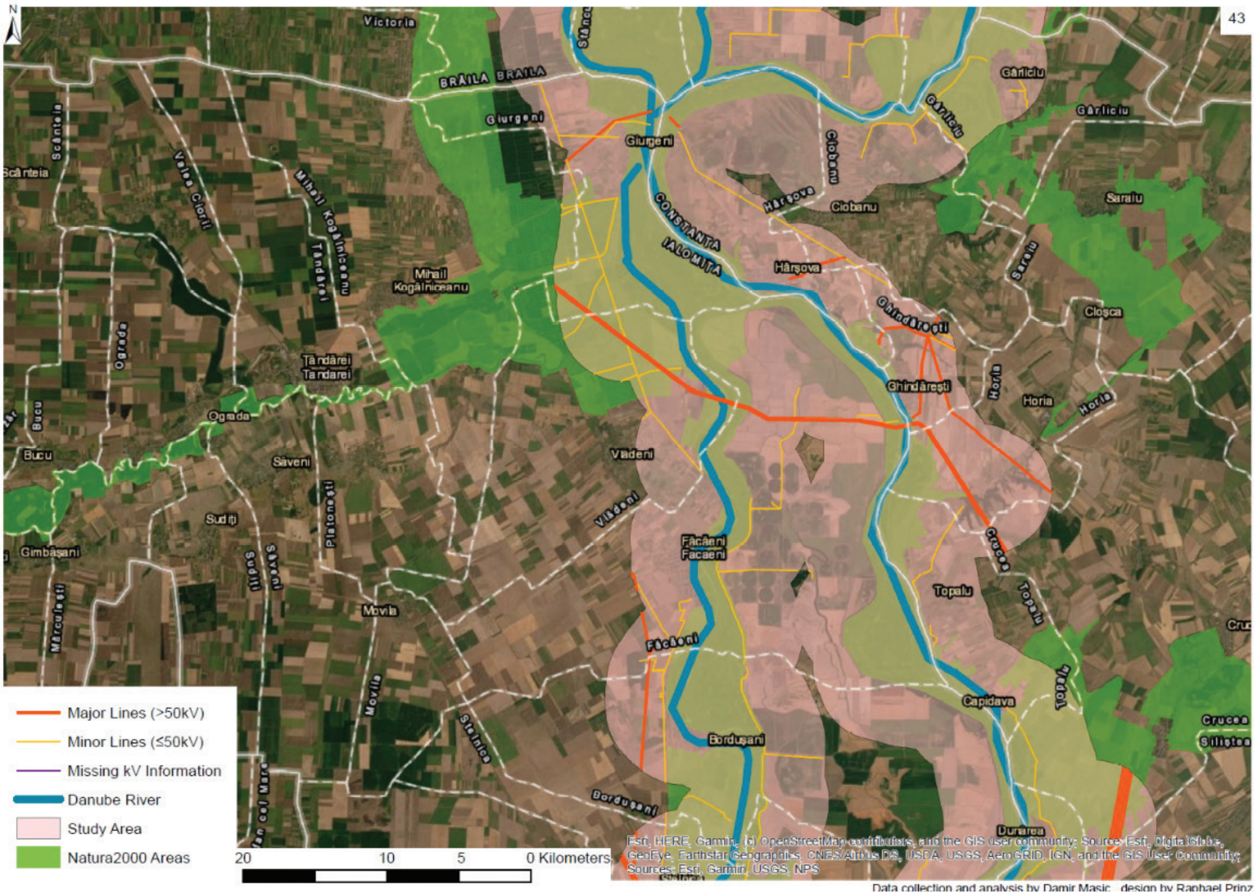
Map 40 (Bulgaria/Romania): Nova Cherna – Tutrakan – Popina



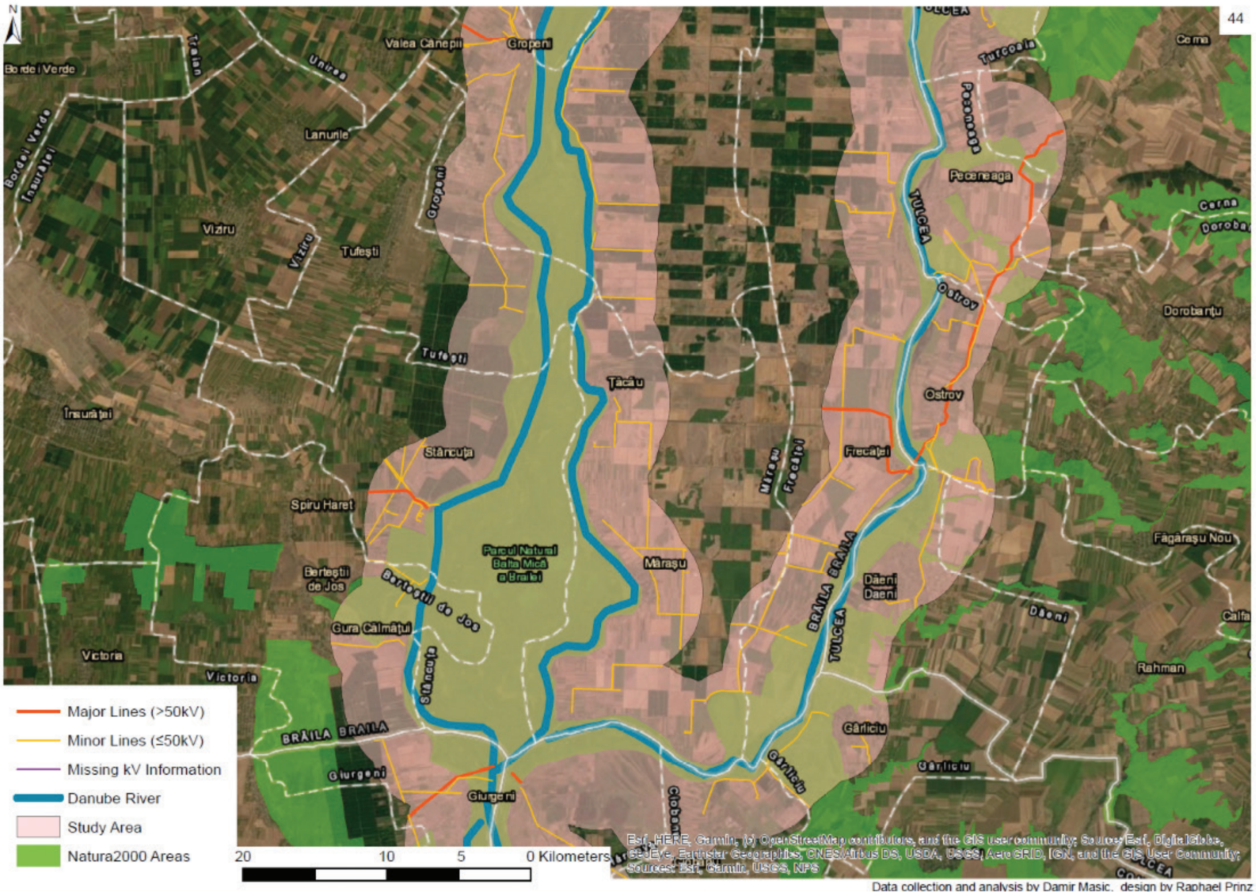
Map 41 (Bulgaria/Romania): Popina – Oltina



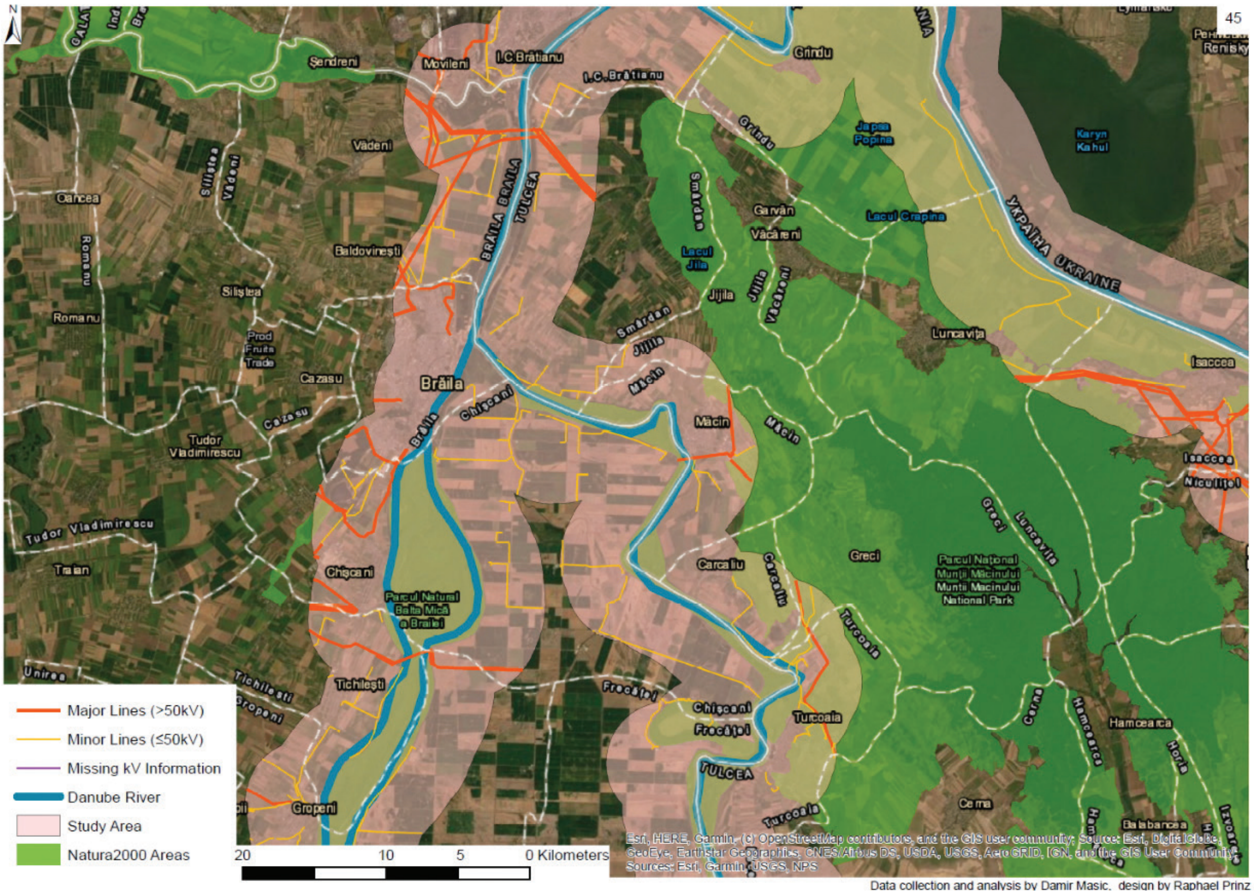
Map 42 (Romania): Oltina – Cernavoda



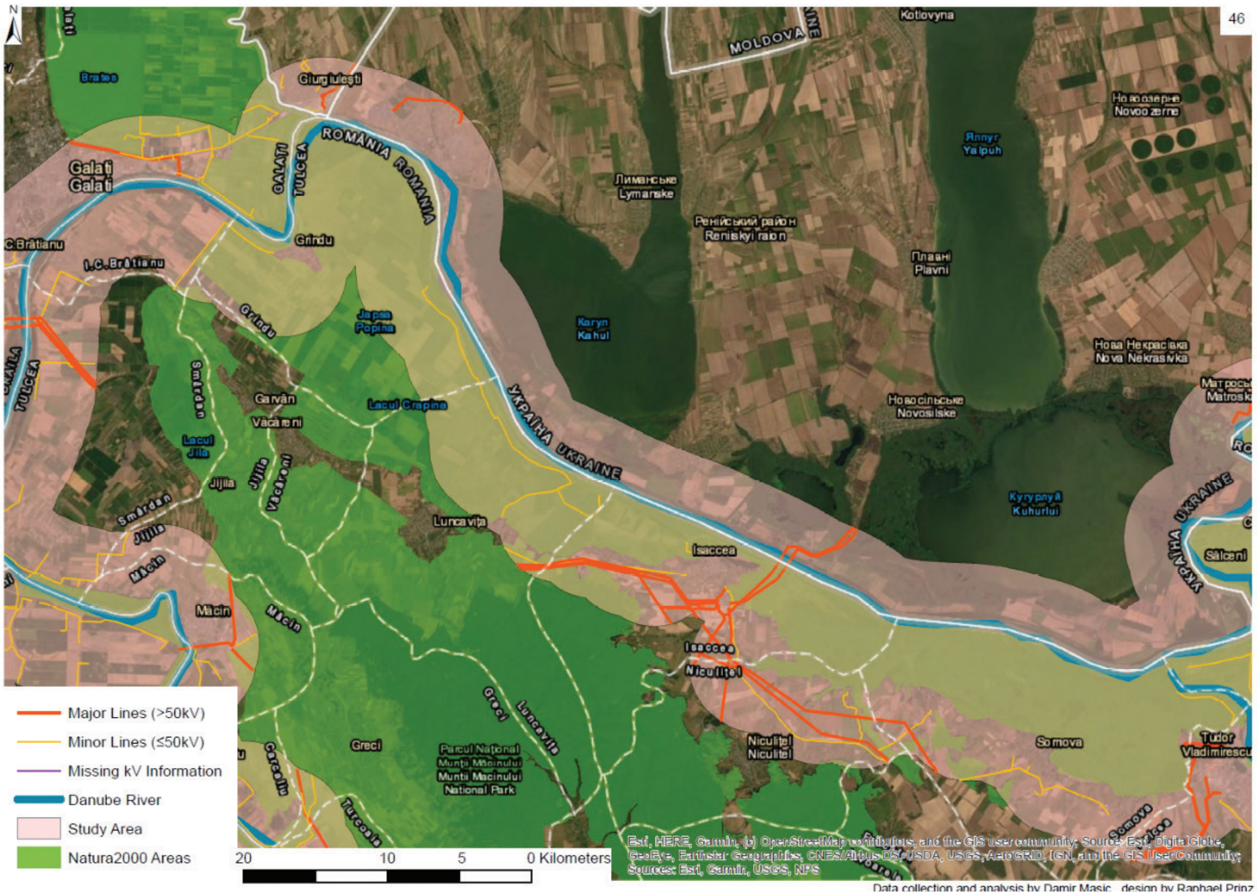
Map 43 (Romania): Cernavoda – Hârșova



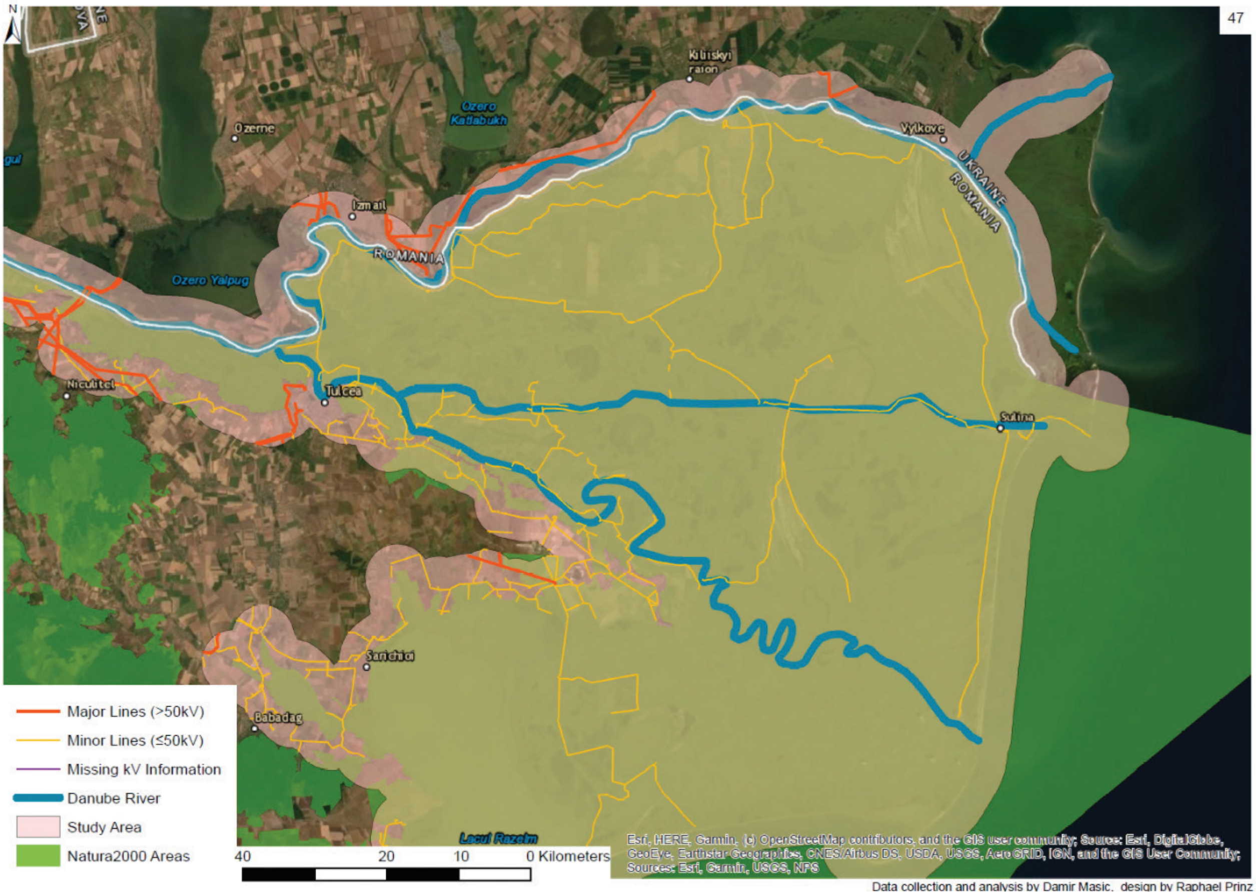
Map 44 (Romania): Hârșova - Gropeni



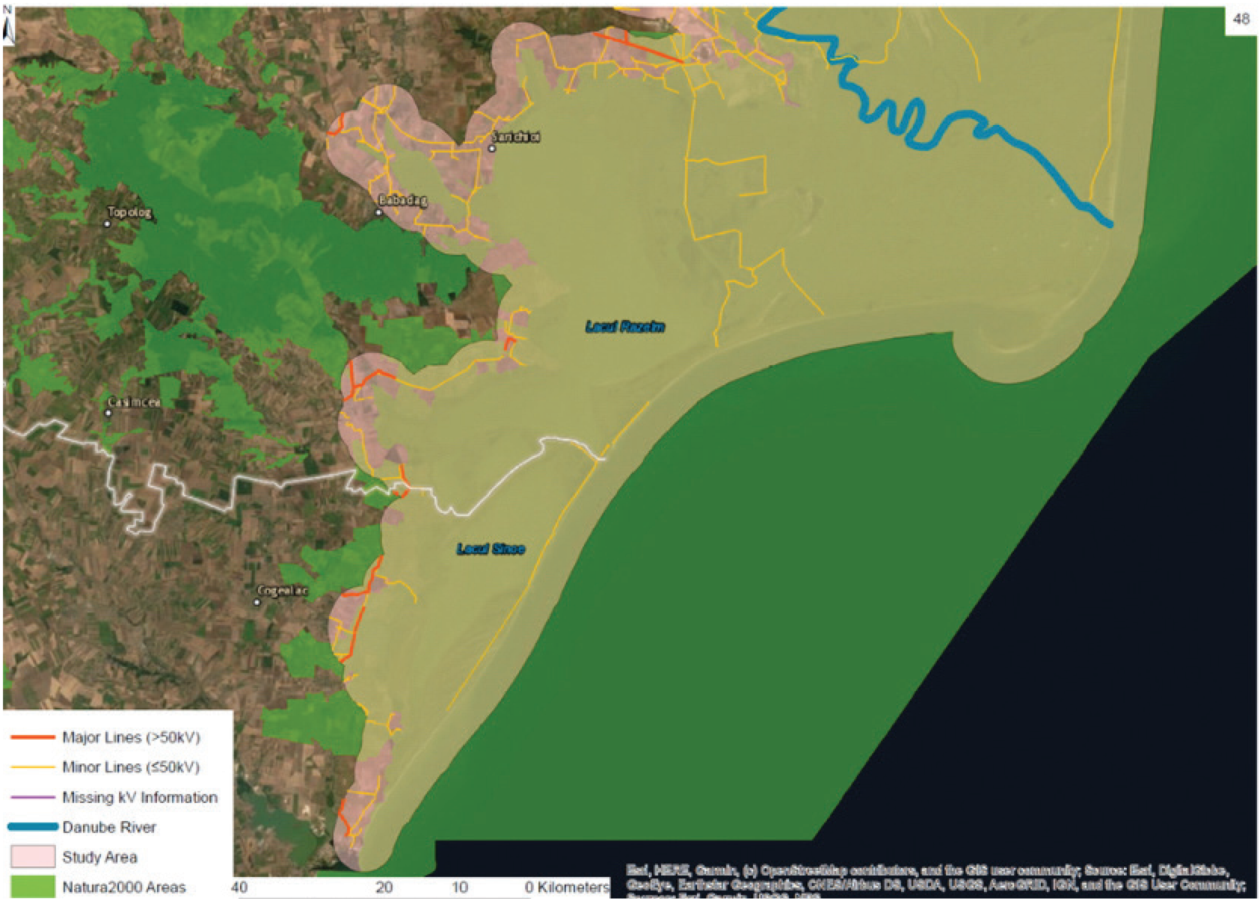
Map 45 (Romania): Gropeni – Braila – Isaccea



Map 46 (Romania/Molodva/Ukraine): Galati – Isaccea



Map 47 (Romania/Ukraine): Tulcea – Sulina



Map 48 (Romania): Danube Delta southern part

Annex 2

Electricity pylons and their risk for birds related to electrocution

Fig. 1: ***High Risk:*** *Metal cross-arm pylon with a combination of support insulators and exposed jumper wire locations. ©* ***Raptor Protection of Slovakia***

*Fig. 2: **High risk:** Corner pylon with a combination of support insulators and exposed jumper wire locations. © **Raptor Protection of Slovakia***

Fig. 3: ***High risk:*** *Electric pole with one exposed jumper wire above the console.*
© Raptor Protection of Slovakia

Fig. 4: ***High risk:*** *Electric pole with three exposed jumper wires above the console.*
© Raptor Protection of Slovakia

Fig. 5: ***Medium risk:*** *Electric pole with a vertical position of support insulators on console.*
© Raptor Protection of Slovakia

*Fig. 6: **Medium risk:** Electric pole with a pair of support insulators in vertical position on console. © **Raptor Protection of Slovakia***

Fig. 7: ***Medium risk:*** *Electric pole transformer with a combination of exposed jumper wires locations. ©* ***Raptor Protection of Slovakia***

Fig. 8: ***Medium risk:*** *Power line switch disconnector.*
© Raptor Protection of Slovakia

Fig. 9: ***Medium risk:*** *Electric pole with hanging exposed jumper wires below the console.*
© Raptor Protection of Slovakia

Fig. 10: ***Low risk:*** *Electric pole with 45° angle of the arms.*
© Raptor Protection of Slovakia

Fig. 11: ***Low risk:*** *Double circuit electric pole with hanging insulators.*
© Raptor Protection of Slovakia

Fig. 12: ***Low risk:*** *Electric pole with hanging insulators.*
© Raptor Protection of Slovakia

Fig. 13: ***Low risk:*** *Double circuit electric pole with 45° angle of the arms.*
© Raptor Protection of Slovakia

Annex 3

List of Special Protected Areas for Birds (Natura 2000 SPA) and Important Bird Areas (IBAs, in the case of Serbia) located in the project area

1.1 List of SPAs and their surface in the study area

No.	Country name	Site code	Site name	SPA surface (ha)	SPA surface within study area (ha)	% of SPA surface within study area (%)
1	Austria	AT1202V00	March-Thaya-Auen	14832.76	700	5
2	Austria	AT1204V00	Donau-Auen östlich von Wien	9100.06	9100	100
3	Austria	AT1205000	Wachau - Jauerling	21110.56	16359	77
4	Austria	AT1207000	Kamp- und Kremstal	24282.67	1800	7
5	Austria	AT1211000	Wienerwald - Thermenregion	79812.84	2001	3
6	Austria	AT1213V00	Sandboden und Praterter-rasse	16019.79	1113	7
7	Austria	AT1216V00	Tullnerfelder Donau-Auen	17763.56	17723	100
8	Austria	AT1218V00	Machland Süd	1226.97	1227	100
9	Austria	AT1219V00	Pielachtal	1025.57	303	30
10	Austria	AT1301000	Nationalpark Donau-Auen (Wiener Teil)	2258	2201	97
11	Austria	AT1304000	Bisamberg (Wiener Teil)	340	167	49
12	Austria	AT3112000	Oberes Donautal	924	925	100
13	Austria	AT3114000	Traun-Donau-Auen	664	610	92
14	Bulgaria	BG0000237	Ostrov Pozharevo	975.79	976	100
15	Bulgaria	BG0000241	Srebarna	1448.22	1430	99
16	Bulgaria	BG0002006	Ribarnitsi Orsoya	475.43	475	100
17	Bulgaria	BG0002007	Ostrov Ibisha	399.32	399	100
18	Bulgaria	BG0002008	Ostrov do Gorni Tsibar	218.43	218	100
19	Bulgaria	BG0002009	Zlatiyata	43498.73	4553	10
20	Bulgaria	BG0002017	Kompleks Belenski ostrovi	7009.77	7010	100
21	Bulgaria	BG0002018	Ostrov Vardim	1167.55	1168	100
22	Bulgaria	BG0002024	Ribarnitsi Mechka	2582.34	2582	100
23	Bulgaria	BG0002025	Lomovete	33451.32	626	2
24	Bulgaria	BG0002030	Kompleks Kalimok	9429.22	9428	100
25	Bulgaria	BG0002031	Stenata	79.73	80	100

26	Bulgaria	BG0002064	Garvansko blato	324.27	324	100
27	Bulgaria	BG0002065	Blato Malak Preslavets	372.22	372	100
28	Bulgaria	BG0002067	Ostrov Golya	414.56	415	100
29	Bulgaria	BG0002074	Nikopolsko plato	22246.4	3648	16
30	Bulgaria	BG0002083	Svishtovsko-Belenska nizina	5439.8	3630	67
31	Bulgaria	BG0002091	Ostrov Lakat	1260.94	1261	100
32	Bulgaria	BG0002104	Tsibarsko blato	909.76	910	100
33	Croația	HR1000016	Podunavlje i donje Podravlje	66335.33	46586	70
34	Germania	DE7037471	Felsen und Hangwälder im Altmühl-, Naab-, Laber- und Donautal	4831.19	1308	27
35	Germania	DE7040402	Wälder im Donautal	1289	893	69
36	Germania	DE7040471	Donau zwischen Regensburg und Straubing	3276.43	3276	100
37	Germania	DE7132471	Felsen und Hangwälder im Altmühltal und Wellheimer Trockental	3610.89	4	0,12
38	Germania	DE7142471	Donau zwischen Straubing und Vilshofen	6914.13	6910	100
39	Germania	DE7229471	Riesalb mit Kesseltal	12068.95	443	4
40	Germania	DE7231471	Donauauen zwischen Lechmündung und Ingolstadt	6995.12	6985	100
41	Germania	DE7243402	Isarmündung	2132	1994	94
42	Germania	DE7330471	Wiesenbrüterlebensraum Schwäbisches Donauried	3994.55	3185	80
43	Germania	DE7427471	Schwäbisches Donaumoos	2592.66	1606	62
44	Germania	DE7428471	Donauauen	8084.84	7744	96
45	Germania	DE7527441	Donauried	4253.18	610	14
46	Germania	DE7624441	Täler der Mittleren Flächenalb	5692.36	1202	21
47	Germania	DE7820441	Südwestalb und Oberes Donautal	43030.98	8192	19
48	Germania	DE7921401	Baggerseen Krauchenwies/ Zielfingen	750.13	736	98
49	Germania	DE8017441	Baar	37701.59	9712	26
50	Germania	DE8018401	Höwenegg	20.74	21	100
51	Germania	DE8116441	Wutach und Baaralb	14002.46	339	2
52	Romania	ROSPA0001	Aliman - Adamclisi	18908.7	423	2
53	Romania	ROSPA0002	Allah Bair - Capidava	11715.7	7623	65
54	Romania	ROSPA0005	Balta Mică a Brăilei	25802	25702	100

55	Romania	ROSPA0007	Balta Vederoasa	2139.6	1807	84
56	Romania	ROSPA0009	Beştepe - Mahmudia	3654.2	3187	87
57	Romania	ROSPA0011	Blahniţa	44003.3	24698	56
58	Romania	ROSPA0012	Braţul Borcea	13299.2	13196	99
59	Romania	ROSPA0013	Calafat - Ciuperceni - Dunăre	29379.3	18049	61
60	Romania	ROSPA0017	Canaralele de la Hârşova	7304.8	7234	100
61	Romania	ROSPA0021	Ciocăneşti - Dunăre	801.2	801	100
62	Romania	ROSPA0023	Confluenţa Jiu - Dunăre	19530.2	7459	38
63	Romania	ROSPA0024	Confluenţa Olt - Dunăre	20483.8	12517	61
64	Romania	ROSPA0026	Cursul Dunării - Baziaş - Porţile de Fier	10331	10326	100
65	Romania	ROSPA0031	Delta Dunării şi Complexul Razim - Sinoie	508302.3	488570	96
66	Romania	ROSPA0032	Deniz Tepe	1896.6	425	22
67	Romania	ROSPA0038	Dunăre - Olteniţa	5927.8	5880	100
68	Romania	ROSPA0039	Dunăre - Ostroave	16243.8	16235	100
69	Romania	ROSPA0040	Dunărea Veche - Braţul Măcin	19011.8	16040	84
70	Romania	ROSPA0046	Gruia - Gârla Mare	2963.9	2918	98
71	Romania	ROSPA0051	Iezerul Călăraşi	5008.7	1938	39
72	Romania	ROSPA0052	Lacul Beibugeac	469	469	100
73	Romania	ROSPA0053	Lacul Bugeac	1385.4	1384	100
74	Romania	ROSPA0054	Lacul Dunăreni	1269.7	1269	100
75	Romania	ROSPA0056	Lacul Oltina	3309.9	2185	66
76	Romania	ROSPA0060	Lacurile Taşaul - Corbu	2734	199	7
77	Romania	ROSPA0073	Măcin - Niculiţel	67308.8	4580	7
78	Romania	ROSPA0074	Maglavit	3642.5	3641	100
79	Romania	ROSPA0076	Marea Neagră	149143.9	53553	36
80	Romania	ROSPA0080	Munţii Almăjului - Locvei	117770.7	46521	40
81	Romania	ROSPA0090	Ostrovu Lung - Gostinu	2544	2543	100
82	Romania	ROSPA0091	Pădurea Babadag	57912	1423	2
83	Romania	ROSPA0102	Suhaia	4516	3516	78
84	Romania	ROSPA0108	Vedea - Dunăre	22404.2	17525	78
85	Romania	ROSPA0111	Berteştii de Sus - Gura Ialomiţei	6864.6	1	0,02
86	Romania	ROSPA0120	Kogălniceanu - Gura Ialomiţei	7087.6	2204	31
87	Romania	ROSPA0121	Lacul Brateş	15878.9	3185	20

88	Romania	ROSPA0135	Nisipurile de la Dăbuleni	11009.2	9130	83
89	Romania	ROSPA0136	Oltenița - Ulmeni	12405	9382	76
90	Slovacia	SKCHVU004	Dolné Pohronie	229.32	78	34
91	Slovacia	SKCHVU005	Dolné Považie	31195.5	567	2
92	Slovacia	SKCHVU007	Dunajské luhy	16511.58	17572	100
93	Slovacia	SKCHVU016	Záhorské Pomoravie	31072.92	98	0,32
94	Slovacia	SKCHVU029	Sysľovské polia	1772.94	297	17
95	Ungaria	HUDD10003	Gemenc	19641.18	17279	88
96	Ungaria	HUDD10004	Béda-Karapancsa	8722.01	7715	88
97	Ungaria	HUDI10002	Börzsöny és Visegrá-di-hegység	49556.83	12405	25
98	Ungaria	HUDI10003	Gerecse	29597.89	2510	8
99	Ungaria	HUDI10006	Tatai Öreg-tó	2623.98	556	21
100	Ungaria	HUFH10004	Mosoni-sík	13096.43	78	1
101	Ungaria	HUFH30004	Szigetköz	17183.02	11938	69
102	Ungaria	HUKN10001	Felső-kiskunsági szikes puszták és turjánvidék	15776.02	1096	7
103	Ungaria	HUKN10002	Kiskunsági szikes tavak és az őrjegi turjánvidék	35722.19	174	0,49
Total SPA					1,095,581	36%
1	Serbia		Karadjordjevo	48494.8	4734.9	98
2	Serbia		Usce Save u Dunav	98098.9	8993.6	92
3	Serbia		Gornje Podunavlje	22606.7	17799.7	79
4	Serbia		Koviljski rit	95942.1	9556.4	100
5	Serbia		Fruska gora	49205.3	3053	6
6	Serbia		Mala Vrbica	19142.8	1914.2	100
7	Serbia		Djerdap	77163.5	38892.3	50
8	Serbia		Labudovo okno	64886.9	6488.6	100
9	Serbia		Dunavski lesni odsek	53043.8	5304.3	100
Total IBA Serbia					96737.6	52%