PRESPA OHRID NATURE TRUST (PONT)

“Description of the Connectivity Conservation Area (CCA) in North-Western Greece: a PONT study”

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Photo of the cover page: Balkan chamois group with kids on mt Tymfi (photo credit: Balkan Chamois Society) and brown bear on mt Tymfi (photo credit: Balkan Chamois Society).
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1. INTRODUCTION

1.1. Connectivity conservation

Connectivity conservation is a topical issue in conservation science, as important areas with great natural capacity, biodiversity value and great potential in ecosystem services delivery should be connected with natural areas or corridors to maximize the integrity of ecological processes in fragmented landscapes (Battisti et al. 2022). Land use change, including land artificialization, is the most important driver of global diversity decline (IPBES 2019; Díaz et al. 2019). Land artificialization refers to land take, the conversion of natural land to artificial surfaces, including sealed surfaces with an impermeable material (EEA 2019a), and derives from urbanization, road sprawl and industrial activities expansions, including the deployment of renewable energy sources infrastructures (Ibisch et al. 2016; Theobald et al. 2020; UN 2015). Landscape fragmentation refers to the division of habitat into smaller and more isolated fragments separated by a matrix of human-transformed land cover and is reported to reduce biodiversity and impair key ecosystem functions by decreasing biomass and altering nutrient cycles (Haddad et al. 2015). Increasing the extent of land under conservation management, restoring degraded land and generalizing landscape-level conservation planning is the most efficient tool to reverse biodiversity decline and ecosystem degradation at a global, regional and local scale (Leclère et al. 2020).

Establishing well-connected natural areas through ecological networks is the key strategy toward this aim. This is recognized in the first target of the Kunming-Montreal global biodiversity framework, aspiring to bring the loss of areas of high biodiversity importance and ecosystems of high ecological integrity close to zero by 2030 (CBD 2022). This is also explicitly recognized in the EU Biodiversity Strategy for 2030 (EC 2020), where article 2.1. calls for a coherent network of protected areas that would legally protect a minimum of 30% of the EU’s land area and 30% of the EU’s sea area and integrate ecological corridors as part of a true Trans-European Nature Network while strictly protecting at least a third of the EU’s protected areas, including all remaining EU primary and old-growth forests. Although Greece has almost achieved the 30% target of its land protection under a system of protected areas (Natura 2000 cover in Greece is 27.3%), the challenge now is defining natural areas that can act as stepping stones or ecological corridors allowing the free movement of wildlife among their habitats, including Natura 2000 sites.

1.2. Study area and objectives

The current study assesses the options and opportunities for enhancing connectivity conservation in North-Western Greece. The Greek study area extends from Prespa National Park to the North, up to the southern part of Northern Pindos National Park (Mitsikeli Mt), along the Greek-Albanian borders. The area extends over 5,844 km². It has high ecological value, as evinced by the extended Natura 2000 network of protected areas (Fig. 1b). The specific goal of the study is to understand the connectivity potential of the broader PONT study area, including Albania, North Macedonia and Greece (Fig. 1a). It specifically aims to understand how the Polis-Sopot-Valamare-Gramoz Connectivity conservation Area in SE Albania (see purple target corridor in Fig. 1a) (Melovski D. et al. 2022) relates to one or more respective Connectivity conservation Areas (CCAs) within the study area (Fig. 1b). The CCA defined is expected to benefit biodiversity and ecosystem function, with a special focus on enhancing the connectivity of large mammal habitats.
Frame of the study

The study was assigned by the “Prespa Ohrid Nature Trust” (PONT), a foundation established under German Law, supporting Protected Areas (PAs) and Environmental Actors (EAs) in the PONT Focus Area in Albania, North Macedonia and Greece, with the mission to conserving nature for a sustainable future through long-term partnerships and financing to the Consultant “Charitakis Papaioannou EE.”

The study's research team comprises (a) The Consultant, Dr. H. Papaioannou. He is a conservation biologist with long-standing research experience in the study area with a special focus on large mammal and Balkan chamois ecology and conservation. He has accomplished several conservation and sustainable development projects for the Epirus region, having authored a suite of books, reports and eco-guides for the same area. (b) A. Manolopoulos, a GIS and data analyst expert working with wildlife. (c) M. Petridou, an expert on wolf ecology with GIS expertise, is currently finalizing her Ph.D. thesis on human-wolf conflict minimization, including the project study area in her research. (d) V. Kati, a Professor of Biodiversity Conservation and head of the Biodiversity Conservation Lab in the Dep. of Biological Applications and Technology of the University of Ioannina, has long-standing research experience in the study area in the applied conservation science and the science-policy interface.
The Consultant provides deliverables as indicated in the TOR and the Consultancy Services Agreement, related to (a) The study design and methodology, (b) A preliminary outline/ map of potential Connectivity Conservation Area(s), (c) A report describing the Connectivity conservation Area(s)-CCA(s) in NW Greece and (d) A report including a suite of suggestions to PONT on launching a connectivity initiative in the Connectivity conservation Area(s) indicated in the previous deliverables. The current study refers to the third deliverable outlined in the methodological design of enhancing connectivity conservation in North-Western Greece (Papaioannou et al. 2022).

2. METHODS

2.1. Delineation of the PP-CCA

Without large mammal accurate distribution data, this study adopted a landscape-based approach for enhancing connectivity in NW Greece (Papaioannou et al. 2022). We aimed to understand the connection of the ecosystems of Prespes National Park with the ecosystems of North Pindos National Park through one or several large corridors functioning as connectivity conservation areas. To do so, we employed a multilevel integrated approach for the terrestrial part of the study area, combining the approaches of wilderness area preservation (roadless areas thematic map) with fragmentation minimization (Landscape Fragmentation Index thematic map) and ecosystem services delivery (Natura 2000 ecosystem connectivity map). Freshwater connectivity was treated as a separate thematic map (section 2.3). The distribution range maps of large mammal species were not included in the process of CCA(s) delineation since they are coarse scale range maps at 10km X 10 km scale. They were used to cross-check the overlap of CCA(s) with the range of large mammal species (sections 6 to 9). Due to the high naturalness of the study area, it was possible to designate only one large connectivity area, hereafter Pindos-Prespes Connectivity conservation Area (PP-CCA). The workflow of this process is presented in Fig. S1, and the methodological steps in Appendix I.1

2.2. Description of the PP-CCA

We prepared a suite of thematic maps to describe the PP-CCA in terms of topography, hydrography, habitat types (vegetation), human impact, landscape fragmentation, wilderness character, administration configuration, and protected areas. We also prepared relevant thematic maps and accessed the appropriate open sources to present pressures and threats in the PP-CCA associated with land use change (land take and forest encroachment), fire vulnerability, human-originated or natural pressures in the Natura 2000 network of protected areas, and infrastructure deployment of Renewable Energy Sources (wind, solar, hydropower). The methodological steps of thematic map preparation and data analysis are presented in Appendix I.2.

2.3. Delineation of large mammals’ corridors

Connecting roadless areas: the rationale

The main output of the current study is the delineation and description of the PP-CCA as a large “corridor” of high naturalness that connects the ecosystems of the Prespes-N.Pindos National Parks. However, we proceeded to a connectivity analysis exercise within the PP-CCA at a finer scale, targeting specifically four large mammal species: the Balkan chamois (*Rupicapra rupicapra balcanica*), the brown bear (*Ursus arctos*), the grey wolf (*Canis lupus*) and the otter (*Lutra lutra*). Habitat connectivity analysis is usually handled on a species-by-species case, using detailed species distribution and habitat use data, which allows for performing habitat suitability mapping and, subsequently, a connectivity analysis to define ecological corridor among the targeted species habitats (Melovski et al. 2022a,b).

In the absence of such detailed distribution and habitat-used data for the four targeted large mammals, we used the roadless sites as a surrogate of adequate habitats for the three targeted terrestrial mammal species (Balkan chamois,
grey wolf and brown bear). Scientific evidence shows that the Balkan chamois avoids roads and human settlements and shows a human avoidance pattern by selecting the roadless parts of the mountains it inhabits, as indicated for the Tymfi mountain (Kati et al. 2020b). A telemetry study also showed that the brown bear showed a similar avoidance pattern, selecting sites of low human disturbance during the day and areas of high human disturbance during the night in the absence of human activities. It selected habitats with naturalized crops (i.e., abandoned/non-intensive) close to water sources, while around their hibernation period, they were found to select rough-terrain areas (del Garbriel Hernando et al. 2021). Finally, while the wolf is an opportunistic and flexible predator with large spatial requirements, it is reported to avoid human disturbance when selecting breeding sites (rendezvous sites); these sites are away from roads and villages, close to water sources, and have low forest fragmentation (Iliopoulos et al. 2014). Moreover, a recent study showed that wolves attempt to mitigate human disturbance by increasing their nocturnality in areas with high human disturbance (i.e., areas with a high occurrence of humans, vehicles, dogs, and livestock) (Petridou et al. under review - b). Recent research has also underlined the wilderness character of the roadless areas of Greece: roadless sites are inaccessible, deprived of human infrastructures, have low human disturbance, great cover of forested land and harsher topography (Kati et al. 2020a, Kati et al. under review). Considering the characteristics of roadless areas combined with the targeted species’ ecology (sections 6-9) with particular reference to their sensitivity to human disturbance, we used roadless sites as surrogates of important habitats for large mammals. Further research is needed on the fine-scale distribution pattern and habitat selection of the four targeted large mammal species to delineate corridors among their core habitats while cross-checking with our roadless approach.

**Weighted overlay analysis: chamois, bear, wolf**

In our analysis, we considered by convention the roadless areas within the PP-CCA as core habitats for the chamois, the bear and the wolf. We then connected the roadless areas with corridors that considered the minimization of the mobility and energetic costs for the targeted species. We calculated two cost surfaces for the mobility (a) of the Balkan chamois and (b) of large carnivores, namely the bear and the wolf. We prepared four thematic maps (criteria maps) for each of the two cost surfaces for corridor selection to be used in the analysis: habitat suitability, slope, distance to roads, and hydrography. Each criterion was classified on a 1 to 10 scale. Habitat evaluation on a 1-10 scale was performed after expert opinion based on the ecology of the species, whereas slope, distance to roads and distance from freshwater resources were calculated through GIS. The selected corridors for the Balkan chamois should be located in adequate habitats for the species, in steeper terrains, away from roads and in proximity to freshwater resources, minimizing the energy cost for its free movement among the roadless areas (see species ecology in section 6). The selected corridors for the brown bear and the grey wolf should be located in adequate habitats for the species, in terrains with milder slopes, away from roads and in proximity to freshwater resources, minimizing the energy cost for the free movement of the species among the roadless areas (see species ecology in sections 7 and 8). We then weighted all criteria to create the two map surfaces for the Balkan chamois and large carnivores. These surfaces show the cost in terms of the mobility of each species group within the CCA. The workflow of this process is presented in Fig. S1, and the methodological steps of thematic maps and data analysis are in Appendix I. 3

**Corridor selection: chamois, bear, wolf**

Within these mobility cost surfaces, we estimated the ecological connectivity corridors having as basis the roadless areas, which also coincided with the distribution range of the three target species. We applied a cost connectivity
algorithm (Based on Set Theory, Urban and Keitt, 2001) between the roadless areas and the cost surfaces. This method finds the optimal corridor between a set of given areas (roadless areas). The corridor avoids the areas of the cost surface which have high values. The outcome of this method is the optimal connectivity corridor together with the secondary corridors that indicate the overall corridor connectivity. The corridors under the name “priority corridors” are indicative of the corridors that large mammals can use since no detailed distribution data are available.

**Otter connectivity**

We combined all information related to the study area’s hydrographic features, producing a map of the freshwater network across the six basins of the PP-CCA. Since the otter is strongly dependent on freshwater resources (see species ecology in section 9), its mobility is restricted along rivers, streams, and lakes. Therefore, the freshwater map function as the otter connectivity map of free movement along freshwater resources.

**2.4. Stakeholder consultation**

After producing the PP-CCA, we shared the map of the PP-CCA with several stakeholders and experts with a longstanding professional and research experience in the study area, besides the research team members, for consultation. We shared with all stakeholders the PP-CCA and additionally, we shared the indicative corridors (PC) with selected experts on large mammals. We have contacted the following:

(a) EKBY- Hellenic Center for Habitats and Wetlands,
(b) N.E.C.C.A. (Natural Environment & Climate Change Agency) and the respective Management Units within the study area (Prespa and N. Pindos National Parks),
(c) The Society for the Protection of Prespa,
(d) Callisto NGO [PP-CCA and PC for brown bear and wolf],
(e) Arcturos NGS [PP-CCA and PC for brown bear and wolf],
(f) Consultant Company undertaking the special environmental study for the W. Macedonia,
(g) Hellenic Ornithological Society,
(h) Zagori Ecomuseum (Social Cooperative Enterprise),
(i) Dr. Mertzanis Giorgos, conservation biologist- expert on brown bear,
(j) Dr. Iliopoulos Giorgos, conservation biologist- expert on wolf and
(k) Mr. Theodoropoulos, environmental scientist, M.Sc.- expert on otter.
(l) Regarding Balkan chamois, there was no need to ask any other scientist, as Dr. Papaioannou H. participated in this study, is the expert on this species.

A summary of the Stakeholders’ feedback is presented in Appendix I.4.
2.5. Overview of geospatial data used

We present an overview of the geospatial data used in the spatial analysis (Table 1). As a background map, we have used the coastline of Greece provided by the Hellenic Navy Hydrographic Service (HNHS 2018). Spatial analysis was performed in ArcGIS Desktop.

Table 1: Overview of the geospatial datasets used in the current study

<table>
<thead>
<tr>
<th>Reference</th>
<th>Datasets</th>
<th>Type</th>
<th>Source</th>
<th>Access</th>
</tr>
</thead>
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<tr>
<td>Geodata 2015g</td>
<td>Municipalities borders (Kallikratis) 11-4-2015</td>
<td>vector</td>
<td><a href="https://geodata.gov.gr/dataset/ethnika-parka">https://geodata.gov.gr/dataset/ethnika-parka</a></td>
<td>29/12/2022</td>
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<tr>
<td>Copernicus 2022</td>
<td>Corine Land Cover change between 2000 and 2006 100x100m resolution</td>
<td>raster</td>
<td><a href="https://land.copernicus.eu/pan-european/corine-land-cover/lcc-2000-2006">https://land.copernicus.eu/pan-european/corine-land-cover/lcc-2000-2006</a></td>
<td>29/12/2022</td>
</tr>
<tr>
<td>Copernicus 2022</td>
<td>Corine Land Cover change between 2006 and 2012 (dataset v.2020_20u1), 100x100m resolution</td>
<td>raster</td>
<td><a href="https://land.copernicus.eu/pan-european/corine-land-cover/lcc-2006-2012?tab=download">https://land.copernicus.eu/pan-european/corine-land-cover/lcc-2006-2012?tab=download</a></td>
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<tr>
<td>Copernicus 2022</td>
<td>Corine Land Cover change between 2012 and 2018 (dataset v.2020_20u1), 100x100m resolution</td>
<td>raster</td>
<td><a href="https://land.copernicus.eu/pan-european/corine-land-cover/lcc-2012-2018?tab=download">https://land.copernicus.eu/pan-european/corine-land-cover/lcc-2012-2018?tab=download</a></td>
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<td>-----------</td>
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<tr>
<td>HII 2019</td>
<td>Human Influence Index</td>
<td>raster</td>
<td>Human Impact Index of the year 2019, 300x300m resolution <a href="https://wcshumanfootprint.org/data-access">https://wcshumanfootprint.org/data-access</a></td>
<td>29/12/2022</td>
</tr>
<tr>
<td>OSM 2022</td>
<td>OSM</td>
<td>vector</td>
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<td>6/10/2022</td>
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<td>Kassara et al. 2022</td>
<td>Roadless areas</td>
<td>vector</td>
<td>The roadless map of Greece. Mendeley Data, v2. <a href="http://doi.org/10.17632/s6zh89fb5c.2">http://doi.org/10.17632/s6zh89fb5c.2</a> Installation polygons of current (operational license) and future (installation license, production license or under evaluation) Renewable Energy Sources projects <a href="https://geo.rae.gr/">https://geo.rae.gr/</a></td>
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<td>RES projects</td>
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3. THE PINDOS-PRESPES CONNECTIVITY CONSERVATION AREA (PP-CCA)

3.1. Extent

Our analysis resulted in one wide connectivity conservation area, under the name Pindos-Prespes Connectivity conservation Area (PP-CCA), covering a total of 4,387 km$^2$, which accounts for 75% of the study area. This area can function as a single corridor connecting the ecosystems of Prespa National Park to the ecosystems of Northern Pindos National Park, up to the Mitsikeli mountain. Figure 2 presents the PP-CCA and the configurations of the spatial overlap of the three criteria used for its delineation: roadless areas (Kassara et al. 2022), areas with very low fragmentation (LFI<1.5) defined after the Landscape Fragmentation Index of the European Environmental Agency (EEA 2019 b), and the areas defined by the connectivity map for Ecosystem Services maintenance, including the Natura 2000 network of protected areas in the study area, provided by the Hellenic Center for Habitats and Wetlands (EKBY) (EKBY 2019). Each polygon of the PP-CCA was scored from one to three, according to the number of the criteria satisfied (Fig. 2).

Figure 2: The Pindos-Prespes Connectivity conservation Area (PP-CCA) and the spatial configuration of the three criteria used: (a) Roadless areas, (b) Landscape Fragmentation Index score <1.5 and (c) the Connectivity map for Ecosystem Services maintenance, including the Natura 2000 network
The PP-CCA covers most of the study area with few gaps.

- It comprises an extensive compact part at the south to the center of the study area, which includes all the mountainous and hilly areas of the Northern Pindus mountain range: Mt Mitsikeli, Mt Timfi, Mt Trapezitsa, Mt Smolikas-Kleftis, Mt Vasilitsa, Mt Aygo, Mt-Tambouri, Mt Nemertsika, Mt Grammos and Mt Voio.
- Then from the south to the north, there is quite a large area at the center-east part of the study area, which is not included in the PP-CCA as it does not cover any of the three criteria taken into account in our methodology. This is the hilly area NW of Grevena, west of Tsotyli and Neapoli and south-south west of Kastoria. The reason for this can be easily seen on the map as many agriculture plots are scattered around several settlements.
- Then at the north part of the study area up to the borders with the Prespa National Park, there is another more or less compact part of the PP-CCA. It includes Mt Vitsi, the east part of Mt Varnountas and Mt Male-Madi. In contrast to the southern part of the PP-CCA, this part in the north is characterized by few gaps in the middle and at the NW.
- It is important to mention here that the south-central part of the PP-CAA is connected with the north one with only one narrow zone at the west (Dipotamia-Komninades zone), attached at the border zone with Albania and, more specifically, to the central-east point of the Polis-Sopot-Valamare-Gramoz CCA in Albania.
- Finally, it is worth mentioning that the extensive compact part of the PP-CCA located at the south-central part of the study area does not include two polygons at the southwest edge. One is the flat area of Konitsa plain where the two rivers, Aoos and Voidomatis, are connected. This is expected as Konitsa plain is the main agricultural area in NW of Ioannina, close to the borders with Albania. The other polygon is in Pogoni municipality, where several agricultural facilities exist.

3.2. Topography

We considered four elevation zones out of the Digital Elevation Model of Greece (DEM 2019) to describe the PP-CCA topography: <500m, 500-1000m, 1000-1500m, and >1500. The PP-CCA is a mountainous area with an average elevation of 1200m (StDev 366), ranging from 375m up to 2637m (Smolikas mountain summit). The greatest part of the PP-CCA (47.2%) lies in the elevational zone of 1000 – 1500 m, 31% in the zone of 500-1000m, 20% in the highest zone above 1500m and only 1.4% in the lowest elevational zone below 500m (Figure 3a).
We also considered the open database of the European mountain areas (EEA 2019c) to calculate the proportion of land that can be characterized as a mountainous less-favored area. In such areas, considerable limitations exist in using the land and where an appreciable increase in the cost of working under two criteria: (a) the existence, because of altitude, of very difficult climatic conditions, the effect of which is substantially to shorten the growing season, and (b) at a lower altitude, the presence over the greater part of the area in question of slopes too steep for the use of machinery or requiring the use of very expensive special equipment (EEA 2010). In Greece, mountainous areas are characterized as those with an altitude over 800m, an altitude of 600–800m with a slope over 16%, or an altitude below 600m with a slope over 20% (EEA 2010). According to the above criteria, 72% of the PP-CCA falls within the mountainous less-favored zone of Europe.

We finally considered the European dataset of the mean slope length and steepness factor (LS factor) (JRC & ESDAC 2022) and calculated its average of the PP-CCA. LS factor is a dimensionless index ranging from 0 to 99 that combines the slope length and angle to describe the effect of topography on soil erosion. Higher LS values correspond to polygons of harsher topography and greater erosion risk (Panagos et al. 2015). The mean LS factor for the PP-CCA is 5.87, showing a much higher erosion risk than the average of the Greek territory (LS=3.8) and Europe (LS=1.63) (Fig.3b).

3.3. Hydrography

We considered the hydrographical thematic map (Fig. S2d) combining three datasets (EKBY 2019b, Geodata 2015, MEE 2013) to calculate the extent of lakes and the length of permanent rivers and non-permanent streams. Lakes
cover 42.3 km² and the length of the hydrographic network rises to 13,803 km, comprising non-permanent streams (13,333 km) and rivers of permanent flow (470 km) (Fig. 4, Table 2). Aliakmonas basin is the most extended basin of the PP-CCA (46%), followed by Aoos (36%). There are six main hydrographic basins lying within the PP-CCA (Table 2).

**Table 2:** Hydrographic basins (HB) of the PP-CCA, their area and percentage of the PP-CCA extent(%): Lakes: area of lakes. Rivers: length of permanent rivers. Streams: length of non-permanent streams. Total: total length of the hydrographic network.

<table>
<thead>
<tr>
<th>Hydrographic basin</th>
<th>Area (km²)</th>
<th>%</th>
<th>Lakes (km²)</th>
<th>Rivers (km)</th>
<th>Streams (km)</th>
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<td>36</td>
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<td>Arachthos</td>
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<td>Erigonos</td>
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<td>Pinios</td>
<td>35</td>
<td>1</td>
<td>1</td>
<td></td>
<td>101</td>
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<tr>
<td><strong>Total</strong></td>
<td><strong>4387</strong></td>
<td><strong>100</strong></td>
<td><strong>42.3</strong></td>
<td><strong>470</strong></td>
<td><strong>13333</strong></td>
</tr>
</tbody>
</table>
3.4. Habitat types

We considered the relevant geospatial data of Europe’s ecosystem types that follow the EUNIS-MAES habitat classification system (EEA 2019c). A pronounced naturalness characterizes the PP-CCA as human settlements, artificial land and agricultural land cover less than 3% of the area. Forests are the dominant broad habitat category in the PP-CCA (Table 3, Figure 5).

“G-Woodland, forest and other wooded land” category covers most of the area of PP-CCA with 77.91%. “Broadleaved deciduous woodland” (G1) represents most of it (42.91%), followed by ‘Coniferous woodland” (G3) (18.33). “Broadleaved woodlands” (G1) are dominated mostly by several species of oak (Quercus sp.) and beech (Fagus sylvatica), whereas “Coniferous woodland” (G3) is represented by black pine (Pinus nigra), fir (Abies borisii-regis) and at high altitude zones -at the south part of the PP-CCA- by Bosnian pine (Pinus heldreichi).
The second category in the PP-CCA is “E-Grasslands and land dominated by forbs, mosses and lichens,” covering 13.35% of the PP-CCA, represented mainly by “Dry grasslands” (E1) (7.6%), followed by “Alpine and subalpine grasslands” (E4) (2.54%) and “Seasonally wet and wet grasslands” (E3) (2.53%).

The third category is “F- Heathland, scrub and tundra,” covering just only 3.25% of the PP-CCA and is represented by “Maquis, arborescent matorral and thermo-Mediterranean bushes” (F5) with 1.92% and “Arctic, alpine and sub-alpine scrub” (F2) with 1.22%.

The fourth category is “I- Arable land and marker gardens,” with 2.29% relating to the cultivated land in the PP-CCA.

The fifth category is “H- Inland unvegetated or sparsely vegetated habitats,” covering 1.87% of the PP-CCA.

Finally, all the rest categories cover very small parts of the PP-CCA. “C-Inland Surface waters” covers only 0.88%, “D- Mires, bogs and fens” only 0.04% and “J- constructed, industrial and other artificial habitats” only 0.41%, indicating the low level of human impact infrastructures in the PP-CCA.

<table>
<thead>
<tr>
<th>EUNIS level 1</th>
<th>EUNIS level 2</th>
<th>Percent of CCA</th>
</tr>
</thead>
<tbody>
<tr>
<td>C - Inland surface waters</td>
<td></td>
<td>0.88</td>
</tr>
<tr>
<td>C1 - Surface standing waters</td>
<td></td>
<td>0.86</td>
</tr>
<tr>
<td>C2 - Surface running waters</td>
<td></td>
<td>0.02</td>
</tr>
<tr>
<td>D - Mires, bogs and fens</td>
<td></td>
<td>0.04</td>
</tr>
<tr>
<td>D4 - Base-rich fens and calcareous spring mires</td>
<td></td>
<td>0.01</td>
</tr>
<tr>
<td>D5 - Sedge and reedbeds, normally without free-standing water</td>
<td></td>
<td>0.03</td>
</tr>
<tr>
<td>E - Grasslands and land dominated by forbs, mosses or lichens</td>
<td></td>
<td>13.35</td>
</tr>
<tr>
<td>E1 - Dry grasslands</td>
<td></td>
<td>7.60</td>
</tr>
<tr>
<td>E2 - Mesic grasslands</td>
<td></td>
<td>0.69</td>
</tr>
<tr>
<td>E3 - Seasonally wet and wet grasslands</td>
<td></td>
<td>2.53</td>
</tr>
<tr>
<td>E4 - Alpine and subalpine grasslands</td>
<td></td>
<td>2.54</td>
</tr>
<tr>
<td>F - Heathland, scrub and tundra</td>
<td></td>
<td>3.25</td>
</tr>
<tr>
<td>F2 - Arctic, alpine and subalpine scrub</td>
<td></td>
<td>1.22</td>
</tr>
<tr>
<td>F3 - Temperate and mediterranean-montane scrub</td>
<td></td>
<td>0.06</td>
</tr>
<tr>
<td>F5 - Maquis, arborescent matorral and thermo-Mediterranean brushes</td>
<td></td>
<td>1.92</td>
</tr>
<tr>
<td>FB - Shrub plantations</td>
<td></td>
<td>0.06</td>
</tr>
<tr>
<td>G - Woodland, forest and other wooded land</td>
<td></td>
<td>77.91</td>
</tr>
<tr>
<td>G1 - Broadleaved deciduous woodland</td>
<td></td>
<td>42.91</td>
</tr>
<tr>
<td>G3 - Coniferous woodland</td>
<td></td>
<td>18.33</td>
</tr>
<tr>
<td>G4 - Mixed deciduous and coniferous woodland</td>
<td></td>
<td>9.35</td>
</tr>
<tr>
<td>G5 - Lines of trees, small anthropogenic woodlands, recently felled woodland, early-stage woodland and coppice</td>
<td></td>
<td>7.31</td>
</tr>
<tr>
<td>EUNIS level 1</td>
<td>EUNIS level 2</td>
<td>Percent of CCA</td>
</tr>
<tr>
<td>---------------</td>
<td>---------------</td>
<td>----------------</td>
</tr>
<tr>
<td>H - Inland unvegetated or sparsely vegetated habitats</td>
<td>1.87</td>
<td></td>
</tr>
<tr>
<td>H2 - Screes</td>
<td>0.36</td>
<td></td>
</tr>
<tr>
<td>H3 - Inland cliffs, rock pavements and outcrops</td>
<td>0.77</td>
<td></td>
</tr>
<tr>
<td>H5 - Miscellaneous inland habitats with very sparse or no vegetation</td>
<td>0.74</td>
<td></td>
</tr>
<tr>
<td>I - Arable land and market gardens</td>
<td>2.29</td>
<td></td>
</tr>
<tr>
<td>I1 - Arable land and market gardens</td>
<td>2.28</td>
<td></td>
</tr>
<tr>
<td>I2 - Cultivated areas of gardens and parks</td>
<td>0.01</td>
<td></td>
</tr>
<tr>
<td>J - constructed, industrial and other artificial habitats</td>
<td>0.41</td>
<td></td>
</tr>
<tr>
<td>J1 - Buildings of cities, towns and villages</td>
<td>0.18</td>
<td></td>
</tr>
<tr>
<td>J2 - Low density buildings</td>
<td>0.15</td>
<td></td>
</tr>
<tr>
<td>J3 - Extractive industrial sites</td>
<td>0.05</td>
<td></td>
</tr>
<tr>
<td>J4 - Transport networks and other constructed hard-surfaced areas</td>
<td>0.04</td>
<td></td>
</tr>
</tbody>
</table>
Figure 5: Main ecosystem types in the PP-CCA after the EUNIS classification system (level 1).
3.5. Human Impact

We calculated the mean Human Influence Index (HII) for the study area compared to the Greek territory. The HII is an integrated index (scale of 1-100) that accounts for five major human pressures: population density, land cover, infrastructures, accessibility, and power (Sanderson et al. 2022). We used the most current database of 2019 (HII 2019), and we found that the mean HII in the study area ranges from 1.38 to 58 on the 1-100 scale with an average value of **10.75**, which is lower than the national average (17.5) (Kati et al. under review). The Pindos-Prespes CCA is less impacted by human activities than the rest of the country.

3.6. Landscape fragmentation

The road network of the PP-CCA includes 3,962 km of roads, according to the Open Street Map Database (OSM 2022) (Figure 6a). The road density in the PP-CCA is **0.9 km of roads/km²** and is three-fold time lower than the road density of Greece (2.82 km/km²) (Kati et al. 2020), though the road network of the country is not fully mapped and both densities are underestimated.

We also considered the Landscape Fragmentation Index (LFI) provided by the European Environmental Agency (EEA 2019b). The LFI assesses the degree to which movement between different parts of the landscape is interrupted by Fragmentation Geometry: the presence of impervious surfaces and traffic infrastructure, including medium-sized roads. It is calculated in terms of the number of meshes per 1000 km² (The Effective Mesh Density - seff values) and concludes to five fragmentation zones of different fragmentation degrees from very low (0–1.5), low (1.5–10), medium (10–50), high (50–250) and very high (>250). LFI is a straightforward index measuring landscape fragmentation and its connectivity potential. PP-CCA is an area of low fragmentation degree as the greatest part (93%) falls in the zone of very low or low fragmentation of the LFI (Table 4), indicating the undisturbed free movement of wildlife species among their habitats.

**Table 4**: Landscape Fragmentation Index (LFI) categories cover in the PP-CCA and percentage of each zone cover (%)

<table>
<thead>
<tr>
<th>Fragmentation zone (seff values)</th>
<th>PP-CCA area (km²)</th>
<th>Percent (%) of PP-CCA area</th>
<th>Percent (%) of Greece</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very low (0-1.5)</td>
<td>2743</td>
<td>63</td>
<td>14</td>
</tr>
<tr>
<td>Low (1.5-10)</td>
<td>1313</td>
<td>30</td>
<td>38</td>
</tr>
<tr>
<td>Medium (10-50)</td>
<td>247</td>
<td>6</td>
<td>31</td>
</tr>
<tr>
<td>High (50-250)</td>
<td>73</td>
<td>2</td>
<td>13</td>
</tr>
<tr>
<td>Very high (&gt;250)</td>
<td>11</td>
<td>0.2</td>
<td>5</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>4387</strong></td>
<td><strong>100</strong></td>
<td><strong>100</strong></td>
</tr>
</tbody>
</table>
3.7. Roadless and wilderness areas

We used the most current database of the roadless map of Greece (Kassara et al. 2022) that was produced by the ROADLESS project (BCL 2022). A Roadless Core Area (RCA) is defined as any land patch (excluding large waterbodies) that has a size greater than 1 km² and lies at least 1 km away from the nearest road (Kati et al. under review) since most negative road impacts occur at a 1 km distance along roadsides (Ibisch et al. 2016). Roadless Area (RA) is the RCA with a buffer zone of 1 km, i.e., any land patch of a size greater than 1 km² that is deprived of roads accessible by motor vehicles and other important infrastructures (paths included). **Roadless areas cover 15% of the PP-CCA**, concluding to a Roadless Fragmentation Index (RFI) that is more than double the national average (RFI=6.10% in Greece: roadless land/Greek land) (Kati et al. under review). The PP-CCA hosts **25 roadless areas** of a size ranging between 7.14 to 202.75 km² (**Table 5, Figure 6**).

The PP-CCA also has a strong **wilderness character**. According to the European guideline on wilderness in Natura (EC 2013), a wilderness area is “an area governed by natural processes. It is composed of native habitats and species and is large enough for the effective ecological functioning of natural processes. It is unmodified or only slightly modified and without intrusive or extractive human activity, settlements, infrastructure or visual disturbance”. According to
the same guideline, a site can be recognized as a wilderness site if it combines four criteria: size, undevelopedness, undisturbedness, and naturalness. The criteria of undevelopedness and undisturbance are satisfied by imposed inaccessibility delivered by the absence of roads. The high naturalness is confirmed by the great extent of natural vegetation in the whole area of the PP-CCA (>97%), reaching 100% in the larger RAs (Kati et al. 2020 a, and Kati et al. under review). The site should be at least 5 km² or 30 km² according to European studies, to be defined as wilderness when the other criteria are satisfied (Brackhane et al. 2019; Broggi 2015; Carver 2016) and over 20 km² in the USA (1964). Therefore, all 25 roadless sites can be characterized as wilderness areas in the PP-CCA if the 5 km² threshold is used, 18 sites if the 10 km² is used, and five sites if the more strict threshold of 30km² size is used (Table 5, Figure 6).

The Natura 2000 network of protected areas covers most of the wilderness areas well. However, one large wilderness area in the locality Gyftissa-Tampouri (37.4 km²), is not protected, together with four more medium-sized wilderness areas in the Municipality of Konitsa (Table 5). Finally, it seems that very low to low fragmentation values of the broader landscape of PP-CCA around the wilderness areas provide an adequate wilderness continuum of reduced human modification character (EWS 2019).

These findings are of topical interest since roads are reported to have numerous negative impacts on species and ecosystem function, undermining habitat connectivity, whereas defining and well-preserving roadless areas has gained global recognition as a tool to halt biodiversity loss and maintain ecosystem services and habitat connectivity (Ibisch et al. 2016; Kati at al. 2020a, Laurance et al. 2014; Laurance 2015, Selva et al. 2015). The PP-CCA contributes to the national SEBI13 indicator used in the national report of the Greek State of Environment referring to the “fragmentation of natural and semi-natural areas” (SEBI 13 -European Streamline Biodiversity Indicator) and calculated through the extent of roadless areas extent in Greece.

The PP-CCA also contributes to the national roadless policy of Greece, recently adopted by the Greek government (2022) (Kati et al. 2020a, 2022), delivering so far 8 RAs (BCL 2022). The PP-CCA includes two legally protected roadless areas within the National Park of Northern Pindos: Tymfi mountain (Governmental gazette: FEK 1006/31.12.2021), extending from 460 to 2497m and covering an area of 202,75 km², and Smolikas mountain (Governmental gazette: FEK 1009/31.12.2021), extending from 782m to 2637m and covering an area of 102,89 km² (Figure 6). Both these roadless areas are suggested to be strictly protected in the Environmental Assessment Study for the broader area of Northern Pindos National Park. The study is currently under consultation, expected to be formalized as a Presidential Decree that will permanently define the land uses in the Natura 2000 network.
Table 5: Roadless areas in the PP-CCA and wilderness character in terms of their size. RA: size of the roadless area. RCA: size of the Roadless Core Area. Natura 2000 (%): overlap with the Natura 2000 network of protected areas. * RA legally protected as such.

<table>
<thead>
<tr>
<th>Name</th>
<th>RA (km²)</th>
<th>RCA (km²)</th>
<th>Natura 2000 (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Large wilderness sites (&gt;30 km²)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mount Tymfi*</td>
<td>202.75</td>
<td>115.7</td>
<td>96.55</td>
</tr>
<tr>
<td>Mount Smolikas*</td>
<td>102.89</td>
<td>54.9</td>
<td>99.27</td>
</tr>
<tr>
<td>Arkoudorema-Flega-Avgo</td>
<td>56.88</td>
<td>23.3</td>
<td>94.45</td>
</tr>
<tr>
<td>Mount Grammos</td>
<td>52.33</td>
<td>18.1</td>
<td>100.00</td>
</tr>
<tr>
<td>Gyftissa-Tampouri</td>
<td>37.41</td>
<td>10.8</td>
<td>0.42</td>
</tr>
<tr>
<td><strong>Medium-size wilderness sites (10-30 km²)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>RA013 (Mun. Prespes)</td>
<td>27.13</td>
<td>8.4</td>
<td>100.00</td>
</tr>
<tr>
<td>RA142 (Mun. Konitsa)</td>
<td>17.64</td>
<td>3.4</td>
<td>0.00</td>
</tr>
<tr>
<td>RA150 (Mun. Konitsa)</td>
<td>17.21</td>
<td>3.2</td>
<td>0.00</td>
</tr>
<tr>
<td>RA203 (Mun. Pogoni)</td>
<td>16.76</td>
<td>2.4</td>
<td>100.00</td>
</tr>
<tr>
<td>RA083 (Mun. Konitsa)</td>
<td>16.52</td>
<td>4.6</td>
<td>0.00</td>
</tr>
<tr>
<td>RA229 (Mun. Konitsa)</td>
<td>15.73</td>
<td>2.0</td>
<td>0.00</td>
</tr>
<tr>
<td>RA285 (Mun. Konitsa, Zagori)</td>
<td>15.05</td>
<td>1.6</td>
<td>94.55</td>
</tr>
<tr>
<td>RA178 (Mun. Grevena, Konitsa)</td>
<td>15.04</td>
<td>2.7</td>
<td>11.02</td>
</tr>
<tr>
<td>RA226 (Mun. Pogoni)</td>
<td>13.81</td>
<td>2.1</td>
<td>100.00</td>
</tr>
<tr>
<td>RA241 (Mun. Grevena, Konitsa)</td>
<td>13.64</td>
<td>1.9</td>
<td>100.00</td>
</tr>
<tr>
<td>RA217 (Mun. Konitsa, Nestoriou)</td>
<td>12.51</td>
<td>2.2</td>
<td>100.00</td>
</tr>
<tr>
<td>RA342 (Mun. Orestida, Voio)</td>
<td>11.41</td>
<td>1.3</td>
<td>0.00</td>
</tr>
<tr>
<td>RA081 (Mun. Konitsa)</td>
<td>10.89</td>
<td>4.7</td>
<td>95.24</td>
</tr>
<tr>
<td><strong>Small-size wilderness sites (5-10 km²)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>RA298 (Mun. Konitsa)</td>
<td>9.92</td>
<td>1.5</td>
<td>0.00</td>
</tr>
<tr>
<td>RA393 (Mun. Prespes)</td>
<td>9.54</td>
<td>1.0</td>
<td>0.00</td>
</tr>
<tr>
<td>RA370 (Mun. Metsovo)</td>
<td>9.02</td>
<td>1.1</td>
<td>0.00</td>
</tr>
<tr>
<td>RA239 (Mun. Konitsa)</td>
<td>8.39</td>
<td>1.9</td>
<td>100.00</td>
</tr>
<tr>
<td>RA308 (Mun. Konitsa)</td>
<td>7.90</td>
<td>1.5</td>
<td>0.00</td>
</tr>
<tr>
<td>RA231 (Mun. Pogoni)</td>
<td>7.17</td>
<td>2.0</td>
<td>100.00</td>
</tr>
<tr>
<td>RA200 (Mun. Pogoni)</td>
<td>7.14</td>
<td>2.5</td>
<td>100.00</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>714.68</strong></td>
<td><strong>52.20</strong></td>
<td><strong>55.66</strong></td>
</tr>
</tbody>
</table>
Figure 7: Roadless areas in the Pindos-Prespes Connectivity conservation Area, indicating large (over 30 km²), medium (10-30 km²) and small size (5-10 km²) wilderness areas and their cover by the Natura 2000 network. Mount Tymfi and Mount Smolikas are legally protected as road free land.
3.8. Administrative units and population density in the PP-CCA

We considered the openly available data of the administrative units of Greece provided by the geodata platform (Geodata 2015 b,c,d,f) to present the administrative configuration of the PP-CCA. The PP-CCA falls within the Region of Epirus (Ioannina Regional Unit: 7 municipalities) and the Region of West Macedonia (Grevena, Kozani, Kastoria and Florina Regional Units: 8 municipalities) (Table 6, Fig. 8). The Region of Thessaly covers a minor part of the PP-CCA.

Table 6: Cover (%) of the administrative units in the Pindos-Prespes Connectivity conservation Area (PP-CCA), permanent residents in each municipality (within and outside PP-CCA) and population trend at the regional scale after the national population census of 2021.

<table>
<thead>
<tr>
<th>Region</th>
<th>Regional Unit</th>
<th>Municipality</th>
<th>Percentage (%) of PP-CC</th>
<th>Population M</th>
<th>Regional trend</th>
</tr>
</thead>
<tbody>
<tr>
<td>Epirus</td>
<td>Ioannina</td>
<td>Ioannina</td>
<td>1</td>
<td>113094</td>
<td>-5.1%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Zagori</td>
<td>21.4</td>
<td>3384</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Konitsa</td>
<td>20.9</td>
<td>5325</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Pogoni</td>
<td>4.6</td>
<td>6859</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Metsovo</td>
<td>3.6</td>
<td>5429</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Zitsa</td>
<td>0.1</td>
<td>13630</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Grevena</td>
<td>Grevena</td>
<td>0.1</td>
<td>67161</td>
<td>-10.1%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Voio</td>
<td>3.3</td>
<td>21440</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Kastoria</td>
<td>Kastoria</td>
<td>12.7</td>
<td>33227</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Nestorio</td>
<td>Nestorio</td>
<td>1.1</td>
<td>2188</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Orestida</td>
<td>Orestida</td>
<td>6.9</td>
<td>10633</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Florina</td>
<td>Florina</td>
<td>0.8</td>
<td>29611</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Amyntaio</td>
<td>Amyntaio</td>
<td>3.6</td>
<td>14331</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Prespes</td>
<td>Prespes</td>
<td>3.6</td>
<td>1220</td>
<td></td>
</tr>
<tr>
<td>Thessaly</td>
<td>Trikala</td>
<td>Kalambaka</td>
<td>0.9</td>
<td>19290</td>
<td>-6.2%</td>
</tr>
</tbody>
</table>

According to the last population census of Greece (ELSTAT 2022), there is an overall decline of the order of 10% and 5% in the Regions of West-Macedonia and Epirus, respectively. We present the estimated number of permanent residents per municipality, considering the full municipality extent (inside and outside the PP-CCA) (ELSTAT 2022) (Table 6, Fig. 7).

The Pindos-Prespes Connectivity conservation Area includes 245 municipal units (local communities) according to the national inventory of cities and settlements (Geodata 2015f). Only four cities fall within or are adjacent to the PP-CCA (Fig. 8): Kastoria, Konitsa, Metsovo and Nestorio.
Figure 8: Cities and administrative unities of the PP-CCA and cities.
3.9. Human economic activities related to land

Since there is no detailed spatial data on human activities and land uses across different economic sectors, we present statistical data from the last census of the agricultural and livestock sectors at the Regional level (ELSTAT 2021). In the Region of Western Macedonia, land abandonment has increased, as the area of agricultural land used has declined by 15.7% between 2009 and 2020. The current land under agricultural use in the Region of Western Macedonia (2020) is 2,227 km² accounting mostly for arable land (74.8%), vineyards (0.9%), tree cultivations (3.7%) and other agricultural lands (20.6%). The livestock sector includes cattle (40,233 animals), sheep (392,391 animals), goats (146,500 animals), pigs (9,093 animals) and poultry (104,356 animals), showing a significant declining trend for poultry (-66%), pigs (-59%), goats (-10.5%) and less for sheep (-2%) for the period 2009-2020 (ELSTAT 2021). The proportion of people working in the agricultural sector exclusively, mainly, or secondarily has dramatically declined by 34%, 71% and 58%, respectively, for 2009-2020. On the other hand, beekeeping and biological farming have substantially increased by 294% and 29.3%, respectively.

In the Region of Epirus, land abandonment was even more prominent than in Western Macedonia, as the area of agricultural land used declined by 31.3% between 2009 and 2020. The current land under agricultural use in the Region of Epirus (2020) is 714.82 km² accounting mostly for tree cultivations (32.2%), arable land (30.6%), vineyards (0.5%), greenhouses (0.2%) and other agricultural lands (36.5%). The livestock sector includes cattle (71,908 animals), sheep (466,506 animals), goats (127,224 animals), pigs (142,081 animals) and poultry (12,401,622 animals). Poultry is one of the main livestock sectors showing a substantial increase of 17%, along with cattle breeding (an increase of 17%) and pigs (an increase of 31%). On the contrary, sheep and goat livestock capital substantially decreased by 42% and 36%, respectively, in 2009-2020 (ELSTAT 2021). The proportion of people working in the agricultural sector exclusively, mainly, or secondarily has dramatically declined by 35%, 68% and 33%, respectively, for 2009-2020. On the other hand, beekeeping and biological farming have substantially increased by 448.3% and 16.1%, respectively.

The general trends should also apply to the PP-CCA that falls within the Regions of Epirus and West-Macedonia. We conclude, therefore, that the PP-CCA has experienced an important land abandonment from human farming activities, as indicated by the increase of abandoned agricultural fields and the decline of people working in the agricultural sector. Sheep/goat breeding, formerly one of the key economic activities in the PP-CCA, shows a sharp decline, locally replaced by cattle breeding, whereas mainly beekeeping and secondarily biological farming is flourishing.

3.10. Land ownership

No comprehensive land mapping exists for Greece, as the national Cadastre has not yet been delivered, so spatial data on land ownership are unavailable. There are three forms of land in the PP-CCA:

**Private land**: It refers mainly to settlements and the zone around them that has an agricultural use as arable fields, tree cultivations, gardens, or pastures (mainly formerly abandoned lands used for grazing), entailing small-scale infrastructures for people or livestock (secondary houses, stables etc.). Forests can also belong to individuals, but the percentage of forests and woodlands privately owned by monasteries, individuals, groups of individuals or organizations and foundations is only 22.5% nationally (Spanos 2015). Since artificial land accounts only for 0.4% of the PP-CCA and agricultural land only for 2.3% (see above 3.4.), the part of the PP-CCA of private character should be minimal. However, there is an issue regarding the former agricultural land that after having been abandoned for many decades (just after II WW) became gradually forested. This land may be private, belonging to individuals, whereas the Forestry service claims that it is public, belonging to the State.
**Municipal land:** It refers to municipal forests and grasslands managed by the Municipality. At the national scale, local municipalities own 12% of Greek forested land (mainly forests and grasslands) (Spanos 2015). The proportion is not known for the PP-CCA. However, the extent of municipal forests at the territories of communities located in forested areas, especially in conifer and beech forests, should account for a greater proportion, which may be around 50% of the forested land, especially in Zagori, Konitsa and Metsovo municipalities (pers. Com. with Forestry Service of Ioannina).

**Public land:** It belongs to the State and includes lakes, rivers, forests, woodlands, grasslands, scrubs and other natural vegetation areas managed by Public authorities, such as the Forest Service. Most (65.5%) of the forested land of Greece (forests and grasslands) is of public character (Spanos 2015). Given that natural habitats cover the greatest part (94%) of the PP-CCA, we conclude that the majority of land (with forests or without forests) in the PP-CCA should be of public character.

### 3.11. Protection status of PP-CCA

We considered the national database of the Natura 2000 network (YPEN 2020) and overlaid it with the boundaries of the National Parks (Geodata 2015g) as well as the geographic boundaries of Wildlife sanctuaries (Geodata 2015e) to evaluate the combined protection status from all protected area statuses within the PP-CCA.

The greatest part of the Pindos-Prespes CCA (65.7%) is under protection status, accounting for a cumulative area of 2,883 km² (Fig. 8). It includes 20 sites of the Natura 2000 network of protected areas, 25 wildlife sanctuaries and the Northern Pindos National Park.

The Pindos NP covers a great part of the PP-CCA (1866 km²- 39%) and is under the responsibility of the Management Unit of Pindos National Park of the Natural Environment & Climate Change Agency (NECCA 2023). The Management Unit of the Protected Areas of Epirus (Lake Pamvotida Ioannina) is adjacent to the PP-CCA to the south (33.4km², 0.68% of the PP-CCA) and the Prespes National Park (and the respective Management Unit of Prespes National Park and Protected Areas of Western Macedonia) is adjacent to the PP-CCA to the North (Fig. 9).

The PP-CCA hosts 20 Natura 2000 sites (Table 7, Fig. 9), covering 2,142 km² (excluding overlapping sites) and accounting for almost half of the PP-CCA (48.8%), a proportion that is significantly larger than the national cover (Natura 2000 cover in Greece: 27.4%). The Pindos-Prespes CCA includes 6 Special Protection Areas (SPAs) that are protected under the Birds’ Directive (EC 2009), ten sites of Special Areas of Conservation (SAC) that are designed under the Habitats’ Directive (EC 1992) and four sites of SAC/SPA that are important under the provisions of both Directives. According to the Standard Data Forms (SDFs) for the Natura 2000 sites (SDF 2022), target large mammals of this study occur in most of the sites of the network (only five sites without target large mammal presence) (Table 7).

**Wildlife sanctuaries** are permanently or provisionally set aside for wildlife conservation as hunting-ban zones. There are 25 wildlife sanctuaries in the PP-CCA, extending over 529 km² and accounting for 12% of the PP-CCA (Table 8, Fig.8). They add an area of a further 160 km² under protection status (lying outside the Natura 2000 network and the National Parks).
Figure 9: Natura 2000 sites, Wildlife sanctuaries and boundaries of the Pindos National Park and Lake Pamvotida Ioannina National Park.
Table 7: Natura 2000 sites of the Prespa-Pindos CCA and occurrence of the four large mammal species according to the Standard Data Forms (SDFs)

<table>
<thead>
<tr>
<th>Site code</th>
<th>Site type</th>
<th>Site name</th>
<th>Area (km²)</th>
<th>Large mammal occurrence (SDFs)</th>
</tr>
</thead>
<tbody>
<tr>
<td>GR1310001</td>
<td>SAC</td>
<td>VASILITSA</td>
<td>80.4</td>
<td>Chamois            Bear  Wolf  Otter</td>
</tr>
<tr>
<td>GR1310002</td>
<td>SPA</td>
<td>VALIA KALNTA KAI TECHNITI LIMNI AOUOU ETHNIKOS DRYMOS PINDOU (VALIA KALNTA) - EVRYTERI PERIOCHI</td>
<td>144.6</td>
<td></td>
</tr>
<tr>
<td>GR1310003</td>
<td>SAC</td>
<td>ORI ORLIKAS KAI TSOURIGIAKAS</td>
<td>67.2</td>
<td></td>
</tr>
<tr>
<td>GR1320001</td>
<td>SAC</td>
<td>LIMNI KASTORIAS</td>
<td>46.7</td>
<td></td>
</tr>
<tr>
<td>GR1320002</td>
<td>SAC/SPA</td>
<td>KORYFES OROUS GRAMMOS</td>
<td>340.1</td>
<td></td>
</tr>
<tr>
<td>GR1320003</td>
<td>SPA</td>
<td>LIMNI ORESTIAS (KASTORIAS)</td>
<td>37.7</td>
<td></td>
</tr>
<tr>
<td>GR1340001</td>
<td>SAC/SPA</td>
<td>ETHNIKOS DRYMOS PRESPON</td>
<td>3.7</td>
<td></td>
</tr>
<tr>
<td>GR1340003</td>
<td>SAC/SPA</td>
<td>ORI VARNOUNTA</td>
<td>0.3</td>
<td></td>
</tr>
<tr>
<td>GR1340006</td>
<td>SAC</td>
<td>OROS VERNON - KORYFVI VITSI</td>
<td>81.4</td>
<td></td>
</tr>
<tr>
<td>GR1340009</td>
<td>SAC</td>
<td>ORI VARNOUNTA – EVRYTERI PERIOCHI</td>
<td>15.0</td>
<td></td>
</tr>
<tr>
<td>GR1340100</td>
<td>SAC</td>
<td>ETHNIKOS DRYMOS PRESPON – EVRYTERI PERIOCHI</td>
<td>76.3</td>
<td></td>
</tr>
<tr>
<td>GR2130001</td>
<td>SAC</td>
<td>ETHNIKOS DRYMOS VIKOU - AOOU</td>
<td>129.6</td>
<td></td>
</tr>
<tr>
<td>GR2130002</td>
<td>SAC/SPA</td>
<td>KORYFES OROUS SMOLIKAS</td>
<td>197.1</td>
<td></td>
</tr>
<tr>
<td>GR2130004</td>
<td>SAC</td>
<td>KENTRIKO TMIMA ZAGORIOU</td>
<td>329.4</td>
<td></td>
</tr>
<tr>
<td>GR2130006</td>
<td>SAC</td>
<td>PERIOCHI METSOVOU (ANILIO - KATARA)</td>
<td>72.6</td>
<td></td>
</tr>
<tr>
<td>GR2130008</td>
<td>SAC</td>
<td>OROS MITSIKELI</td>
<td>85.8</td>
<td></td>
</tr>
<tr>
<td>GR2130009</td>
<td>SPA</td>
<td>OROS TYMFI (GKAMILA)</td>
<td>277.6</td>
<td></td>
</tr>
<tr>
<td>GR2130010</td>
<td>SPA</td>
<td>OROS DOUSKON, ORAIKASTRO, DASOS MEROPIS, KOILADA GORMOU, LIMNI DELVINAKIIOU</td>
<td>173.4</td>
<td></td>
</tr>
<tr>
<td>GR2130011</td>
<td>SPA</td>
<td>KENTRIKO ZAGORI KAI ANATOLIKO TMIMA OROUS MITSIKELI</td>
<td>534.1</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th></th>
<th>Chamois</th>
<th>Bear</th>
<th>Wolf</th>
<th>Otter</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>20</td>
<td>10</td>
<td>13</td>
<td>2</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td>2,142</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

26
Table 8: Wildlife sanctuaries in the Prespa-Pindos CCA

<table>
<thead>
<tr>
<th>WS code</th>
<th>WS Name</th>
<th>Area (km²)</th>
<th>Area within Natura 2000</th>
<th>Area outside Natura 2000</th>
<th>% area in Natura 2000</th>
</tr>
</thead>
<tbody>
<tr>
<td>K112</td>
<td>Limni-Vouno Kastorias</td>
<td>65.8</td>
<td>41.4</td>
<td>24.4</td>
<td>63</td>
</tr>
<tr>
<td>K139</td>
<td>Katafiki-Megali Petra-Skala Gramou</td>
<td>12.3</td>
<td>11.9</td>
<td>0.4</td>
<td>96</td>
</tr>
<tr>
<td>K145</td>
<td>Arrenon (Grammou)</td>
<td>28</td>
<td>28.0</td>
<td>0.0</td>
<td>100</td>
</tr>
<tr>
<td>K156</td>
<td>Agia Sotira</td>
<td>15.8</td>
<td>0.0</td>
<td>15.8</td>
<td>0</td>
</tr>
<tr>
<td>K159</td>
<td>Tria Alonia-Mantani-Vounopika (Eptachoriou)</td>
<td>9.5</td>
<td>0.0</td>
<td>9.5</td>
<td>0</td>
</tr>
<tr>
<td>K161</td>
<td>Vourkopotamos-Ganadio-Pyrgos-Pyrsogiannis</td>
<td>22</td>
<td>0.0</td>
<td>22.0</td>
<td>0</td>
</tr>
<tr>
<td>K170</td>
<td>Valia Kyrna (Samarinas)</td>
<td>17.1</td>
<td>17.1</td>
<td>0.0</td>
<td>100</td>
</tr>
<tr>
<td>K172</td>
<td>Pades</td>
<td>20.8</td>
<td>20.8</td>
<td>0.0</td>
<td>100</td>
</tr>
<tr>
<td>K175</td>
<td>Charadra Aoou (Konitsas-Eleftherou-Papigkou)</td>
<td>35.2</td>
<td>34.3</td>
<td>0.9</td>
<td>98</td>
</tr>
<tr>
<td>K181</td>
<td>Papigko</td>
<td>10.6</td>
<td>10.6</td>
<td>0.0</td>
<td>100</td>
</tr>
<tr>
<td>K184</td>
<td>Palaemonastiro-Batefourlo (Perivoliou)</td>
<td>11.9</td>
<td>1.5</td>
<td>10.4</td>
<td>13</td>
</tr>
<tr>
<td>K193</td>
<td>Prosilio-Ronitsa (Delvinakiou)</td>
<td>12.3</td>
<td>12.3</td>
<td>0.0</td>
<td>100</td>
</tr>
<tr>
<td>K196</td>
<td>Kyra Kali-Trypimeni (Monastiriou-Kranias)</td>
<td>24.2</td>
<td>7.4</td>
<td>16.8</td>
<td>30</td>
</tr>
<tr>
<td>K199</td>
<td>Tsouka Karali-Veloni (Kranias)</td>
<td>17</td>
<td>0.0</td>
<td>17.0</td>
<td>0</td>
</tr>
<tr>
<td>K205</td>
<td>Metsovo-Chrysovitsa-Grevenitio</td>
<td>31.1</td>
<td>30.1</td>
<td>1.0</td>
<td>97</td>
</tr>
<tr>
<td>K209</td>
<td>Athanasios-Sipitoura (Asprapangelon-Elatis)</td>
<td>3.3</td>
<td>3.3</td>
<td>0.0</td>
<td>100</td>
</tr>
<tr>
<td>K904</td>
<td>Katafygio agrias zois &quot;Florinas&quot;</td>
<td>13.9</td>
<td>0.0</td>
<td>13.9</td>
<td>0</td>
</tr>
<tr>
<td>K913</td>
<td>Zarkaniki Avgerinou Dimou Tsotyliou</td>
<td>16.6</td>
<td>0.0</td>
<td>16.6</td>
<td>0</td>
</tr>
<tr>
<td>K589</td>
<td>Aetomilitsa</td>
<td>18</td>
<td>18.0</td>
<td>0.0</td>
<td>100</td>
</tr>
<tr>
<td>K600</td>
<td>Flampourario-Vovousa</td>
<td>13.2</td>
<td>13.2</td>
<td>0.0</td>
<td>100</td>
</tr>
<tr>
<td>K614</td>
<td>Kastanofyto-Melanthio-Zevgostasio-Niki-Lagka</td>
<td>12.3</td>
<td>0.0</td>
<td>12.3</td>
<td>0</td>
</tr>
<tr>
<td>K713</td>
<td>Sfikas Dimou Prespon</td>
<td>46.6</td>
<td>45.4</td>
<td>1.2</td>
<td>97</td>
</tr>
<tr>
<td>K739</td>
<td>Illochoriou - Vrysochoriou Dimou Tymfis</td>
<td>44.8</td>
<td>42.8</td>
<td>2.0</td>
<td>95</td>
</tr>
<tr>
<td>K754</td>
<td>Ontria Zonis Dragasias Dimou Tsotyliou</td>
<td>11.1</td>
<td>0.0</td>
<td>11.1</td>
<td>0</td>
</tr>
<tr>
<td>K834</td>
<td>Lapana Dimon Kastorias - Korestion</td>
<td>15.7</td>
<td>0.0</td>
<td>15.7</td>
<td>0</td>
</tr>
</tbody>
</table>
4. CHALLENGES TO CONNECTIVITY AND THREATS IN PP-CCA

4.1. Land use change

We considered land use change within the PP-CCA, using the Corine Land Cover (CLC) Inventory (Copernicus 2022), namely the changes in Land Cover between four different CLC periods from 1990 to 2018 (see Table 1). We calculated two key indicators of land use change: land take and forest encroachment (Table 9).

Table 9: Land conversion to artificial land (land take) and land conversion from open to forested land (forest encroachment) in the PP-CCA since 1990

<table>
<thead>
<tr>
<th>Period of land use change</th>
<th>Land take (km²)</th>
<th>Forest encroachment (km²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1990-2000</td>
<td>1.2</td>
<td>26.7</td>
</tr>
<tr>
<td>2000-2006</td>
<td>1.4</td>
<td>9</td>
</tr>
<tr>
<td>2006-2012</td>
<td>1.2</td>
<td>16.6</td>
</tr>
<tr>
<td>2012-2018</td>
<td>4.2</td>
<td>0.4</td>
</tr>
<tr>
<td>Total</td>
<td>8</td>
<td>52.7</td>
</tr>
</tbody>
</table>

**Land take**

Land take is converting natural and seminatural land to artificial land (EEA 2019d). Artificial land includes housing, urban spaces, industrial and commercial sites, transport networks, mines, quarries and dumpsites, construction sites and any infrastructure. Land take directly degrades soils, biodiversity, and ecosystem function, including productivity decline, loss of carbon storage capacity, and the disruption of nutrient and hydrological cycles (UNCCD 2017). The European Union has recently published the EU Soil Strategy for 2030, halting land degradation and setting a long-term objective by 2050 to reach non-net land take (EC 2021). We calculated land take for the PP-CCA as the conversion of any CLC type to artificial land (category CLC=1). A total of 8 km² of the natural and seminatural area in the PP-CCA has been converted to artificial land, with a peak in 2012-2018. This rate of land take is low, accounting for 0.17% of the PP-CCA area, having been artificialized within 28 years (average annual land take of 28,57 ha/year) as compared with the higher land take rates in Greece and Europe (EEA 2019d).

**Forest encroachment**

Forest encroachment is the process of forest expansion at the expense of former open habitats of agricultural or grassland character through vegetation succession. We calculated the area of forest encroachment using the CLC database as the conversion of open land (Corine Land Cover-CLC 321, 322, 331, 334) to forested land (CLC 31, 323, 324). Forest encroachment accounts for 52.7 km² since 1990, accounting for 1.09% of the PP-CCA (Table 9). According to the Greek legal frame (Article 67 of Law 998/1979), if agricultural land is gradually forested, it is characterized as forested land and cannot change use and be recultivated. This law encouraged forest encroachment after land abandonment. It has been recently modified after a new law of 2022 (Article 93 Law 4915/2022) to allow land recultivation in former agricultural fields (satellite imagery of 1945 or 1960) of a size up to 30 acres (3ha). Former abandoned agricultural fields that are forested land can change the use to arable land or tree cultivations.

This process of natural regeneration is reported to negatively impact open-dwelling species such as invertebrates, reptiles, plants or farmland species. Previous research in the broader area of Pindos has proved the negative impact of agricultural land abandonment and forest encroachment on bird communities (Zakkak et al. 2015a, b), lizards...
and butterflies (Slancarova et al. 2016). Vegetation is swiftly regenerated after land abandonment, and medium-intensity grazing and the enhancement of wild ungulates are recommended to maintain vegetation heterogeneity in abandoned fields (Zakkak 2018). On the other hand, expanding shrubs and forests can positively affect several ecosystem functions, including carbon sequestration and mitigating climate change effects. For this reason, the conservation and restoration of forests are explicitly referred to the EU Biodiversity Strategy by 2030 (EC 2020), to the Kunming-Montreal Global biodiversity framework (CBD 2022) and to the Paris agreement (UN 2015) for maintaining carbon sinks. Forest expansion following agricultural land abandonment can favor several forest-dwelling species that use forested lands and forest resources for cover, feeding and nesting, including large mammals (see chapter 6). Therefore, forest encroachment might increase the connectivity of habitats for forest-dwelling mammal species while decreasing the habitat connectivity for other species dependent on open habitats.

4.2. Fire Vulnerability

Fire is a major threat to the Mediterranean ecosystems. We calculated the number of fires and their total burnt area for 2008-2022, according to the European Forest Fire Information System (EFFIS 2022). During 2008-2022, 28 fire events were recorded, resulting in 17.5 km² of burnt land. Broadleaved forests and transitional woodland-shrubland were the two vegetation types most heavily impacted, accounting for the greatest percentage of the total burnt land (Fig. 10). Given that the proportion of burnt area was 3.2% of the Greek territory for the period 2008-2022 (Kati et al. under review), the proportion of land burnt in the PP-CCA was 0.36% and about ten-fold times lower than the national average. The PP-CCA has shown so far a great resistance to fires, which might be attributed, among others, to the significant part of the area that has remained roadless, given that most fires in the Mediterranean are human-induced (Tedim et al. 2022).

**Figure 10:** Share of the total burnt area in the PP-CCA (17.5 km²) across the vegetation types impacted.

4.3. Threats within Natura 2000 sites

We set up a database of all the pressures/threats recorded in the Natura 2000 network, considering the Standard Data Forms of all 20 Natura 2000 sites of the PP-CCA. The database included 545 records of pressures and threats
(plus seven unknown threats and 11 records of no threats and pressures). An overall number of 109 pressures/threats types have been recorded, grouped into 13 general categories, according to the European classification of the EIONET.

The non-sustainable agricultural practices (A) and use of biological resources (20%) are the two main fields where most threats and pressures are recorded (40%), followed by other human disturbances (G-12%) and transport (D-9%). Negative human interventions with a direct impact on wildlife were ranked in the top five most frequent threats, referring to trapping, poisoning, and poaching (27), poaching (17) and hunting (25). The disturbance by roads was also ranked in the top five most frequent threat shortlist (23), together with unsustainable grazing practices (18) (Table 10). The threat of anthropogenic reduction of habitat connectivity (J03.02) is recorded ten times in the Natura 2000 network of the PP-CCA, and several other pressures/threats are related to habitat connectivity negatively affecting wildlife, including land abandonment (A04.03) that can have positive or negative impacts to wildlife dependent on the species (see 4.1.) (Table 10).

Table 10: Frequency (N) of the pressures and threats with over ten occurrences recorded in the Natura 2000 network sites of the PP-CCA and percent frequency (%) of all threats by general threat categories (overall number of pressures/threats records: 545). C: pressure/threat related to connectivity.

<table>
<thead>
<tr>
<th>Threat category</th>
<th>Frequency (N)</th>
<th>Frequency (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A - Agriculture</td>
<td></td>
<td></td>
</tr>
<tr>
<td>A04</td>
<td>grazing</td>
<td>18</td>
</tr>
<tr>
<td>A04.01</td>
<td>intensive grazing</td>
<td>14</td>
</tr>
<tr>
<td>A04.03</td>
<td>abandonment of pastoral systems, lack of grazing</td>
<td>13</td>
</tr>
<tr>
<td>A10.01</td>
<td>removal of hedges and copses or scrub</td>
<td>12</td>
</tr>
<tr>
<td>B - Sylviculture, forestry</td>
<td></td>
<td>36</td>
</tr>
<tr>
<td>C - Mining, extraction of materials and energy production</td>
<td></td>
<td>14</td>
</tr>
<tr>
<td>D - Transportation and service corridors</td>
<td></td>
<td>49</td>
</tr>
<tr>
<td>D01.01</td>
<td>paths, tracks, cycling tracks</td>
<td>11</td>
</tr>
<tr>
<td>D01.02</td>
<td>roads, motorways</td>
<td>23</td>
</tr>
<tr>
<td>E - Urbanisation, residential and commercial development</td>
<td></td>
<td>30</td>
</tr>
<tr>
<td>F - Biological resource use other than agriculture &amp; forestry</td>
<td></td>
<td>111</td>
</tr>
<tr>
<td>F03.01</td>
<td>hunting</td>
<td>25</td>
</tr>
<tr>
<td>F03.02.03</td>
<td>trapping, poisoning, poaching</td>
<td>27</td>
</tr>
<tr>
<td>F04.02</td>
<td>collection (fungi, lichen, berries etc.)</td>
<td>11</td>
</tr>
<tr>
<td>F05.04</td>
<td>poaching</td>
<td>17</td>
</tr>
<tr>
<td>G - Human intrusions and disturbances</td>
<td></td>
<td>68</td>
</tr>
<tr>
<td>G02.02</td>
<td>skiing complex</td>
<td>17</td>
</tr>
<tr>
<td>G05.11</td>
<td>death or injury by collision</td>
<td>10</td>
</tr>
<tr>
<td>Threat category</td>
<td>Frequency (N)</td>
<td>Frequency (%)</td>
</tr>
<tr>
<td>-----------------</td>
<td>--------------</td>
<td>---------------</td>
</tr>
<tr>
<td>H-Pollution</td>
<td>12</td>
<td>2%</td>
</tr>
<tr>
<td>I-Invasive, other problematic species and genes</td>
<td>7</td>
<td>1%</td>
</tr>
<tr>
<td>J-Natural System modifications</td>
<td>44</td>
<td>8%</td>
</tr>
<tr>
<td>J03.01.01 reduction of prey availability (including carcasses)</td>
<td>12</td>
<td></td>
</tr>
<tr>
<td>J03.02 anthropogenic reduction of habitat connectivity</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>K-Natural biotic and abiotic processes (without catastrophes)</td>
<td>42</td>
<td>8%</td>
</tr>
<tr>
<td>K01.01 erosion</td>
<td>11</td>
<td></td>
</tr>
<tr>
<td>K03.06 antagonism with domestic animals</td>
<td>12</td>
<td></td>
</tr>
<tr>
<td>L - Geological events, natural catastrophes</td>
<td>19</td>
<td>3%</td>
</tr>
<tr>
<td>L09 fire (natural)</td>
<td>15</td>
<td></td>
</tr>
<tr>
<td>M-Climate change</td>
<td>2</td>
<td>0%</td>
</tr>
<tr>
<td>U-Unknown</td>
<td>7</td>
<td></td>
</tr>
<tr>
<td>X- No threats or pressures</td>
<td>11</td>
<td></td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>545</strong></td>
<td><strong>100%</strong></td>
</tr>
</tbody>
</table>
4.4. Renewable Energy Sources (RES) Infrastructures in the PP-CCA

We considered the most current database of Renewable Energy Sources (RES) openly provided by the Regulatory Authority of Energy’s web portal (RAE 2023) and calculated the number of RES projects under different licensing stages: ranked under decreased maturity stage from currently operating (installed), having permission for operation, for production and under evaluation at the earliest stage of licensing. Appendix II includes the detailed inventory of projects for the PP-CCA.

Table 11: Projects of Renewable Energy Sources (RES) in the PP-CCA under the four permission stages for wind, solar and hydropower.

<table>
<thead>
<tr>
<th>RES Type</th>
<th>Permission stage</th>
<th>Number of applications</th>
<th>Power (MW)</th>
<th>Area of installation polygon (km$^2$)</th>
<th>No of wind turbines</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wind</td>
<td>Installed</td>
<td>2</td>
<td>27.30</td>
<td>0.5</td>
<td>15</td>
</tr>
<tr>
<td></td>
<td>Operation</td>
<td>6</td>
<td>43.40</td>
<td>1.6</td>
<td>32</td>
</tr>
<tr>
<td></td>
<td>Production</td>
<td>31</td>
<td>483.90</td>
<td>30.6</td>
<td>128</td>
</tr>
<tr>
<td></td>
<td>Under evaluation</td>
<td>5</td>
<td>84.60</td>
<td>7.8</td>
<td>18</td>
</tr>
<tr>
<td></td>
<td><strong>Total wind power</strong></td>
<td><strong>44</strong></td>
<td><strong>639.20</strong></td>
<td><strong>40.5</strong></td>
<td><strong>196</strong></td>
</tr>
<tr>
<td>Solar</td>
<td>Production</td>
<td>2</td>
<td>47.00</td>
<td>0.3</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Under Evaluation</td>
<td>1</td>
<td>100.00</td>
<td>2.5</td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>Total solar power</strong></td>
<td><strong>3</strong></td>
<td><strong>147.00</strong></td>
<td><strong>2.8</strong></td>
<td></td>
</tr>
<tr>
<td>Hydropower</td>
<td>Installed</td>
<td>2</td>
<td>7.50</td>
<td>1.6</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Operation</td>
<td>10</td>
<td>15.93</td>
<td>3.3</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Production</td>
<td>58</td>
<td>92.72</td>
<td>24.7</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Under Evaluation</td>
<td>20</td>
<td>14.82</td>
<td>6.5</td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>Total hydropower</strong></td>
<td><strong>90</strong></td>
<td><strong>130.97</strong></td>
<td><strong>36.1</strong></td>
<td></td>
</tr>
</tbody>
</table>

According to the spatial analysis of RES projects, there are currently only four RES projects operating in the PP-CCA, namely two wind power stations and two hydropower stations operating in the PP-CCA. There will soon be another six wind power stations and ten hydropower stations since they are mature projects with a permit for operation (under construction). The RES infrastructure is a major threat in the future as if all RES projects are to be licensed, there will be 137 RES infrastructures with nominal power of 971 MW. The hydropower sector is the most important threat to the connectivity of the PP-CCA and particularly so for its hydrographic network. The wind energy sector is the second most important threat, with 44 wind power stations that would create at least 40.5 km$^2$ of artificialized land in their respective installation polygons. The negative impacts of RES on biodiversity and ecosystem degradation are extensive (Bennun 2021, Botelho 2017), and RES infrastructures are considered a major threat to habitat destruction, fragmentation and degradation, undermining habitat connectivity. Given the high naturalness area of the PP-CCA, a recent study on the sustainable spatial planning of wind energy infrastructures in Greece has excluded its greatest part (58,6%) as a potential investment zone for wind energy development (Kati et al. 2021).
Figure 11: Map of the wind energy (a), solar energy (b) and hydropower (c) projects that are currently operating, have a permit for operation, have a permit for production or are under evaluation in the PP-CCA.
5. Governance and Management

Competent from the state's point of view for decision-making and implementation of actions to protect and manage the natural environment, including the protection and conservation of populations of wild fauna species, is the Ministry of Environment and Energy and specifically the following General Directorates, Directorates and Departments:

- General Directorate of Environmental Policy/ Directorate of Natural Environment and Biodiversity Management/ Department of Biodiversity & Department of Protected Areas.
- General Directorate of Forests/ General Directorate of Forest and Forest Environment.
- General Directorate of Forests/ Forestry Policy Implementation Inspections (Forest Coordination and Inspection Directorates, Forest Departments/ Forest Offices including a special office for Wildlife and Game Management), known as “Forestry Service”.

The Forestry Service implements the forestry policy concerning the protection and management of forests. The Game Office is responsible for all aspects of wildlife matters in each Forestry department. In addition, the role of the Forestry Service in terms of wildlife is important because: (a) The decision-making and implementation of wildlife management measures fall primarily within its obligations and duties, including the issuance of hunting regulations and the declaration, abolition or modification of boundaries of wildlife sanctuaries, b) It operates as game police. However, it is worth mentioning that an active role in the protection of wild animals and the natural environment, in general, is also played by the game wardens who belong to the Hunting Federations and specifically in the PP-CCA in the 5th Hunting Federation of Epirus and 6th Hunting Federation of Macedonia-Thrace.

Recently a new agency for nature conservation and management has been established in the Ministry of Environment and Energy. This organization is the Natural Environment and Climate Change Agency (NECCA), which is responsible for the management of protected areas in Greece, preserving biodiversity, promoting and implementing sustainable development actions, and tackling climate change.

NECCA consists of the central directorate and regional structures, the Protected Areas Management Units. PP-CCA includes areas of responsibility of the North Pindos National Park Management Unit and the Prespa National Park and the Western Macedonia Protected Areas Management Unit. However, very small sections in the south and southeast of the PP-CCA belong to the responsibility of the Epirus Protected Areas Management Unit.

The Ministry of Rural Development and Food and its regional directorates are indirectly involved in issues related to the natural environment, especially regarding crops, pasture management and freshwater. The Regional authorities, with their various services, are involved in many issues concerning the implementation of strategic development, construction of projects and infrastructures, and maintenance. The same, but on a local scale, applies to the municipalities. The Decentralized Administration of Epirus-western Macedonia participates in planning and implementing the environmental spatial and urban planning policies and other environmental aspects (water protection and management etc.).

Finally, several other organizations, agencies, entities, NGOs, associations of professionals, societies and independent individuals with the same interests, are involved in nature use/conservation/management.

Figure 12 presents a summary of the main stakeholders in the PP-CCA, and Table 12 their role.
Figure 12: Key stakeholders involved in the management of PP-CCA
Table 12: Governance overview: competent authorities and organizations involved in management of the Pindos-Prespes CCA

<table>
<thead>
<tr>
<th>CATEGORIES OF ENTITIES</th>
<th>INVOLVED AGENCIES/ SERVICES/GROUPS OF PEOPLE</th>
<th>SUB-CATEGORY</th>
<th>COMPETENCES - ACTIONS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ministry of Environment and Energy</td>
<td>Forest Service</td>
<td>Forest Inspection Directorates</td>
<td>Administration, exploitation and management of public forests and forest lands. Forestry surveillance of private forests and forest lands. Execution and maintenance of forestry technical works. Protection of forests and woodland areas. Licensing - consultation. Protection and management of wildlife and habitats. Wildlife guarding and control of illegal activities in the natural environment of every category. Determining and implementing hunting decisions (game species, hunting periods, etc.).</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Forest Coordination Directorates</td>
<td>Administration, exploitation and management of public forests and forest lands. Forestry surveillance of private forests and forest lands. Execution and maintenance of forestry technical works. Protection of forests and woodland areas. Licensing - consultation. Protection and management of wildlife and habitats. Wildlife guarding and control of illegal activities in the natural environment of every category. Determining and implementing hunting decisions (game species, hunting periods, etc.).</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Forest Directorates</td>
<td>Administration, exploitation and management of public forests and forest lands. Forestry surveillance of private forests and forest lands. Execution and maintenance of forestry technical works. Protection of forests and woodland areas. Licensing - consultation. Protection and management of wildlife and habitats. Wildlife guarding and control of illegal activities in the natural environment of every category. Determining and implementing hunting decisions (game species, hunting periods, etc.).</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Forest Departments/ sub-departments</td>
<td>Administration, exploitation and management of public forests and forest lands. Forestry surveillance of private forests and forest lands. Execution and maintenance of forestry technical works. Protection of forests and woodland areas. Licensing - consultation. Protection and management of wildlife and habitats. Wildlife guarding and control of illegal activities in the natural environment of every category. Determining and implementing hunting decisions (game species, hunting periods, etc.).</td>
</tr>
<tr>
<td>CATEGORIES OF ENTITIES</td>
<td>INVOLVED AGENCIES/SERVICES/GROUPS OF PEOPLE</td>
<td>SUB-CATEGORY</td>
<td>COMPETENCES - ACTIONS</td>
</tr>
<tr>
<td>------------------------</td>
<td>--------------------------------------------</td>
<td>--------------</td>
<td>-----------------------</td>
</tr>
<tr>
<td>Ministry of Environment and Energy</td>
<td>Natural Environment and Climate Change Agency</td>
<td>Central Service</td>
<td>Implementation of the policy measures set by the Ministry of Environment and Energy for the management of protected areas in Greece, the preservation of biodiversity and the promotion and implementation of sustainable development actions and tackling climate change. Management of protected areas and biodiversity, Environmental licensing (category A projects), Issuance of field research permits. Consultation on projects. Monitoring of wildlife populations, Monitoring and Management of habitats, Supervision of Protected Areas and populations of wild fauna species, Consultation to Services for environmental licensing within Protected Areas, Environmental information and education actions.</td>
</tr>
<tr>
<td></td>
<td>Protected Area Management Units</td>
<td>Central office</td>
<td>Management of grazing lands - pastures</td>
</tr>
<tr>
<td>Ministry of Rural Development and Food</td>
<td>Supervised bodies of the Ministry of Rural Development and Food</td>
<td>General Organization of agricultural land improvements/Local Organization of agricultural land Improvements</td>
<td>Management (i.e., administration, operation and maintenance) of land improvement projects (land improvement projects are the dams, the irrigation canals, the drainage ditches, pumping stations, small technical, agricultural road construction, etc.) of their area of jurisdiction and distribution of irrigation water to land cultivators</td>
</tr>
<tr>
<td></td>
<td></td>
<td>General Directorates of Development Planning, Environment and Infrastructure</td>
<td>Environmental licensing (category B projects), Implementation of development strategies. Implementation of projects, Regulation of grazing management. Enforcement of compliance with environmental conditions for activities and projects of category B, Approval of environmental conditions of projects and activities.</td>
</tr>
<tr>
<td>Regions (Region of Epirus/ Region of Western Macedonia)</td>
<td>General Directorates of Development and Environment</td>
<td></td>
<td>Approval of environmental conditions of projects and activities, Rational management of energy and natural resources, Taking measures to protect the environment, Elaboration and approval of the regional management plan of solid waste.</td>
</tr>
<tr>
<td></td>
<td>General Directorates of Regional Agricultural Economy and Veterinary Medicine</td>
<td>Department of Fisheries</td>
<td>Issuance of decisions to determine the duration, start and end dates of the fishing prohibition period in rivers, lakes and artificial lakes, as well as decisions to impose special or additional restrictive fishing measures in internal waters.</td>
</tr>
<tr>
<td>CATEGORIES OF ENTITIES</td>
<td>INVOLVED AGENCIES/SERVICES/GROUPS OF PEOPLE</td>
<td>SUB-CATEGORY</td>
<td>COMPETENCES – ACTIONS</td>
</tr>
<tr>
<td>------------------------</td>
<td>--------------------------------------------</td>
<td>--------------</td>
<td>-----------------------</td>
</tr>
<tr>
<td>Municipalities</td>
<td>Directorates of Agricultural Affairs</td>
<td>Departments of Agriculture and Fisheries</td>
<td>Implementation of development strategies at their areas of responsibility, Elaboration of basic infrastructure and development projects. Management of municipal forests, woodlands and grasslands.</td>
</tr>
<tr>
<td></td>
<td>Directorates of Environment and Spatial Planning</td>
<td>Departments of Environment and Spatial Planning</td>
<td>Water protection and management, Environmental licensing (category A2 projects), Technical inspections of projects. Agricultural and fisheries issues in the context of the relevant regulations.</td>
</tr>
<tr>
<td>Decentralized administration of Epirus-Western Macedonia/General Directorates of Spatial, Environmental &amp; Agricultural Policy</td>
<td>Water Directorates</td>
<td>Water Resources Monitoring and Protection Departments</td>
<td>Planning and implementation of the environmental, spatial planning and urban planning policies, within the framework of the principles and national guidelines for the protection of the environment and sustainable development. (Coordination of actions for the monitoring and protection of the environment, the process of preliminary environmental assessment and evaluation of projects, the approval of environmental conditions of projects and activities, etc.). Water protection and management. (Collection and processing of water quantity and quality data, monitoring and control of quality parameters and quantitative status of protected areas, implementation of measures to control point and diffuse pollutant emissions in water, etc.).</td>
</tr>
<tr>
<td></td>
<td>Directorates of Technical Control</td>
<td>Departments of Natural Resources</td>
<td>Management of utilization of renewable energy sources with all required licensing and monitoring procedures.</td>
</tr>
<tr>
<td>Ministry of citizen Protection</td>
<td>Police/ Border police</td>
<td></td>
<td>Assistance in cases of illegal activities, e.g. Poaching.</td>
</tr>
<tr>
<td>Energy Regulator Authority</td>
<td>Universities</td>
<td></td>
<td>Participation in the licensing process of the Renewable energy sources stations, as well as in the process of evaluating the applications for granting a production license. Issuance of production licenses. Elaboration of studies on the biology and ecology of wildlife species and their habitats and on biodiversity in general, Formulation of scientifically based proposals and management measures for species and their habitats. Education and training to research techniques new scientists.</td>
</tr>
<tr>
<td>Research bodies</td>
<td>Research Institutes</td>
<td></td>
<td>Elaboration of studies on the biology and ecology of wildlife species and their habitats and on biodiversity in general, Formulation of scientifically based proposals and management measures for species and their habitats.</td>
</tr>
<tr>
<td>CATEGORIES OF ENTITIES</td>
<td>INVOLVED AGENCIES/ SERVICES/GROUPS OF PEOPLE</td>
<td>SUB-CATEGORY</td>
<td>COMPETENCES - ACTIONS</td>
</tr>
<tr>
<td>------------------------</td>
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<td>----------------------</td>
</tr>
<tr>
<td>Ministry of Education and Religious Affairs</td>
<td>Education Centers for the Environment and Sustainability</td>
<td>Development Agencies</td>
<td>Implementation of environmental educational programs, Informing and raising awareness of students and members of local communities through environmental education actions.</td>
</tr>
<tr>
<td>Exemplar Forests</td>
<td>Exemplar Forest of Voio</td>
<td>Construction and operation companies of large projects in the natural environment</td>
<td>Implementation of sustainable area management strategies, protection and promotion of biodiversity and -in general- natural and cultural heritage Implementation of development strategies, Tourist promotion &amp; promotion actions, Design of interpretive routes.</td>
</tr>
<tr>
<td>Development Agencies</td>
<td>Environmental Non-Governmental Organizations, Associations</td>
<td>Outdoor activities professionals</td>
<td>Identification of environmental problems, informing authorities, Elaboration of programs for the natural environment including wild fauna/mainly protected species, Voluntary participation in environmental activities (e.g. recordings of wild fauna species), Participation in Citizen Science programs.</td>
</tr>
<tr>
<td>Environmental organizations</td>
<td>Wind Farms, Solar Panel Installations, Small and large hydroelectric projects, Ski resorts, etc. Mountain guides, rafting guides, organizers of mountain running races, etc.</td>
<td>Associations of outdoor activities</td>
<td>Installation and operation of infrastructure, Interventions in the natural environment, Exploitation of natural resources.</td>
</tr>
<tr>
<td>Construction and operation companies of large projects in the natural environment</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Outdoor activities professionals</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Associations of outdoor activities</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hunting organizations</td>
<td>Hunting Confederation, 5th Hunting Federation of Epirus, 6th Hunting Federation of Macedonia-Thrace, Local Hunting Associations</td>
<td></td>
<td>Practice of hunting by their members in the natural environment, including the habitats of protected species of wild fauna, Operation of hunting corps. Awareness-raising for hunters aiming to the prevention of incidents of illegal hunting, Participation in monitoring the population size of fauna species.</td>
</tr>
<tr>
<td>CATEGORIES OF ENTITIES</td>
<td>INVOLVED AGENCIES/SERVICES/GROUPS OF PEOPLE</td>
<td>SUB-CATEGORY</td>
<td>COMPETENCES - ACTIONS</td>
</tr>
<tr>
<td>---------------------------------------------</td>
<td>---------------------------------------------</td>
<td>-------------------------------------</td>
<td>--------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Professional groups and individuals</td>
<td>Livestock breeders and their associations</td>
<td></td>
<td>Use of natural and semi-natural ecosystems for grazing</td>
</tr>
<tr>
<td>Professional groups and individuals</td>
<td>Loggers and their associations</td>
<td></td>
<td>Use of natural and semi-natural ecosystems for logging</td>
</tr>
<tr>
<td>Professional groups and individuals</td>
<td>Farmers (agricultural land cultivators)</td>
<td></td>
<td>Use of agricultural ecosystems for cultivation</td>
</tr>
<tr>
<td>Individuals</td>
<td>Fishermen</td>
<td></td>
<td>Use of natural ecosystems - inner waters (rivers and lakes) for fishing</td>
</tr>
<tr>
<td>Individuals</td>
<td>Hunters</td>
<td></td>
<td>Use of natural and semi-natural ecosystems for hunting</td>
</tr>
<tr>
<td>Individuals</td>
<td>Hikers/ mountaineers/cyclists/ kayakers/ climbers/ runners</td>
<td></td>
<td>Use of natural and semi-natural ecosystems for recreational activities</td>
</tr>
</tbody>
</table>
6. Balkan Chamois (Rupicapra rupicapra balcanica)

6.1. Ecological overview for the Balkan chamois in Greece

Ecology

The Northern chamois (Rupicapra rupicapra) is a medium-small goat-antelope of robust form. Fully grown individuals may reach a height of 80–85 cm in males and 75–80 cm in females and a full body length of 125–135 cm (Couturier 1938). Both sexes possess short ebony dark horns that curve sharply backward towards the tip. The color of the coat varies seasonally, from reddish brown in summer to dark brown/black in winter.

Northern chamois mostly occur from the treeline to elevations up to 3,000 m in summer and descend to lower elevations in conifer forests in winter (Ballo 2010; Lovari et al. 2006; Nesti et al. 2010; Anderwald et al. 2015, 2016). Extant Northern chamois populations are found in a wide range of habitats: besides alpine and subalpine meadows, pastures, forests, and clearings, the species also occurs on scree slopes, in rocky areas, and in shrublands (Ballo 2010; Nesti et al. 2010; Darmon et al. 2012; Anderwald et al. 2015). The Balkan chamois in Greece has been reported to have an annual range of 6,491 ha in Tymfi mountain, which falls within the study area (Kati et al. 2020b), and 5,502 ha in Giona mountain, which is its southernmost limit of distribution (Papaioannou et al. 2015). It follows the typical range-use pattern in Tymfi mountain: the minimum seasonal range was recorded in winter, indicating that winter is the main stress period for the species, and the minimum core area has been reported during autumn, as it is the rutting period for the species (Kati et al. 2020b). A reverse Mediterranean range-use pattern has been reported in Giona mountain, with the smallest seasonal range and core area recorded during the summer period and then in the rutting period (autumn), indicating the summer is the main stress period for the species, while the populations show an aggregative pattern during the rutting period for breeding (Papaioannou et al. 2015). In Tymfi mountain, chamois selected north-facing slopes in pine forests in winter and spring, and in summer and autumn, it preferred higher elevations with a substantial cover of rocks and screes, favoring east-facing or north-facing slopes, respectively (Kati et al. 2020b). Balkan chamois uses steep slopes in Tymfi (seasonal averages value 30°–32°) and Giona (seasonal averages value 30°–35°). Some populations can also spend the entire year in forested areas due to adaptation to long-time disturbance factors, like livestock presence (accompanied by shepherd dogs) and intensive hunting/poaching. Animals have been observed drinking water in the rivers at the bottom of gorges from 2017 onwards in the study area (Aoos gorge) (Kati et al. 2020b). This behavior of staying close to water resources and the stressful summer period in arid mountains indicate that global warming is affecting the species in Greece. In Tymfi mountain, the chamois always selected areas away from the human settlements, roads, and areas where hunting was allowed, also avoiding south-facing slopes. A substantial area of the species distribution in Greece (40%) falls within the hunting ban zones of the country, estimated to account for 16.5% of the Greek territory (Kati et al. 2020b).

Chamois are intermediate feeders (Hofmann 1989) with a diet consisting mostly of graminoids throughout the year (e.g., Schröder and Schröder 1984; Bertolino et al. 2009; Redjadj et al. 2014). Besides graminoids, forbs, dwarf shrubs, and conifer material also contribute to the diet seasonally.

The rut normally occurs in the period between early November and early December in Europe (Krämer 1969), but in Greece seems to start earlier (mid-October) (Papaioannou 2021). Females older than three years give birth to one kid in May (mid-April to the beginning of June). Females and kids form groups that may consist of a few decades of individuals. In contrast, males are solitary or form very small groups. Males join the females’ groups during the rut period. Rutting behaviour occurs in daylight, but it has been recorded once at night in Rhodopes mountain (Papaioannou et al. 2020).
Distribution and population size

The Northern chamois (*Rupicapra rupicapra*) occurs in central & southeast Europe and western Asia and consists of seven subspecies, including the Balkan Chamois (*Rupicapra rupicapra balcanica*), which has a scattered and fragmented distribution throughout the Balkan countries. Regarding Balkan chamois distribution in Greece, there are 30 distinct sub-populations (and there are indications for a few additional ones) stretching through the Northern Pindos Mtns, the Central and Southern Pindos Mts, the mountains of Central Greece, Olympus Mt, Rhodope Mtns and some of the mountains along the N-NW border. The total Greek population size is estimated to be between 1,330 and 1,765 individuals (Papaioannou 2021).

Conservation status

According to IUCN, the Northern chamois is classified as Least Concern (LC), whereas the Balkan chamois is included in Annexes II and IV of the Habitat Directive 92/43 EEC and in Annex III of the Bern Convention as well. The Balkan chamois is classified as Nearly Threatened (NT) in the Greek Red Data Book of Endangered Animals. According to Greek law, it is designated as a protected species, and its hunting is prohibited. Its Conservation Status in Greece was rated in 2019 as Unfavourable-Bad (U2).

6.2. Balkan chamois in the Pindos-Prespes CCA

Distribution and populations

Our analysis indicated that the distribution range of the Balkan chamois covers 2,444 km² within the PP-CCA. Its distribution range is restricted in the central and southern parts of the PP-CCA. The PP-CCA fully (100%) covers the Balkan chamois distribution range of the study area. The species distribution range accounts for 55% of PP-CCA (Fig.13a).

According to the action plan for the Balkan chamois (Papaioannou 2012), the PP-CCA includes the populations of 12 mountains of Northern Pindos: Grammos, Smolikas-Kleftis, Trapezitsa, Timfi, Ligkos, Vasilitsa, Kleftes-Flabouro, Central Zagori, Nemertsika, Northern Gramos-Voio, Zigos-Katara and Mitsikeli. There are indications for three small populations of the species in three more localities of the PP-CCA, namely in Tabouri-Gyftissa mountain, Gormos gorge and Varnountas mountain. The estimated population size in the PP-CCA is 575-710 individuals, according to the populations referred to in the national action plan (Papaioannou 2021). The distribution range presented in Fig.13a indicates the potential distribution area of the species at a coarse scale (10kmX10km), and further research is needed to confirm the species' presence across the 12 mountains to investigate its occurrence in the three more areas, and to provide a fine-scale map of its current distribution within the broader range of the species in the PP-CCA.

Threats and pressures

In Greece, the major threat/pressures for the species' survival nationwide is poaching, followed by the construction and use of roads, livestock breeding under certain conditions, population fragmentation and genetic isolation, disturbance due to hunting, tourism and mountain sports, mineral extraction and climate change (Papaioannou 2021). Those populations on the border with neighboring Balkan countries are adversely affected by interventions from other countries. Table 13 assesses the importance of the 11 different types of threats/pressures affecting the Balkan Chamois populations for Greece (Papaioannou 2021) and for the PP-CCA after expert opinion.

The main threat to the Balkan chamois in PP-CCA is poaching, carried out with the use of hunting rifles and, in some cases, with military weapons (Papaioannou, 2016, 2021). Hunting of the Balkan chamois is not allowed in Greece. However, hunting is included in the Pressures on the species in the sense of disturbance when this activity occurs in its habitats (e.g. during hunting wild boars with the drive method). The road network that runs through or is close to
the crucial habitats of the Balkan chamois is a particularly negative factor for its populations, as it leads to an increased degree of disturbance, linked to legal hunting and other human activities and mainly to the facilitation of poaching activity (Kati et al., 2020, Papaioannou 2016, 2021).

Regarding the threats and pressures from outside the EU territory, we note that Balkan chamois populations located in the transboundary zone are of interest to poachers from both countries, but it seems impossible to stop this activity when poachers come from the neighbor country. So, for example, the BC population of Mt Grammos has suffered a lot during the last decades because Albanian poachers systematically visit the habitats of the species in the Greek territory (Papaioannou 2016, 2021).

Regarding the other threats, we note the following: Renewable energy sources and especially the installation of wind farms in the habitats of the BC result in the transformation of the natural habitat into artificially modified land and provide access to the public and especially to poachers but also hunters, taking into account that hunting is a significant disturbance factor against the BC. Similarly, impounding the water of springs and streams for hydroelectric installations could cause problems for the species, denying it access to water resources. The deployment of RES does not currently affect chamois habitats in the Mts of Tymfi and Smolikas, which have significant BC habitats and are protected as road-free zones of any RES infrastructure. However, future RES deployment of wind and solar infrastructures in the chamois habitats might be of serious concern, as well as hydroelectric dams, given the pattern observed for the species in the last years relating to the scarcity of water resources.

Finally, grazing by livestock takes -in some cases- a particularly massive character, and this mainly concerns cattle farming which tends to replace the traditional goat-sheep livestock raising. This seems to cause degradation of the BC habitats in the mountainous and subalpine areas and overuse of the water resources, as in parts of Mt Tymfi (Papaioannou 2021).
Table 13: Assessment of the intensity of Threats (T) and Pressures (P) for the Balkan chamois as non-existing (0), low (*), medium (**) and high (***) intensity at national scale according to the Action Plan and at the local scale for the PP-CCA after expert opinion. O: origin of pressure/threat. H: human pressure, N: Natural pressure.

<table>
<thead>
<tr>
<th>Threats/Pressures</th>
<th>Description</th>
<th>Code</th>
<th>Type</th>
<th>Origin</th>
<th>Greece</th>
<th>PP-CCA</th>
</tr>
</thead>
<tbody>
<tr>
<td>RES infrastructures</td>
<td>Development of renewables infrastructure of wind, solar and hydroelectric power</td>
<td>na</td>
<td>T</td>
<td>H</td>
<td>0</td>
<td>**</td>
</tr>
<tr>
<td>Illegal shooting</td>
<td>Illegal shooting/ killing</td>
<td>G10</td>
<td>P/T</td>
<td>H</td>
<td>***</td>
<td>***</td>
</tr>
<tr>
<td>Roads construction</td>
<td>Roads, paths, railroads and related infrastructure (e.g. bridges, viaducts, tunnels)</td>
<td>E01</td>
<td>P/T</td>
<td>H</td>
<td>***</td>
<td>***</td>
</tr>
<tr>
<td>Hunting of other species</td>
<td>Hunting</td>
<td>G07</td>
<td>P</td>
<td>H</td>
<td>***</td>
<td>***</td>
</tr>
<tr>
<td>Intensive livestock grazing or overgrazing</td>
<td>Intensive grazing or overgrazing by livestock</td>
<td>A09</td>
<td>P/T</td>
<td>H</td>
<td>**</td>
<td>**</td>
</tr>
<tr>
<td>Tourism activities and outdoor activities</td>
<td>Sports, tourism and leisure activities</td>
<td>F07</td>
<td>P/T</td>
<td>H</td>
<td>**</td>
<td>*</td>
</tr>
<tr>
<td>Climate change</td>
<td>Temperature changes due to climate changes</td>
<td>N01</td>
<td>T</td>
<td>N/H</td>
<td>**</td>
<td>**</td>
</tr>
<tr>
<td>Extraction of minerals</td>
<td>Extraction of minerals (e.g. rock, metal ores, gravel, sand, shell)</td>
<td>C01</td>
<td>P/T</td>
<td>H</td>
<td>**</td>
<td>No</td>
</tr>
<tr>
<td>Isolation and fragmentation</td>
<td>Reduced fecundity / genetic depression (e.g. inbreeding or endogamy)</td>
<td>L05</td>
<td>T</td>
<td>N/H</td>
<td>**</td>
<td>**</td>
</tr>
<tr>
<td>Threats and pressures from outside the member state</td>
<td>Threats and pressures from outside the Member State</td>
<td>Xo</td>
<td>P</td>
<td>H</td>
<td>**</td>
<td>No</td>
</tr>
<tr>
<td>Threats and pressures from outside the EU territory</td>
<td>Threats and pressures from outside the EU territory</td>
<td>Xe</td>
<td>P</td>
<td>H</td>
<td>**</td>
<td>***</td>
</tr>
<tr>
<td>Extensive grazing or undergrazing by livestock</td>
<td>Extensive grazing or undergrazing by livestock</td>
<td>A10</td>
<td>T</td>
<td>H</td>
<td>**</td>
<td>**</td>
</tr>
</tbody>
</table>

**Conservation knowledge background**

No special conservation measures have ever been applied for the Balkan chamois, specifically for the PP-CCA. Conservation measures at a national scale that benefit the species are: (a) the general ban on its hunting throughout the country according to the Greek legislation (Legislative Decree 86/1969), (b) the banning of hunting in the established wildlife sanctuaries and national park core areas, (c) the implementation of the study regarding the Balkan chamois National Action Plan and (d) the legislation of roadless areas in Tymfi and Smolikas areas (see 3.7.).
We present the studies targeting Balkan chamois, involving the populations in the study area.

**A. Studies and projects on the Balkan chamois in the PP-CCA**

**B. Studies and projects at a broader scale, including the PP-CCA**

**C. Studies and projects at a national scale**
The most important and comprehensive study of the above list is the National Action Plan (Papaioannou 2021 – N 12) published in the governmental gazette (FEK 3664/B/09.08.2021). The general objective of the National Action Plan (NAP) is to contribute towards ensuring the survival of the Balkan Chamois (Rupicapra rupicapra balcanica) by improving the species’ Conservation Status at a national level, namely turning its current ‘U2- I’ status into ‘U1- I’. Its main objectives involve implementing those measures that would safeguard and enhance the population size and the geographical distribution of the Balkan Chamois, at both the local and the national levels. Specific objectives concern the chamois population at a local and national level, its habitat features, its distribution and range, its critical zones and ensuring the connectivity between isolated populations. A series of actions are proposed, which are grouped into seven sets of Measures: Population Conservation & Improvement, Conservation and Improvement of Habitat Status, Preservation/ Extension of Geographical Distribution and Reduction of Fragmentation, Institutional Framework (Legislation and Policy), Monitoring and Research, Public awareness and environmental education, International cooperation.

Finally, the association for the protection of the Balkan chamois (Balkan Chamois Society), founded in 2007 and based in the study area, carries out -usually on a voluntary base- indicative monitoring actions of the species' populations with automatic recording machines, population counts, recording of threats and pressures, policy and maintains close contacts with local stakeholders and individuals to protect the species. The Biodiversity Conservation Lab (BCL) of the Department of Biological Applications & Technology (founded in 2017) also undertakes ecological studies for protected areas management, landscape and biodiversity conservation, and large mammal species ecology, including the Balkan chamois.
**Indicative ecological corridors for the Balkan chamois**

A total of 66 ecological corridors (optimal and secondary) connected to the roadless areas of the PP-CCA, are indicative corridors that would facilitate the free and low-energy cost movement of the Balkan chamois among the 25 roadless areas of the PP-CCA (see Table 5). Corridors are visualized as lines (Fig 12c) and their properties are summarized in Table 14. The selected corridors are mainly located in adequate habitats for Balkan chamois, steeper terrains, away from all types of roads and in proximity to freshwater resources, minimizing the energy cost for its free movement among the roadless areas (Fig. 12b) after the scoring of the above factors through expert opinion (see Table S1). Optimal corridors had the maximum weighted overlay score, whereas secondary corridors could be used as alternative movement paths among the roadless areas with lower weighed overlay scores.

**Table 14**: Indicative ecological corridors facilitating the free movement of the Balkan chamois among the 25 roadless sites of the Pindos-Prespes Connectivity conservation Area, with reference to the scoring of parameters presented in the Appendix (Table S1).

<table>
<thead>
<tr>
<th>Corridors properties</th>
<th>Optimal corridors</th>
<th>Secondary corridors</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of corridors</td>
<td>21</td>
<td>45</td>
</tr>
<tr>
<td>Total corridor length</td>
<td>249 km</td>
<td>621 km</td>
</tr>
<tr>
<td>Cost per meter of corridor length</td>
<td>2.4 m</td>
<td>2.9</td>
</tr>
</tbody>
</table>

Focusing on the optimal corridors, all the main roadless polygons at the south-central part (Mt Tymfi, Mt Smolikas, Mt Arkoudorema-Flega-Avgo), located into the Northern Pindos national park, are connected to each other. Then the optimal corridors that connect smaller roadless polygons approach the border zone with Albania at the west, attaching the Polis-Sopot-Valamare-Gramoz CCA of Albania, and continue to the north, up to the Prespa national park (RA013). Mt Gyftissa-Tambouri roadless polygon, located around the centre of the PP-CCA, seems to play a crucial role as a stepping stone point between the south and north roadless polygons. Furthermore, it is important to be mentioned that there is only one optimal corridor (no secondary ones) connecting the south-central part of the CCA to the north one and it is at the area of the villages Dipotamia and Komninades. This is due to the narrow bandwidth of the PP-CCA that connects the ecosystems of Prespes NP with those of Northern Pindos NP along the borderline. Another optimal corridor moves from west to the east in the centre of the PP-CCA connecting Mt Grammos -through RA217- with Mt Ontria (RA342), located SE of Nestorio. In addition, there are several secondary corridors connecting all the roadless polygons by alternative directions. As Balkan Chamois prefer the most inaccessible terrain being away from human infrastructure and disturbance, we assume that most of the roadless areas in PP-CCA coincide with crucial chamois habitats, considering that the selected method regarding the determination of indicative corridors between the roadless areas describes quite well the pattern used by BC.

It is worth mentioning that Corridors were determined by a set theory algorithm that determines the most suitable path between a set of areas (In our case Roadless Areas). The suitable path is incrementally defined within a cost surface. The cost surface is limited within the Greek boundaries. The algorithm does not stop creating the corridor if the conditions are not suitable but it will find the least cost path towards the closest roadless area within the CCA. Even if that is a problematic area. It is necessary to identify problematic areas of the corridors (asphalt road crossings etc.) and maybe allocate resources for mitigation.
Figure 13: (a) Distribution range of the Balkan chamois in the study area and in the Pindos-Prespes CCA, (b) mobility cost across PP-CCA, and (c) indicative optimal and secondary ecological corridors for its free movement along roadless areas.
6.3. Chamois bibliography


7. **BROWN BEAR (URSUS ARCTOS)**

7.1. Ecological overview of the brown bear in Greece

*Ecology*

The brown bear (*Ursus arctos*) is the largest carnivore in Europe. The species is characterized by sexual dimorphism, with males being usually larger and heavier than females. Males in Greece weigh 110 - 250 kg and females 70-120 kg. Hibernation is a behavioral trait of brown bears to cope with the scarcity of food during the winter and, in Greece, lasts for a mean of 83 days, from late December to late March (Mertzanis et al. 2011). Denning bears lower their temperatures by a few degrees (from 38°C to 34°C), decrease their heart and respiratory rates, and cease basic biological functions such as eating, drinking, urinating, and defecating. However, the alertness of denning bears is still high and the animals can wake up easily when disturbed, which may cause failure to re-hibernate, roaming for scarce food resources, and early consumption of stored fat. Female bears give birth during hibernation, usually to 1-3 cubs, and young bears accompany the mother for 1.5-3.5 years.

Brown bears in Greece occupy mainly areas with increased forest cover, in deciduous forests (oak, beech etc.) and coniferous (black pine, fir, spruce etc.) trees in the mountainous and semi-mountainous zones (500-1800 meters altitude), but also areas with lower forest cover and scrub vegetation (Mertzanis et al. 2021). Earlier telemetry studies in Greece have found bears to show a clear preference for mixed agro-forestry systems, mixed broadleaved forests, and small-scale agricultural lands (Kanellopoulos et al. 2006, Mertzanis et al. 2008). A more recent telemetry study has found habitat use and selection to differ between individual bears, depending on their sex and age, as well as on the temporal scale (i.e. day of the year and time of the day) (de Garfield Hernando et al. 2021). The latter study showed that bears used areas of low human disturbance during the day and areas of high human disturbance during the night and selected habitats with naturalized (i.e. abandoned/non-intensive) crops close to water sources while around their hibernation period they were found to select rough-terrain areas (del Garfield Hernando et al 2021).

Brown bears are omnivorous in Greece and have a diverse diet that mainly consists of food items of plant origin (88%) and less of animal origin (12%) (Mertzanis et al. 2021). Their diet varies throughout the annual cycle: green vegetation is most prevalent during the spring, fruits and cereals during the summer, and hard mast (i.e. acorns, beech seeds) during autumn (Paralikidis et al. 2010). Regarding animal material, invertebrates (e.g. ants, wasps) are important food items during spring and summer, while livestock is also occasionally consumed (Paralikidis et al. 2010).

Brown bears are solitary animals; however, territory overlap between neighboring animals is common, while the females with cubs systematically avoid large males (Mertzanis et al. 2021). The territory of males covers an average of 271 km², and the territory of females covers 118 km² (Mertzanis et al. 2011). The marking of tree trunks (mainly conifers) and power poles in key points of the territory is a dominant feature of male bears, especially during the breeding season (May-July) (Karamanlidis et al. 2007).

*Distribution and population size*

Brown bears in Greece reach their southernmost European distribution. After centuries of decline, the species has had an encouraging recovery in Greece during the last decades, including a population size increase (~500 individuals) Pylidis et al. 2021, Karamanlidis et al. 2015), a range expansion (Bonnet Lebrun et al. 2019) and a genetic recovery (Karamanlidis et al. 2015). The distribution of the species covers 24,105 km², and its range covers 37,603 km² (Mertzanis et al. 2021).
Brown bears in Greece survive in two previously disconnected populations: a) in Pindos and Peristeri, two adjacent mountain ranges in western Greece, and b) in Rhodopi mountain range in eastern Greece (Mertzanis et al. 2009). The bear population of Pindos/Peristeri is connected to the Dinaric-Pindos bear populations, and the Rhodopi population is connected to the East Balkan bear populations. The Pindos/Peristeri bear population can be further divided into two geographical sub-nuclei populations of Peristeri and Pindos (Karamanlidis et al. 2018). Recent genetic studies, however, indicated low genetic diversity for bears in western Greece with asymmetric gene flow from South to North between neighboring subpopulations, mediated mainly by males (Karamanlidis et al. 2018), as well as an increased inbreeding score in the National Parks of Prespa and Rhodopi (Tsalazidou-Founta et al. 2022).

**Conservation status**

According to European Community legislation (Habitats Directive 92/43/EEC), the brown bear in Greece is strictly protected (Annex II and IV). Moreover, bears in Greece are fully protected under the Bern Convention (Annex II). These provisions prohibit deliberate disturbance of individuals, particularly during breeding, rearing, and hibernation, and additionally require authorities to explicitly prohibit damages to breeding, resting, and hibernating sites. According to Greek law, the species is designated as a strictly protected species, and its killing, capture and exhibition to public view are strictly prohibited. The species is classified as Endangered (EN) in the Greek Red Data Book of Endangered Animals. Its Conservation Status in Greece was rated in 2019 as Unfavourable – Inadequate (U1), showing an improving conservation trend.

**7.2. The Brown bear in the Pindos-Prespes CCA**

**Distribution and population**

According to our analysis, the brown bear distribution in PP-CCA covers 4,131 km² (Fig.14a). The PP-CCA covers the greatest part of the brown bear distribution range in the study area, and the species distribution range accounts for 94% of PP-CCA. The census population size (Nc) of the brown bear was estimated with genetic analysis in large parts of the study area: Florina Regional Unit: 154 individuals (2018, Project LIFE AMYBEAR), Northern Pindos National Park: 202 individuals (2022, Project LIFE ARCPROM), Kastoria region: 219 individuals (2015, project LIFE ARCTOS KASTORIA).

**Threats and pressures**

In Greece, according to the 3rd National Six-Year Report on the Implementation of Directive 92/43/EEC and the National Brown Bear Action Plan (Mertzanis et al. 2021), the main threats/pressures for the brown bear are related primarily to the alteration, loss and fragmentation of habitats (A01, A07, B09, B10, B15, B16, D01, D02, D03, D07, E01, F05, Table 15), the construction of linear transportation infrastructure (roads and railways, E01), the non-sustainable forest practices and land use changes (A01, A07, B09, B10, B15, B16) as well as poaching (G10) and incidental killing (G12). In general, there are 18 types of Threats/Pressures affecting the brown bear populations in Greece (Table 15).
Table 15: Assessment of the intensity of Threats (T) and Pressures (P) for the brown bear as low (*), medium (**) and high (***)) intensity at the national scale according to the Action Plan and at the local scale for the PP-CCA after expert opinion. O: origin of pressure/threat. H: human pressure, N: Natural pressure.

<table>
<thead>
<tr>
<th>Threats/Pressures</th>
<th>Description</th>
<th>Code</th>
<th>Type</th>
<th>Origin</th>
<th>Greece</th>
<th>PP-CCA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Non-sustainable forestry</td>
<td>Clear-cutting, removal of all trees</td>
<td>B09</td>
<td>P</td>
<td>H</td>
<td>***</td>
<td>***</td>
</tr>
<tr>
<td>Poaching</td>
<td>Illegal shooting/ killing</td>
<td>G10</td>
<td>T</td>
<td>H</td>
<td>***</td>
<td>***</td>
</tr>
<tr>
<td>Renewable energy infrastructure</td>
<td>Wind, wave and tidal power, including infrastructure</td>
<td>D01</td>
<td>P/T</td>
<td>H</td>
<td>**</td>
<td>***</td>
</tr>
<tr>
<td>Renewable energy infrastructure</td>
<td>Hydropower (dams, weirs, run-off-the-river), including infrastructure</td>
<td>D02</td>
<td>P/T</td>
<td>H</td>
<td>**</td>
<td>***</td>
</tr>
<tr>
<td>Renewable energy infrastructure</td>
<td>Solar power, including infrastructure</td>
<td>D03</td>
<td>T</td>
<td>H</td>
<td>**</td>
<td>*</td>
</tr>
<tr>
<td>Oil/gas pipelines infrastructure</td>
<td>Oil and gas pipelines</td>
<td>D07</td>
<td>P</td>
<td>H</td>
<td>**</td>
<td>**</td>
</tr>
<tr>
<td>Road construction</td>
<td>Roads, paths, railways and related infrastructure (e.g. bridges, viaducts, tunnels)</td>
<td>E01</td>
<td>P/T</td>
<td>H</td>
<td>**</td>
<td>***</td>
</tr>
<tr>
<td>Tourism activities and outdoor activities</td>
<td>Creation or development of sports, tourism and leisure infrastructure (outside the urban or recreational areas)</td>
<td>F05</td>
<td>P/T</td>
<td>H</td>
<td>**</td>
<td>**</td>
</tr>
<tr>
<td>Incidental killing</td>
<td>Bycatch and incidental killing (due to fishing and hunting activities)</td>
<td>G12</td>
<td>P/T</td>
<td>H</td>
<td>**</td>
<td>**</td>
</tr>
<tr>
<td>Poisoning</td>
<td>Poisoning of animals (excluding lead poisoning)</td>
<td>G13</td>
<td>P/T</td>
<td>H</td>
<td>**</td>
<td>**</td>
</tr>
<tr>
<td>Vandalism or arson</td>
<td>Vandalism or arson</td>
<td>H04</td>
<td>P</td>
<td>H</td>
<td>**</td>
<td>**</td>
</tr>
<tr>
<td>Restricted access to protected areas</td>
<td>Closure or restricted access to site/habitat</td>
<td>H06</td>
<td>T</td>
<td>H</td>
<td>**</td>
<td>**</td>
</tr>
<tr>
<td>Climate change</td>
<td>Desynchronization of biological/ecological processes due to climate change</td>
<td>N06</td>
<td>T</td>
<td>N/H</td>
<td>**</td>
<td>**</td>
</tr>
<tr>
<td>Land use change</td>
<td>Conversion of natural or semi-natural lands to intensive crops</td>
<td>A01</td>
<td>P/T</td>
<td>H</td>
<td>**</td>
<td>**</td>
</tr>
<tr>
<td>Land use change</td>
<td>Abandonment of sustainable agricultural and agroforestry systems practices</td>
<td>A07</td>
<td>P/T</td>
<td>H</td>
<td>**</td>
<td>**</td>
</tr>
<tr>
<td>Non-sustainable forestry</td>
<td>Illegal logging</td>
<td>B10</td>
<td>P/T</td>
<td>H</td>
<td>**</td>
<td>**</td>
</tr>
<tr>
<td>Non-sustainable forestry</td>
<td>Non-sustainable forestry practices/short rotation period</td>
<td>B15</td>
<td>P/T</td>
<td>H</td>
<td>**</td>
<td>**</td>
</tr>
<tr>
<td>Non-sustainable forestry</td>
<td>Timber transport/road construction</td>
<td>B16</td>
<td>P/T</td>
<td>H</td>
<td>**</td>
<td>**</td>
</tr>
</tbody>
</table>
**Conservation knowledge background**

**A. Studies and projects on the brown bear in the PP-CCA**

The past and current studies/projects targeting the brown bear in parts of the study area are the following:


2. **LIFE Bear-Smart Corridors (2021-2026).** LIFE20 NAT/NL/001107. Enhancing the viability of Brown Bears in Central Italy and Greece through the development of coexistence corridors.


8. Special Environmental study (monitoring) of the Northern Pindus National Park (2008).


**B. Publications on the brown bear in Greece**


The two main environmental NGOs that work towards the study, protection and management of the populations and habitats of bears in Greece are CALLISTO Wildlife Conservation Society (scientific coordinator: Yorgos Mertzanis) and ARCTUROS (scientific coordinator: Alexandros Karamanlidis).

Indicative ecological corridors for the brown bear

A total of 66 ecological corridors (21 optimal and 45 secondary) connected the roadless areas of the PP-CCA, as indicative corridors that would facilitate the free and low-energy cost movement of the brown bear among the 25 roadless areas of the PP-CCA (see Table S5). Corridors are visualized as lines (Fig 14b), and their properties are summarized in Table 16. The selected corridors are located in adequate habitats for the brown bear in terrains of milder slopes, away from asphalt roads and in proximity to freshwater resources after scoring the above factors through expert opinion (see Table S1). Optimal corridors had the maximum weighted overlay score, whereas secondary corridors could be used as alternative movement paths among the roadless areas with lower weighed overlay scores.

Table 16: Indicative ecological corridors facilitating the free movement of the brown bear and wolf among the 25 roadless sites of the Pindos-Prespes Connectivity conservation Area, with reference to the scoring of parameters presented in the Appendix (Table S1).

<table>
<thead>
<tr>
<th>Corridors properties</th>
<th>Optimal corridors</th>
<th>Secondary corridors</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of corridors</td>
<td>21</td>
<td>45</td>
</tr>
<tr>
<td>Total corridor length</td>
<td>253 km</td>
<td>617 km</td>
</tr>
<tr>
<td>Cost per meter of corridor length</td>
<td>1.7 m</td>
<td>2.2</td>
</tr>
</tbody>
</table>
Figure 14: (a) Distribution range of the Brown Bear in the Pindos-Prespes CCA, (b) mobility cost across PP-CCA, and (c) indicative optimal and secondary ecological corridors for its free movement along roadless areas.
Focusing on the optimal corridors, all the main roadless polygons at the south-central part (Mt Tymfi, Mt Smolikas, Mt Arkoudorema-Flega-Avgo) are connected to each other. Then the optimal corridors, connecting smaller roadless polygons, approach the border zone with Albania at the west, attaching the Polis-Sopot-Valamare-Gramoz CCA of Albania, and continues to the north, up to the Prespa national park. It is important to be mentioned that there is only one optimal corridor connecting the south-central part of the CCA to the north one and it is at the area of the villages Dipotamia and Komninades, located SW of Kastoria at the point where the PP-CCA presents its smaller width. Another optimal corridor moves from west to the east in the centre of the PP-CCA connecting Mt Grammos with Mt Ontria (RA342), located SA of Nestorio. In addition, several secondary corridors connect all the roadless polygons by alternative directions.

7.3. Brown bear bibliography


8. WOLF (CANIS LUPUS)

8.1. Ecological overview of the grey wolf in Greece

Ecology

The grey wolf (*Canis lupus*) is the world’s largest canid. In Mediterranean areas, the species' weight ranges from 20 to 40 kg, and its length from 90-150 cm. It is a social and territorial animal living in packs. The size of the pack depends on food availability, and in Greece is equal to a mean of 5.1 wolves (Iliopoulos et al. 2015). Wolf’s lifespan is around 10 years, and it mates from January to March, having a gestation period of 63 days. The female wolf gives birth once per year, during April-May, at a litter size of 1-6 pups.

The wolf is an opportunistic animal. In central and northeastern Europe, wolves rely mainly on wild ungulates, such as wild boars, roe deer, and red deer (Newsome et al. 2016). In Greece, as in other Mediterranean areas, wolves largely feed on livestock, such as goats, sheep, and cattle (Petridou et al. 2019). Nonetheless, in areas of Greece where wild ungulate populations have increased, wolves also feed on wild boars and roe deer (Iliopoulos et al. 2021, Petridou et al. 2018). The issue of wolf-livestock conflicts in Greece is severe, and wolves cause damages to livestock that correspond to average annual compensation costs of ~$950,000 (Petridou et al. under review). Wolf-human conflicts in Greece are further intensified by the high number of incidences concerning wolf depredation of hunting dogs (Iliopoulos et al. 2021).

The wolf is adaptable to all terrestrial habitats. In Greece, wolves live in a high diversity of habitats, from the mixed mountainous forests of N. Pindus, up to the high altitude zone (>2000 m altitude) and down to the edges of plains and villages/towns in search of food (Iliopoulos 2018). However, wolves avoid human disturbance when they select their breeding sites; these sites are away from forest roads and villages, close to water sources, and with a low forest fragmentation (Iliopoulos et al. 2014). Moreover, wolves are sensitive to human disturbance regarding their temporal activity and they increase their nocturnality in areas with high human disturbance (i.e. areas with a high occurrence of humans, vehicles, dogs, and livestock) (Petridou et al. 2023).

Distribution and population size

Grey wolves in Greece have experienced decades of persecution, bounties, and legal use of poison baits (Iliopoulos 2010). After 1993, a stricter legal status reversed the wolf population decline, and its distribution has been expanded mainly in south-central Greece, Boetia, and Attica. During the most recent population census (Iliopoulos et al. 2015), Greece's wolf population was estimated to be 795-1020 individuals, excluding lone wolves, with an average number of 156 wolf packs. The species distribution in Greece covers 60,000 km². The wolf territory size in Greece is, on average equal to 383 km².

Conservation status

According to the Habitats, Directive 92/43/EEC the wolf in Greece south of 39° longitude is listed in Appendix II and IV, while wolf populations north of 39° are listed in Appendix V. Moreover, the Bern Convention fully protected wolves throughout their range in Greece (Annex II). According to the convention, wolf killing, capture and trade are forbidden. The treaty requires the authorities to explicitly prohibit damage to breeding sites and the disturbance of individuals at those places. The wolf is classified as Vulnerable (VU) in the Greek Red Data Book of Endangered Animals. Its Conservation Status in Greece is Inadequate (U1) with improving conservation status.
8.2. The wolf in the Pindos-Prespes CCA

**Distribution and population**

Wolf distribution in PP-CCA covers 4,364 km² (99% of CCA). The population size in the PP-CCA is unknown.

**Threats/Pressures**

In Greece, according to the 3rd National Six-Year Report on the Implementation of Directive 92/43/EEC, the major threat/pressure for the grey wolf is poaching, followed by the reduction of domestic prey availability and the low availability of wild prey, habitat fragmentation, and hybridization. In general, there are nine types of pressures/threats affecting the wolf population in Greece (Table 17).

**Table 17:** Assessment of the intensity of Threats (T) and Pressures (P) for the wolf as low (*), medium (**) and high (***) intensity at the national scale according to the Action Plan and at the local scale for the PP-CCA after expert opinion. O: origin of pressure/threat. H: human pressure, N: Natural pressure.

<table>
<thead>
<tr>
<th>Threats/Pressures</th>
<th>Description</th>
<th>Code</th>
<th>Type</th>
<th>Origin</th>
<th>Greece PP-CCA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Poaching</td>
<td>Trapping, poisoning, poaching</td>
<td>F03.02.03</td>
<td>P/T</td>
<td>H</td>
<td>***</td>
</tr>
<tr>
<td>Poaching</td>
<td>Predator control</td>
<td>F03.02.04</td>
<td>P/T</td>
<td>H</td>
<td>***</td>
</tr>
<tr>
<td>Reduction of prey availability</td>
<td>Abandonment of pastoral systems, lack of grazing</td>
<td>A04.03</td>
<td>P/T</td>
<td>H/N</td>
<td>***</td>
</tr>
<tr>
<td>Reduction of prey availability</td>
<td>Reduction of prey availability (including carcasses)</td>
<td>J03.01.01</td>
<td>P/T</td>
<td>H/N</td>
<td>***</td>
</tr>
<tr>
<td>Reduction of prey availability</td>
<td>Intensive mixed animal grazing</td>
<td>A04.01.0</td>
<td>P/T</td>
<td>H/N</td>
<td>***</td>
</tr>
<tr>
<td>Low availability of wild ungulates/ lack of proper hunting management of wild ungulates</td>
<td>Hunting</td>
<td>F03.01</td>
<td>P/T</td>
<td>H</td>
<td>**</td>
</tr>
<tr>
<td>Habitat fragmentation</td>
<td>Roads, motorways</td>
<td>D01.02</td>
<td>P/T</td>
<td>H</td>
<td>**</td>
</tr>
<tr>
<td>Habitat fragmentation</td>
<td>Anthropogenic reduction of habitat connectivity</td>
<td>J03.02</td>
<td>P/T</td>
<td>H</td>
<td>**</td>
</tr>
<tr>
<td>Wolf-dog hybridization</td>
<td>Genetic pollution -animals</td>
<td>I03.01</td>
<td>P/T</td>
<td>H/N</td>
<td>**</td>
</tr>
</tbody>
</table>

**Conservation knowledge background**

The past and current studies/projects targeting the grey wolf in parts of the study area are the following:

In Greece, a National Wolf Action Plan has not yet been developed. The main environmental NGO that works towards the study, protection and management of the populations and habitats of wolves in Greece is CALLISTO Wildlife Conservation Society (scientific coordinator for the wolf: Yorgos Iliopoulos). The Biodiversity Conservation Lab (BCL) of the Department of Biological Applications & Technology (founded in 2017) of the University of Ioannina is in the proximity of the PP-CCA and also undertakes ecological studies for protected areas management, landscape and biodiversity conservation, large mammal species ecology, including the wolf ecology and human-wolf conflict mitigation (M. Petridou, Ph.D. student). Field work for the above Ph.D. thesis was undertaken in the southern part of the PONT study area.

**Indicative ecological corridors for the wolf**

Given that the same methodology and parameter scoring was used for the brown bear and the wolf, the ecological corridors (optimal and secondary) connecting the roadless areas of the PP-CCA were the same for the brown bear. However, the distribution range maps of the two species are different, and corridors are visualized on the distribution range map background. These corridors should facilitate the wolf’s free and low-energy cost movement among the 25 roadless areas of the PP-CCA (see Table 5). Corridors are visualized as lines (Fig 14b), and their properties are summarized in Table 16. The selected corridors are located in adequate habitats for the wolf, in terrains of milder slopes, away from asphalt roads and in proximity to freshwater resources, after scoring the above factors through expert opinion (see Table S1). A recent publication under review for the broader Pindos area confirms that wolves prefer milder slopes and avoid asphalt roads (Petridou et al. 2023). Optimal corridors had the maximum weighted overlay score, whereas secondary corridors could be used as alternative movement paths among the roadless areas with lower weighed overlay scores. A description of the optimal and secondary corridors is included in the previous chapter, as wolf and brown bear are treated together, consisted one class under the name large carnivores. As a result, Fig. 14 (b, c) is the same as Fig. 15 (b,c), and Table 16 is the same as in the previous chapter.

**Table 16**: Indicative ecological corridors facilitating the free movement of the brown bear and wolf among the 25 roadless sites of the Pindos-Prespes Connectivity conservation Area, with reference to the scoring of parameters presented in the Appendix (Table S1).

<table>
<thead>
<tr>
<th>Corridors properties</th>
<th>Optimal corridors</th>
<th>Secondary corridors</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of corridors</td>
<td>21</td>
<td>45</td>
</tr>
<tr>
<td>Total corridor length</td>
<td>253 km</td>
<td>617 km</td>
</tr>
<tr>
<td>Cost per meter of corridor length</td>
<td>1.7 m</td>
<td>2.2</td>
</tr>
</tbody>
</table>
Figure 15: (a) Distribution range of the Wolf in the Pindos-Prespes CCA, (b) mobility cost across CCA, and (c) indicative optimal and secondary ecological corridors for its free movement along roadless areas.
8.3. Wolf bibliography


9. OTTER (LUTRA LUTRA)

9.1. Ecological overview of the otter in Greece

Ecology

The Eurasian otter (Lutra lutra) is a carnivorous mammal and a member of the family Mustelidae. It is a flagship species, the top predator of Europe’s freshwater ecosystems. Otters are well-adapted to a semi-aquatic life and are almost always found close to water. They mainly live alongside rivers and canals, marshes, ponds, lakes, streams, estuaries, and rocky shores. Otters are tolerant of a wide range of habitat environments. Important habitat factors are food supply, pollutants, and the availability of secure breeding sites. Generally, healthy populations of otters can be expected in areas with abundant aquatic prey, acceptable water quality, and adjacent habitats that offer plenty of coverage.

Otters can travel large distances, but most adults stay in a well-defined territory where they feed, rest, and reproduce (Kruuk 2006). Otter territories are quantified as the length of riverbanks or coasts. The size of territories depends on habitat quality and food availability. Male otters have much larger territories than female ones. Moreover, one male otter’s territory generally overlaps with several females. Territories have a large range, from a few hundred meters in productive habitats to 30-40 km in length for otters living in impoverished rivers and streams (Galanaki and Gaethlich 2009). Otters mark their territories with their distinctive feces (spraints), which they often deposit on exposed sites as a means of scent communication (Calzada et al. 2010).

Their diet consists mainly of fish, amphibians, and crustaceans, as well as waterbirds, water snakes, and small mammals (Krawczyk et al. 2016).

Distribution range

The Eurasian otter is the most widespread otter species. It suffered a substantial decline in Europe from 1970 to 1990, but it is now recovering in many countries. The otter is widespread in Greece throughout much of the mainland and is also found on some islands (Galanaki and Gaethlich 2009, Galanaki et al. 2019). The species sustains good populations in Epirus, East Macedonia and Thrace, while in the rest of Greece, the populations of otters are more declined (Galanaki and Gaethlich 2009).

Conservation status

The otter is a European Protected Species under the Convention on the Conservation of European Wildlife and Natural Habitats (Bern Convention) - Appendix II (special protection for listed animal species and their habitats). The species is also included in the Directive on the Conservation of Natural Habitats and of Wild Fauna and Flora (Habitats Directive) Annex Ila and IVa (designation of protected areas for animal and plant species listed), which requires statutory protection and the maintenance of “favourable condition” for the species and its habitats. The otter is classified as Endangered (EN) in the Greek Red Data Book of Endangered Animals. Its Conservation Status in Greece is Favourable (FV) with a stable conservation trend.
9.2. The otter in the Pindos-Prespes CCA

Distribution and population

The otter distribution range in the PP-CCA covers 4227 km². The species has a widespread distribution, covering the PP-CCA (96%). Its distribution is linear across rivers and main streams within the different hydrological water basins, though in the case of lakes, such as Lake Kastoria, we consider it more compact. The most recent otter survey in parts of the study area was conducted in 2019 (Theodoropoulos et al. 2019). During this survey, 47 sites in Sarantaporos, Aoos and Voidomatis rivers were examined for otter presence; otters were present in 79% of surveyed sites, which is considered an indicator of a healthy otter population.

Threats/ Pressures

In Greece, according to the National Monitoring project, the major threat/pressure for the otter is road construction, poaching, dam construction, land use change, poisoning, and water pollution. In general, there are 7 types of pressures/threats affecting the otter population in Greece, as shown in the following table.

Table 18: Assessment of the intensity of Threats (T) and Pressures (P) for the otter as low (*), medium (**) and high (***) intensity at the national scale according to the Action Plan and at the local scale for the PP-CCA after expert opinion. O: origin of pressure/threat. H: human pressure, N: Natural pressure.

<table>
<thead>
<tr>
<th>Threats/Pressures</th>
<th>Description</th>
<th>Code</th>
<th>Type</th>
<th>Reason</th>
<th>Greece</th>
<th>PP/CCA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Road construction</td>
<td>Roads, paths, railroads and related infrastructure (e.g. bridges, viaducts, tunnels)</td>
<td>E01</td>
<td>P/T</td>
<td>H</td>
<td>**</td>
<td>**</td>
</tr>
<tr>
<td>Poaching</td>
<td>Illegal shooting/killing</td>
<td>G10</td>
<td>P</td>
<td>H</td>
<td>**</td>
<td>**</td>
</tr>
<tr>
<td>Dam construction</td>
<td>Abstraction of water, flow diversion, dams and other modifications of hydrological conditions for freshwater aquaculture Conversion from other land uses to housing, settlement or recreational areas (excluding drainage and modification of coastline, estuary and coastal conditions)</td>
<td>G20</td>
<td>P/T</td>
<td>H</td>
<td>**</td>
<td>***</td>
</tr>
<tr>
<td>Land use change</td>
<td>(excluding drainage and modification of coastline, estuary and coastal conditions)</td>
<td>F01</td>
<td>P</td>
<td>H</td>
<td>**</td>
<td>**</td>
</tr>
<tr>
<td>Poisoning</td>
<td>Poisoning of animals (excluding lead poisoning)</td>
<td>G13</td>
<td>P/T</td>
<td>H</td>
<td>**</td>
<td>**</td>
</tr>
<tr>
<td>Water pollution</td>
<td>Mixed source pollution to surface and ground waters (limnic and terrestrial)</td>
<td>J01</td>
<td>P</td>
<td>H</td>
<td>**</td>
<td>**</td>
</tr>
<tr>
<td>Poaching</td>
<td>Illegal harvesting, collecting and taking</td>
<td>G11</td>
<td>T</td>
<td>H</td>
<td>**</td>
<td>**</td>
</tr>
</tbody>
</table>

Conservation knowledge background

Few national or local surveys for determining otter presence in Greece have been conducted so far. Considering parts of the study area, the following surveys have been conducted:


9.3. Otter bibliography

- Calzada, J., Delibes-Mateos, M., Clavero, M., Delibes, M. (2010). If drink coffee at the coffee-shop is the answer, what is the question? Some comments on the use of the sprainting index to monitor otters. Ecological Indicators 10: 560–561
Figure 16: Distribution (a) and Freshwater connectivity (b) map for the otter.
10. ECOLOGICAL IMPORTANCE

The PP-CCA hosts at least 40 different habitat types according to the 92/43 directive for species and habitats distributed into the 14 SCI and SCI/SPA sites of the Natura 2000 network. Nine are high-priority habitat types (91E0, 9530, 6230, 3170, 6230, 6220, 9560, 6260, 3170). The PP-CCA hosts 212 species included in the Annexes II & IV of the Habitats and Species EU Directive (14 mammals, 6 reptiles, 2 amphibians, 11 fish, 9 insects, 4 plants), as well as in Annex 1 of the Birds Directive (169 birds). Besides, many other species have special importance in the local, national or wider frame (e.g. endemic species in Northern Pindos, Greece, South Balkans, protected by Greek legislation etc.). Considering the extent and quality of the habitats, the PP-CCA can host a Lynx population in the near future, as this species has been recorded to approach the Greek-Albanian and N. Macedonian borders, close to the northern point of the PP-CCA.

The PP-CCA is an area of high ecological value for other biodiversity components besides large mammals, such as raptors, being a crucial territory of the Egyptian vulture (*Neophron percnopterus*) or small terrestrial birds and woodpeckers (Kati et al. 2009). The PP-CCA holds forests of old-growth characters that surround churches and chapels in the countryside as sacred groves. These sacred groves extend in Pogoni, Konitsa, and Zagori and are of high ecological value as biodiversity old-growth wood refugia (Avtzis et al. 2018; Benedetti et al. 2021). It also has a great ecological value for butterflies, including *Parnassius apollo* (Tzortzakaki 2021) and other species of European interest, orthopterans, including *Paracaloptenus caloptenoides* as species of European interest and *Prionotropis willemsorum* (endangered grasshopper species endemic to the study area) (Lemonnier-Darcemont et al. 2022) etc.
11. SUMMARY

- **Extent:** PP-CCA covers an area of 4.387 km², which accounts for 75% of the study area.

- **Topography:** The greatest part of the PP-CCA (47.2%) lies in the elevational zone of 1000 – 1500 m, 31% in the zone of 500-1000m, 20% in the highest zone above 1500m and only 1.4% in the lowest elevational zone below 500m. 72 % of the PP-CCA falls within the mountainous less-favored zone of Europe.

- **Hydrography:** The length of the hydrographic network rises to 13,803 km, comprising non-permanent streams (13,333 km) and rivers of permanent flow (470 km) distributed in 6 different hydrological basins. Aliakmonas and Aoos are the most extended basins of the PP-CCA (46% and 36%, respectively).

- **Habitats:** 7 habitat types, according to the EUNIS European classification system (level 1), occur in the PP-CCA. “Woodlands, forest and other woodland land” cover most of the area (77,91%), followed by “Grasslands and land dominated by forbs, mosses and lichens” (13,3%). In contrast, “Constructed, industrial and other artificial habitats” covers only 0,41% of the PP-CCA, indicating the low level of human impact infrastructures in it.

- **Human impact:** The Human impact in the PP-CCA is lower (10.75) than the national average (17.5), according to the Human influence index (HII).

- **Fragmentation:** The road network of the PP-CCA includes 3,962 km of roads. The road density in the PP-CCA is 0,9 km of roads/km², and is three-fold time lower than the road density of Greece (2,82 km/km²). PP-CCA is an area of low fragmentation degree as the greatest part (93%) falls in the low or low fragmentation zone of the Landscape Fragmentation Index (LFI).

- **Wilderness areas:** PP-CCA hosts 25 roadless areas ranging between 7.14 to 202.75 km². PP-CCA includes two legally protected roadless areas within the National Park of Northern Pindos: Tymfi mountain (202,75 km²) and Smolikas mountain (102,89 km²). PP-CCA has a strong wilderness character. The Natura 2000 network of protected areas covers most of the wilderness areas well.

- **Administration:** PP-CCA falls within the Region of Epirus (Ioannina Regional Unit: 7 municipalities) and the Region of West Macedonia (Grevena, Kozani, Kastoria and Florina Regional Units: 8 municipalities), totaling all 245 municipal units (local communities).

- **Population:** According to the last population census of Greece, there is an overall decline of the order of 10% and 5% in the Regions of West-Macedonia and Epirus, respectively (PP-CCA is included in their administration borders).

- **Land abandonment:** In both regions, the land abandonment has increased, as the area of agricultural land use has declined by 15.7% in the Region of Western Macedonia and by 31.3% in the Region of Epirus between 2009 and 2020. The proportion of people working in the agricultural sector exclusively, mainly, or secondarily has dramatically declined by 34%, 71% and 58%, respectively, in the Region of western Macedonia and by 35%, 68% and 33%, respectively in the Region of Epirus, between 2009 and 2020. PP-CCA should undergo an important land abandonment from human farming activities, as indicated by the increase of abandoned agricultural fields and the decline of people working in the agricultural sector, as it is the general trend in the Region of Epirus and Region of W. Macedonia.

- **Land ownership:** No comprehensive land mapping exists for Greece, as the national Cadastre has not yet been completed. PP-CCA land ownership is divided into three categories: private land, municipal land and public land. Public land should cover most of the area.

- **Protected areas:** The greatest part of the PP-CCA (65.7%) is under protection status, accounting for a cumulative area of 2,883 km². It includes 20 sites of the Natura 2000 network of protected areas (covering 2,142 km²), 25 wildlife sanctuaries and the Northern Pindos National Park.
**Land use change:** A total of 8 km$^2$ of the natural and seminatural area in the PP-CCA has been converted to artificial land, with a peak in 2012-2018. Forest encroachment accounts for 52.7 km$^2$ since 1990, accounting for 1.09% of the PP-CCA.

**Fire vulnerability:** 28 fire events were recorded for 2008-2022, resulting in 17.5 km$^2$ of burnt land. Broadleaved forests and transitional woodland-shrubland were the two most heavily impacted vegetation, accounting for the greatest percentage of the total burnt land.

**Threats within Natura 2000 sites:** An overall number of 109 pressures/threats types have been recorded in the Natura 2000 sites located into PP-CCA, grouped into 13 general categories, according to the European classification of the EIONET.

**Renewable Energy Sources (RES) infrastructure:** Although currently, only four RES projects are in operation in the PP-CCA, namely two wind power stations and two hydropower stations, the RES infrastructure is a major threat in the future for the PP-CCA as if all RES projects -being at the stage of operation, production and under evaluation- are to be licensed there will be installed in the PP-CCA 137 RES infrastructures with nominal power of 971 MW. The hydropower sector is the most important threat to the connectivity of the PP-CCA and particularly so for its hydrographic network (2 installed/ 98 in progress). The wind energy sector is the second most important threat, with 44 wind power stations (2 projects installed/ 42 projects in progress).

**Governance and management:** Ministry of Environment and Energy, especially the Forest Service and the recently established Natural Environment and Climate Change Agency (NECCA), both belonging to the above ministry, are the most important stakeholders in the PP-CCA. In addition, the Ministry of Rural Development and Food, the Decentralized Administration of Epirus-Western Macedonia, the Regional Authorities, and the municipalities play a key role in the PP-CCA. Besides them, several other bodies, groups of people or individuals have a significant relationship with certain issues in the PP-CCA.

**Target species:** The PP-CCA seems to have a great conservation value for the four targeted mammal species, covering: (a) 100% of the Balkan chamois distribution range in the PP-CCA and the study area, (b) the greatest part of the brown bear distribution range in the study area, and its distribution range accounts for 94% of PP-CCA, (c) the greatest part of the wolf distribution range in the study area, and its distribution range accounts for 99% of PP-CCA, (d) the greatest part of the otter distribution range in the study area, and its distribution range accounts for 96% of PP-CCA.
12. CONCLUSIONS CONCERNING THE PP-CCA

The PP-CCA seems to fulfill the conditions to function as a wide ecological corridor connecting both its southernmost areas (Northern Pindos National Park) and those located even further south in Greece (Central Pindos) with those located in the north and northeast of either Greece (Prespa National Park) or neighboring Albania (Polis-Sopot-Valamare-Gramoz Connectivity conservation Area) but also in North Macedonia. To some extent it seems that the area already works in such a way. It is worth mentioning that PP-CCA is perfectly adjacent to the CCA of the Polis-Sopot-Valamare-Gramoz in SE Albania. The latter covers 3,175 km², including forests and transitional woodland-scrubs, and to a smaller extent, agricultural land, sparsely vegetated areas, artificial land, wetland and inland waters (Melovski et al. 2022). It also hosts bear, wolf and lynx populations, although it suffers from land fragmentation due to logging, fire and inappropriate use of resources. Taking appropriate measures and actions in the PP-CCA the following can be achieved:

- Contribution to ensuring the maintenance of sustainable populations of the target species of the present study (Balkan chamois, bear, wolf, otter).
- To strengthen and ensure the connectivity of the northern populations of these species (Albania-North Macedonia, Prespa area) with the southern ones (central Pindos).
- Ensuring the connectivity of the northern populations of these species (Albania-North Macedonia, Prespa area) with the southern ones (central Pindos).
- Contributing to the reappearance of these species in areas from which they have already disappeared and to the creation of new populations in suitable habitats that now remain vacant of these species.
- Ensuring the conditions required to enable the return of the lynx to Greece through the PP-CCA and by ensuring the maintenance of a permanent population of the species in the PP-CCA in connection with its northern populations (Albania, North Macedonia, Kosovo).
- Contribution to improving the condition of the populations and habitats of other important species, of all animal groups, that exist in the area.
- Strengthening the preservation of the uniqueness of the Aoos River and its tributaries as one of the last free-flowing rivers in Europe. In particular, in the context of the recent announcements on measures to protect the river by the authorities of the two neighboring countries (Greece, Albania), in order to benefit species directly related to water, such as fish and otters and aquatic life in general, but also all other species.
13. RECOMMENDATIONS FOR CONNECTIVITY ACTIONS IN THE PP-CCA TO BE SUPPORTED BY PONT

13.1. Overarching Goal - The Vision

To contribute to the safeguarding of ecological integrity of the connectivity conservation area, in a way that would support a favourable conservation status for local habitat types, as well as the habitats and populations of rare and protected species of fauna, especially with regard to target species (i.e., Balkan chamois, large carnivores, otter) in relation to the Wider Prespa-Ohrid Area or any other Connectivity conservation Areas in the PONT Focus Region in Greece, Albania and Northern Macedonia. Such a stewardship would secure the survival of these species in the region, as well as their ability to move freely between adjacent areas of high ecological importance, both in Greece and in nearby countries, while taking into consideration the wellbeing of local communities.

13.2. Conservation Objectives

- The conservation and/or improvement of the conservation status of the populations and the habitats of rare and protected species of wild fauna within the boundaries of the PP-CCA.
- The identification of ecologically important zones for rare and protected species of wild fauna, especially with regard to target species (i.e., Balkan chamois, large carnivorous, otter), and the preservation of suitable ecological corridors that would allow them unimpeded connection between their distinct distribution centers, both within and outside the boundaries of the PP-CCA.
- The raising of awareness for the protection of rare and protected species of wild fauna between competent authorities/bodies and local communities, through education, information spreading and the promotion of ecotourism and active participation.

13.3. Proposed Connectivity Conservation Actions

Governance

Capacity-building

- Empower municipalities and local communities, including local environmental NGOs and other stakeholders, to learn new skills and contribute to the enforcement of measures for nature protection and management of human activities, while improving their understanding of the importance of the PP-CCA.

Collaboration

- Promote collaborations between competent authorities (i.e., forestry service, protected area management units etc.), with other stakeholders (i.e., geopark management bodies), municipalities, regional authorities, NGOs and local communities.

Awareness raising

- Raise awareness regarding the ecological importance of the PP-CCA among the competent authorities responsible for developing and approving spatial, development, environmental, and forestry planning, all of which could potentially impact the PP-CCA and its conservation corridors.
- Raise awareness among local communities, municipalities, and competent authorities, with regards to the importance landscape values including its ecological connectivity as a fundamental value for both the natural environment and the wellbeing of local communities, as referred in the Landscape Convention of the Council of Europe ([https://www.coe.int/en/web/landscape#](https://www.coe.int/en/web/landscape#)). Relevant actions will also aim to link the concepts of
“landscape” and “biodiversity”, and to promote a sense of pride and responsibility among local community members.

- Raise awareness among local communities, municipalities, and local authorities about the ecosystem services provided by the PP-CCA.
- Informing and awareness-raising actions targeted at local communities and authorities, regarding the importance of traditional livestock grazing practices and especially that of transhumance livestock systems.
- Raise awareness among local communities, municipalities and authorities with regards to the importance of allowing for ecologically acceptable flows for free-flowing surface water bodies, especially in cases where flow regimes are impacted by water resource development (i.e., agriculture, water supply systems, hydro-electric power projects).
- Establish in the public sphere the concept of the Aoos river as one of the last free-flowing rivers. Relevant actions will aim to integrate this concept into the policies of local authorities, municipalities and shareholders, to develop relevant cross-border cooperation and to promote holistic and sound management of the Aoos river as the only sensible way forward.
- Recognize and promote the conservation importance of uninterrupted and sufficient flow in surface water bodies, and highlighting its importance for fish-stocks, in order to form alliances (i.e., with recreational fishermen) that will aim to restore (or at least protect from further degradation of) the aquatic ecosystems/corridors.
- Raise awareness about and promote the notion of undisturbed natural areas, such as Roadless Areas, for their contribution towards biodiversity conservation, especially with regard to target species, as well as for their potential value for sustainable tourism development.

**Biodiversity conservation**

**Actions towards increasing biodiversity knowledge within the PP-CCA**

- Increase the biodiversity knowledge (distribution, population status, ecological requirements etc) for target species that (a) are endemic in Greece, (b) are threatened (vulnerable, endangered, critically endangered) according to the national and/or European and/or global red list after the IUCN criteria, (c) are protected under the Habitats and Birds’ Directive, (d) are protected under the Greek legislation (Presidential Degree 67/81 or additional laws). Maintain a database where these records will be updated regularly.
- Map habitat types in the Special Protection Areas (SPAs) of the PP-CCA in the same manner as it has already been done for the Sites of Community Importance (SCIs).
- Record and monitor biodiversity within the PP-CCA, through collaboration with expert researchers (i.e., freelance scientists, NGOs, research institutes, universities, etc.).
- Record and map the threats on biodiversity within the PP-CCA and formulation of coping strategies.
- Identification and documentation of the anthropogenic impacts on the landscape, and how the habitat types and flagship species have been affected by man-made structures for renewable energy, with the PP-CCA. Raise awareness in the local communities, municipalities and authorities about the issue, through campaigns.
- Draft a report on the impact of large-scale installation of sustainable energy infrastructure on habitats, target species and the landscape. Raise awareness on the issue among local communities, municipalities and authorities, through campaigning.
- Map all old-growth woods within the PP-CCA, and deliver an open database of their extent, as all old-growth woods should be strictly protected after the European Biodiversity Strategy.
• Map all woods and forests within the PP-CCA that are considered to be “sacred” by local communities, and create an action plan for the sound management, in order to protect their environmental and the cultural values that they echo.

**Actions towards increasing knowledge on target species, with a view to informed management**

• Identify the current and potential core areas for the Balkan chamois (populations and sub-populations) and formulate scenarios for defining conservation corridors through the generation of a suitable spatial model (gathering of field data on the species’ distribution, data processing, scenario and model configuration).

• Identify the current and potential core areas for large carnivores (bear, wolf) and formulate scenarios for defining conservation corridors through the generation of suitable spatial models (gathering of field data on the species’ distribution, data processing, scenario and model configuration).

• Identify the current and potential core areas for the otter and formulate scenarios for defining conservation corridors through the generation of a suitable spatial model (gathering of field data on the species’ distribution, data processing, scenario and model configuration).

• Evaluate the available suitable habitat for the Eurasian Lynx within the PP-CCA. Locate optimal areas for the species as well as potential wildlife corridors both within the PP-CCA and across neighboring countries. Conducting a pilot study to monitor for potential signs of lynx presence (i.e., through camera traps, tracks surveys, etc.) within those optimal areas.

• Assess habitat use by the Balkan chamois during an annual cycle as well as chamois individual mobility through the use of satellite tags/collars, while also chamois herds in the field in order to allow for more focused patrolling of the species in these areas.

• Record and monitor changes in the size and demographic composition of Balkan chamois populations in the PP-CCA. Recording the occurrence of diseases and formulating treatment scenarios.

**Actions focusing on the agricultural/livestock sectors**

• Assessing the impacts on biodiversity and previously provided ecosystem services of the abandonment of agriculture and livestock raising (and the subsequent natural scrub/ forest regeneration) in large areas of the mid-elevation zone (500m-1000m) in the PP-CCA.

• Carrying out a study to determine possible impacts on mountain ecosystems (1000m-2600m) of the recorded transition from the traditional transhumance sheep and goat livestock raising to the present rearing of large numbers of cattle.

**Elimination of poaching**

• Develop an action plan aiming to curb/ eliminate Balkan chamois poaching on Tymfi, Smolikas and Lyngos Mts.

• Draw up a concise poaching incident guidebook, including instructions on the identification of genetic material of animal remains (instructions for conservation staff and citizens).

• Develop and promote a user-friendly application for citizens to easily visualize the boundaries of Wildlife Sanctuaries and other areas where hunting is prohibited, as well as seasonal regulations per hunted species. This would enable them to determine if recorded hunting instances are legal or not.

• Recording and assessing the type and intensity of poaching in wildlife sanctuaries and other statutory no-hunt areas.

**Wildlife barriers**
• Support actions to enhance wildlife crossings on major highways or other artificial barriers (e.g., Paraegnatia Highway).

**Disturbance**

• Evaluate the disturbance caused by legal hunting (especially wild boar hunting) to protected species of wild fauna from.
• Assess the potential impacts of recreational watersport activities (e.g., rafting, kayaking) on wildlife, especially on fish and otter populations.

**Aquatic environment – improved understanding and effective management**

• Identification of the important spawning grounds of fish species in the riverine ecosystems of all PP-CCA catchments, with emphasis on the Aoos River and its tributaries.
• Assessment of the status of the habitats and the local population of trout (and possibly other sympatric species) in the rivers of the wider Aoos river basin.
• Promotion, purchase and installation of electrified otter-proof fences on trout farms in the PP-CCA. The installation of such fences will alleviate conflicts between the otter and trout farm owners, and is expected to reduce human-induced mortality of otters in the PP-CCA.
• Construction of a number of otter holts in selected sections of the Aoos’s Springs Reservoir. The lack of sufficient available nesting sites along the shores of the lake in question, is considered to be a limiting factor on the local otter population.
• Construction of an otter holt and an adjacent hide to offer otter observation opportunities at close quarters, along a suitably selected section of Kastoria lake. This hide will have extensive otter-related material posted in its interior, thus also acting as an informal information point for the species. With the local administrative center of Kastoria lying on the shores of the namesake lake, it is expected that the action will help increase local awareness about the otter and its conservation.
• Restoration of the riparian habitat along an 8 - 10 km stretch of the Aoos river corridor, downstream the town of Konitsa. The illegal extraction of river sediment deposits that is going on along this stretch for decades, has depleted the riparian vegetation and has accelerated the erosion of the riversides and riverbed, with serious consequences for the aquatic organisms. To enhance the natural restoration processes of the habitat in question, selected riparian zones are to be suitably fenced, in order to limit grazing pressure and to deter further extraction of aggregates. The gradual healing of the river ecosystem is expected to massively improve the river stretch’s suitability for a multitude of species, including otters.

**Aquatic environment – barriers**

• Identification of barriers to the movement of fish and otter populations in the riverine ecosystems of all PP-CCA watersheds, with emphasis on the Aoos River and its tributaries. Impact level assessment and formulation of mitigation proposals for the benefit of fish populations and the otter. Implementation of essential measures (e.g., fish ladders).
• Examination on the compliance of existing fresh water barriers with existing legislation (existence of required permits, allowance for ecologically acceptable flows, environmental impact assessments etc.).

**Strengthening of stakeholder networks**

• Strengthening rural community networks, in order to eliminate cases of poisoned bates in the countryside. Poisoned baits have a significant negative effect on the populations of vultures (and especially the Egyptian vulture: the PP-CCA holds one of just three Egyptian vulture territories left in Greece), as well as on large carnivores (i.e., bear, wolf, etc.).
• Support for members of the above networks, through the provision of specialized equipment to prevent damage to livestock from wild animals (bears, wolves, etc.). This is expected to alleviate conflicts between livestock farmers and large carnivores, and therefore to reduce human-induced mortality of large carnivores in the CCA.

• Development of a smartphone/tablet application for stakeholders (such as non-expert scientists, naturalists) to record information regarding local biodiversity (i.e., presence of species, images, tracks, threats) as part of a citizen science project. Development of a pilot application for the Balkan chamois, to be used mainly by the mountaineering community and mountain guides, following the attendance of relevant seminars/e-courses for familiarization with the application.

**Climate change action**

**Gather and evaluate data**

• Compare recent climate data with older ones, in order to model climate change trajectories within the PP-CCA.

• Development and enhancement of research efforts aiming to better understand climate change trajectories.

• Recording and evaluation of changes regarding meteorological data (atmosphere) in relation to changes in physicochemical characteristics (hydrology) in vulnerable micro-ecosystems. Application to alpine-subalpine lakes within the PP-CCA (e.g., Drakolimnes) and promotion of their use as climate change indicators.

**Primary sector-related actions**

• Investigation of methods to enhance goat-sheep livestock raising, mainly in reforested and/or abandoned former agricultural land around the settlements, in order to limit the chances of catastrophic fires.

**Water-related activities**

• Support initiatives for the conservation of drinking water, especially during the summer months, from springs that are located in relatively dry areas (such as the calcareous mountainous regions), in order to benefit the local species of wild fauna, but also livestock raising and visitors.

• Mapping of all small hydrological features of mountainous areas (i.e., small lakes, pools, seasonal or permanent ponds, reservoirs, etc.) and evaluation of their conservation status and ecological importance (including on their potential for supporting species of wild fauna - especially the Balkan chamois, as well as livestock). Application of select measures in some of them.

• Enhancing the restoration of degraded habitat types, especially in areas sensitive to the effects of climate change, such as riparian areas that are now more frequently affected by flash floods due to an increase in the speed and intensity of rain.

**Energy-related activities**

• Explore the potential installation of new technologies and the implementation of novel methods that reduce energy needs.

• Explore the potential of transforming old watermills into small hydro-plants, without further interference with the landscape.
**Capacity building**

**Seminars**
- Holding seminars for competent authorities (Forestry Service, Protected Areas Management Units, etc.) on issues related to environmental values and the importance of maintaining the integrity of the PP-CCA.
- Holding educational seminars for the study-research and protection of the Balkan chamois, designed for and addressed to the competent authorities and agencies (Forestry Service, Protected Area Management Units, Game Guard of Hunting Federations), and related stakeholders (e.g., environmental NGOs).
- Holding educational seminars for the protection of the target species (brown bear, wolf, otter) for the competent authorities and agencies (Forestry Service, Protected Areas Management Units, Game Guard of Hunting Federations), and related stakeholders (e.g., environmental NGOs).
- Holding educational seminars for researchers-scientists with the aim of developing and strengthening skills to participate in biodiversity and habitat surveying, for the evaluation and management of biodiversity within the PP-CCA.
- Holding educational seminars for companies and individuals active in the field of outdoor activities, with the aim of improving their knowledge of the PP-CCA's natural environment, transferring this to their customers and raising their awareness on the importance of the PP-CCA.

**Stakeholder meetings**
- Preparation and holding of meetings environmental experts and agencies regarding the methodological approaches of recording protected species (mainly the target species) within the PP-CCA.

**Publications and educational material**
- Compilation and publication of a practical guide (manual) for the study/research and protection of the Balkan chamois, for use by competent services and agencies (Forestry Service, Protected Area Management Units, Game Guard of Hunting Federations), and related stakeholders (e.g., environmental NGOs).
- Formulation of educational environmental packages on the natural environment, with an emphasis on the target species and the importance of PP-CCA. Implementation in schools and Environmental Education Centers.

**Support volunteering activities and youth engagement**
- Support environmental associations that are active in the area, through the promotion of volunteering work.
- Running of summer school camps for youth (e.g., students) with topics related to environmental values and the importance of maintaining the integrity of the PP-CCA.

**Nature-based tourism as a mean of poverty reduction and economic development while enhancing connectivity conservation:**

**Develop and promote environmentally-friendly tourism**
- Drawing up an action plan for the development of mild and environmentally friendly forms of tourism.
- Highlighting and promoting the importance for local communities of mild and environmentally friendly forms of tourism instead of mass tourism.
- Recording, highlighting and promoting elements of the natural environment that link natural and cultural values.

**Develop environmentally-friendly tourism facilities**
• Support the creation of interpretative-thematic routes presenting the values of the natural environment focusing on selected points of the PP-CCA for use by the local population and visitors with application in education and recreation (recording-documentation, interpretation, signs, mobile applications, etc.).

• Support the creation of interpretive-thematic routes presenting the ecology and threats of PP-CCA target species for use by the local population and visitors with educational and recreational applications (recording-documentation, interpretation, signs, mobile applications, etc.).

• Support the development of hiking trails, as part of building the infrastructure for low-impact eco-tourism activities.

• Support the development of mountain-biking trails, as part of building the infrastructure for low-impact eco-tourism activities.

• Support the transformation of publicly or privately own buildings that have lost their functional purpose (e.g., former school-buildings, warehouses, houses donated to the community, etc.) into functional spaces to showcase and promote the natural and cultural heritage. These could also combine a business branch (e.g., an old building housing an environmental education center, as well as a small guest house), in order to make it self-sustaining for the owner.

• Build small mountain huts/refuges, to accommodate the needs of small groups of hikers/climbers/mountaineers/researchers).

Attract environmentally conscious visitors

• Develop tourist packages that combine recreation with environmental information, awareness and education.

• Promote the area in national and international tourism exhibitions highlighting the role of the PP-CCA in ensuring co-existence between humans and natural environment.

Produce awareness-raising content to attract certain target groups of visitors

• Issuance of material promoting the area in combination with elements of information, education and awareness (maps, books, ecotourism guides, albums, thematic books, promotion video etc.).

Agro- and eco-tourism

• Highlighting and promoting local products and traditional gastronomy.

• Collecting data on traditional practices of land use (livestock farming, cultivation, processing, etc.) and presenting them to visitors.

• Supporting small producers of primary sector within the PP-CCA: Certification of products produced with environmentally friendly methods and linking their promotion mainly to local businesses active in the tourism sector.

• Develop a network of enterprises with eco-friendly business models, that share a joined vision and are willing to support the practices taking place within the PP-CCA.

Transboundary cooperation

Develop and operate shared committees

• Develop a team of experts (nature scientists) from all countries (Greece, Albania, N. Macedonia) in order to share knowledge and good practices in matters regarding the implementation of scientific research and management measures within the PP-CCA.
• Develop a team of experts and representatives from local authorities, management units, the municipalities, and the regional governments, in order to share knowledge and good practices in matters regarding the implementation of scientific research and management measures within the PP-CCA (for every pair of countries with a shared border).

• Develop a team of experts and management bodies (i.e., forestry service, national parks, border police, etc.) in order to enforce good practices and management measures to limit (or eliminate) cases of transboundary environmental crimes, such as poaching of the Balkan chamois.

Co-produce media (i.e., books, documentaries)
• Co-author shared publications to present the ecological importance of the natural heritage in the transboundary areas of all countries, and especially the areas within the PP-CCA, focusing on their ecological importance.
• Co-produce video (i.e., documentaries, promo-clips etc.) to showcase the ecological importance of the natural heritage in the transboundary areas of all countries, and especially the areas within the PP-CCA, focusing on their ecological importance. Promote the produced material through television shows and social media.

Conducting joint conferences
• Conducting joint conferences on topics related to the CCAs of the three countries (environmental values, natural and cultural heritage, primary production - processing and methods, environmental sciences and research, actions and results of implementation of management practices, development - tourism and environment, etc.).

Research for the conservation of wild species
• Record the genetic identity of Balkan chamois across the different populations of the transboundary area that spans across the three countries. Identify links between these populations and any other Balkan chamois population that exist in these three countries or elsewhere.
• Develop and implement a common methodological framework to monitor Balkan chamois populations.
• Collaborate into conducting simultaneous expeditions for the recording and monitoring of Balkan chamois populations of the transboundary areas (e.g., Mt. Grammos, Mt. Nemertsika). Identify the distribution of the species and the seasonal habitat use on the transboundary zones.
• Implement a joint action plan between Greece and Albania for real-time mitigation of poaching, where poachers from one country go for trophy to the other (e.g., Mt. Grammos). Collaborative involvement of all relevant authorities, and management units and other stakeholders. Undertake this action at a pilot capacity in order to evaluate the intensity of poaching cases.

Partnership for the protection of surface waters
• Promote partnerships for the co-management of river watershed that extend across two or more countries (e.g., Aoos river). Promote the concept of ecosystem services that benefit all parts, through a transnational collaboration.

Joint proposals for European funding
• Prepare a collaboration and develop a common vision towards the implementation of joint proposals for European funding, aiming towards nature protection and sustainable development (e.g., Interreg).
APPENDIX I: METHODOLOGY

Chapter 1 presents the methodological steps to define the Pindos-Prespes Connectivity conservation Area (PP-CCA). Chapter 2 presents the spatial analysis performed to describe the PP-CCA. Chapter 3 presents the rationale, the thematic maps produced and the spatial analysis performed to delineate indicative priority corridors for the four targeted large mammals (chamois, brown bear, wolf, otter). Chapter 4 presents the consultation process of cross-checking with experts. Methods are in line with the first deliverable of this study (Papaioannou et al. 2022). The first supplementary figure, Fig S1, presents the methodological steps.
1 Pre-Processing

2 Wide Connectivity Analysis

3 Corridor Connectivity Analysis for Large Mammals

4 Linear referencing & preliminary map

5 Cross-checking & finalizing

1 Assemble all data from all sources into a common geographic framework (Coordinate Projection system, common database, common pixel size and geographic extent)

2a Connectivity conservation Area (CCA): Union of Roadless areas, Natura 2000 network and low fragmentation areas. Output: One wide connectivity area within the study area where corridor analysis will take place.

3a Preparation of layers for corridor connectivity analysis

3a Habitats: Assign values from 1 to 10 to habitat types according to species ecology

3a Slope: Assign values from 1 to 10 to slope categories

3a Roads: Evaluate Euclidean distance to roads. Assign values from 1 to 10

3a Hydrography: Evaluate Euclidean distance to water. Assign values from 1 to 10

3b Weighted overlay for connectivity areas (Cost raster)

3b Large carnivore cost raster surface

3b Balkan chamois cost raster surface

3c Cost connectivity: large carnivore corridors

3c Cost connectivity: Balkan chamois corridors

3b Cost connectivity: Otter corridors

2a Connectivity conservation Area - CCA

4a Linear referencing of corridors

4b Preliminary map

5b Final map

Figure S1: Spatial analysis workflow
1. Delineation of the PP-CCA

Criterion 1: Roadless areas

We followed a Roadless/wilderness maintenance approach (Kati et al. 2020a, under review). We have considered as a first criterion the geospatial database of the roadless map of Greece (Kassara et al. 2022). All the roadless areas of the study area were included and connected in the final output as priority land patches that are road free, deprived of any barrier for animal movement and boost a pronounced wilderness character. All roadless areas should be included in the PP-CCA and would also form the basis for creating priority corridors within the Pindos-Prespes Connectivity conservation Area (Fig S2a).

Criterion 2: Low landscape fragmentation

We then employed the Landscape Fragmentation Index (LFI), delivered by the European Environmental Agency (Effective Mesh Density Data of 2016) (EEA 2019b). We considered only the land with very low fragmentation properties (LFI score 0-1.5) as a criterion for delineating the Connectivity conservation Area (CCA). The remaining land of low up to highly fragmented land (LFI score >1.5) was excluded from the CCA (Fig. S2b).

Criterion 3: Natura 2000 ecosystem connectivity map

We finally utilised an ecosystem-based approach developed by Hellenic Center for Habitats and Wetlands (EKBY) that accounts for a series of indicators and sub-indicators (Fitoka et al. 2020, Hatziiordanou et al. 2019) referring to: (a) landscape evaluation for ecosystem services delivery, classifying landscape units into favorable (natural and semi-natural land patches) and hostile units (urban and intensive agriculture), ecosystem condition in terms of natural potential, calculated on the basis of the (b) Biodiversity State Indicator (variables of protected habitat and species conservation status and degree of the habitats directive (92/43/EC), population trends of breeding birds of the Birds Directive (2009/147/EC), habitat and species distribution patterns and richness, and common bird richness) and (bii) the Anthropogenic Impact Indicator (landscape degradation, and population density), and (c) habitat maintenance ecosystem service supply, developing and index that accounts for the IUCN protection categories, and quantifies land units from no to very high natural potential (six scale gradient) vs a three scale gradient of protection level (no/weak, medium, high). The map captured many aspects related to ecosystem services, but it might be less reliable when knowledge gaps of biodiversity data outside the Natura 2000 network are present. We obtained the relevant geospatial dataset (Fig S2c) from the Hellenic Center for Habitats and Wetlands (EKBY) for the needs of the current study (EKBY 2019). The connectivity map of the Natura 2000 sites for ecosystem service maintenance was a central feature introduced as the third criterion to delineate the CCA.

Hydrography

Data of freshwater organism distribution data are largely lacking. We have assembled different geospatial datasets of the hydrographic network of Greece (Geodata 2015), an extended hydrographic network (MEE 2013) with the wetlands dataset (EKBY 2019b) to produce the hydrographic thematic map in the study area (Fig. S2d). Hydrography was not included as a criterion for the CCA delineation but reflects freshwater connectivity in the study area.

Spatial analysis

The three thematic maps under the respective criteria were overlaid to define the Connectivity conservation Area. Each polygon of the CCA was scored from one to three, according to the number of the criteria satisfied (number of thematic maps superimposed). The final output was only one Connectivity conservation Area (CCA) (See 3.1).
Figure S2: Thematic maps used in the delineation of the PP-CCA: (a) roadless areas, (b) Landscape Fragmentation Index (LFI), (c) Natura 2000 connectivity map for ecosystem services maintenance, (d) Hydrographic network.
2. Description of the PP-CCA

Using open-source geospatial databases, we described the PP-CCA in several aspects (Table 1). Results are presented in chapters 3 and 4.

- **Extent**: We calculated the area of the PP-CCA and its percent cover of the study area.
- **Elevation**: We considered four elevation zones out of the Digital Elevation Model of Greece (DEM 2019) to describe the area of each elevation zone falling within each of the four zones: <500m, 500-1000m, 1000-1500m, >1500.
- **Mountain character**: We also considered the open database of the European mountain areas (EEA 2019c) to calculate the proportion of land in the PP-CCA that can be characterized as a mountainous less-favored area.
- **LS factor**: We considered the European dataset of the mean slope length and steepness factor (LS factor) (JRC & ESDAC 2022) and calculated its average of the PP-CCA.
- **Hydrography**: We considered the hydrographical thematic map (Fig. S2d) combining three datasets (EKBY 2019b, Geodata 2015, MEE 2013) to calculate the extent of lakes and the length of permanent rivers and non-permanent streams.
- **Habitat types**: We considered the relevant geospatial data of Europe's ecosystem types that follow the EUNIS-MAES habitat classification system (EEA 2019c) to calculate the extent of habitat types (level 2 of the EUNIS database) in the PP-CCA.
- **Human impact**: We used the most recent database (HII 2019) to calculate the mean value of the Human Impact Index in the PP-CCA.
- **Road density**: We used the Open Street Map Database (OSM 2022) to calculate the length of roads in the PP-CCA and the road density (km of roads/ km²)
- **Roadless and wilderness areas**: We used the current database of the roadless map of Greece (Kassara et al. 2022) and adopted the approach by Kati et al. (under review) to calculate the extent of roadless land in the PP-CCA and the Roadless Fragmentation Index (%) (area of roadless land/ PP-CCA area).
- **Administrative units**: We considered the openly available data of the administrative units of Greece provided by the geodata platform (Geodata 2015 b,c,d) to present the administrative configuration of the PP-CCA.
- **Population**: We considered the last population census of Greece (ELSTAT 2022) to give the present number of permanent residents in the municipalities that are fully or partially lying within the PP-CCA.
- **Human economic activities related to land use**: We presented the statistical data from the last census of the agricultural and livestock sectors for Epirus and Western Macedonia Regions that partially coincide with the PP-CCA (ELSTAT 2021).
- **Natura 2000 network**: We considered the national database of the Natura 2000 network (YPEN 2020) and overlaid it with the PP-CCA.
- **Management Units of the National Parks**: We considered the borders of the Management Units (Geodata 2016) and overlaid them with the PP-CCA.
- **Wildlife sanctuaries**: We considered the borders of the wildlife sanctuaries (Geodata 2015e) and overlaid it with the PP-CCA.
- **Land use change**: We used the Corine Land Cover (CLC) Inventory (Copernicus 2022) to calculate land take, as the conversion of any CLC type to artificial land (category CLC=1) for the period 1990-2018, and forest
encroachment as the conversion of open land (Corine Land Cover-CLC 31, 32, 331, 334) to forested land (CLC 31, 323, 324).

- **Fire vulnerability**: We calculated the number of fires and their total burnt area for 2008-2022, according to the European Forest Fire Information System (EFFIS 2022).
- **Threats in Natura 2000 sites**: We considered the Standard Data Forms of the Natura 2000 sites of the PP-CCA and performed a frequency analysis of the threats reported.
- **RES projects**: We considered the current database of Renewable Energy Sources (RES) openly provided by the Regulatory Authority of Energy’s web portal (RAE 2023) and calculated the number of RES projects under different licensing stages: ranked under decreased maturity stage from the operating (installed), having permission for operation, for production and under evaluation at the earliest stage of licensing.

3. **Delineation of large mammal corridors**

We first prepared a suite of thematic maps for the four large mammal species to be used in the analysis. We then performed a connectivity analysis, attempting to connect the roadless areas of the PP-CCA to minimize the movement energy costs for the targeted species among undisturbed wilderness areas. The corridors under the name “priority corridors” are indicative of the corridors that large mammals can use since no detailed distribution data are available.

**Distribution maps of large mammals**

We took into account the distribution of the target species at a 10kmX10km grid scale, with data obtained from the national delivery of monitoring species of European interest under article 17 of the Habitats’ Directive (92/43/EC) (EIONET 2015) (Fig. S3).

We reviewed relevant literature for the targeted species while considering the available geospatial databases for the species presence in the study area (see chapter “conservation knowledge background “ in 6.2., 7.2, 8.2, 9.2). Since all bibliographical occurrences were integrated into the national species distribution map at a coarse scale of 10kmX10km scale (EIONET 2015), we used these maps to proceed to corridor delineation within the distribution range of the species within the PP-CCA (Fig. S3).

**Habitat assessment for large mammals**

We have collected data and subsequently produced thematic maps on the habitat preferences of each target species, considering the relevant geospatial data of the Ecosystem types of Europe (EEA 2019c) that follows the EUNIS-MAES habitat classification system. Habitat types were scored from 1 to 10 considering species ecology, after expert opinion (Table S1), and preliminary maps as baseline habitat suitability maps for the target species were produced (Fig. S4).
Table S1: Scoring of habitat types in the PP-CCA after the expert opinion of each of the targeted large mammal species

<table>
<thead>
<tr>
<th>Level1</th>
<th>Level2</th>
<th>Balkan chamois</th>
<th>Large carnivores</th>
</tr>
</thead>
<tbody>
<tr>
<td>C - Inland surface waters</td>
<td>C1 - Surface standing waters</td>
<td>7</td>
<td>7</td>
</tr>
<tr>
<td></td>
<td>C2 - Surface running waters</td>
<td>7</td>
<td>7</td>
</tr>
<tr>
<td>D - Mires, bogs and fens</td>
<td>D4 - Base-rich fens and calcareous spring mires</td>
<td>7</td>
<td>7</td>
</tr>
<tr>
<td></td>
<td>D5 - Sedge and reedbeds, normally without free-standing water</td>
<td>7</td>
<td>7</td>
</tr>
<tr>
<td>E - Grasslands and land dominated by forbs, mosses or lichens</td>
<td>E1 - Dry grasslands</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>E2 - Mesic grasslands</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>E3 - Seasonally wet and wet grasslands</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>E4 - Alpine and subalpine grasslands</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>F - Heathland, scrub and tundra</td>
<td>F2 - Arctic, alpine and subalpine scrub</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>F3 - Temperate and Mediterranean-montane scrub</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>F5 - Maquis, arborescent matorral and thermo-Mediterranean brushes</td>
<td>5</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>F7 - Spiny Mediterranean heaths (phrygana, hedgehog heaths and related coastal cliff vegetation)</td>
<td>10</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>F8 - Shrub plantations</td>
<td>10</td>
<td>2</td>
</tr>
<tr>
<td>G - Woodland, forest and other wooded land</td>
<td>G1 - Broadleaved deciduous woodland</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>G2 - Broadleaved evergreen woodland</td>
<td>5</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>G3 - Coniferous woodland</td>
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<tr>
<td></td>
<td>G4 - Mixed deciduous and coniferous woodland</td>
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<td>1</td>
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<tr>
<td></td>
<td>G5 - Lines of trees, small anthropogenic woodlands, recently felled woodland, early-stage woodland and coppice</td>
<td>10</td>
<td>2</td>
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<tr>
<td>H - Inland unvegetated or sparsely vegetated habitats</td>
<td>H2 - Screes</td>
<td>1</td>
<td>5</td>
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<tr>
<td></td>
<td>H3 - Inland cliffs, rock pavements and outcrops</td>
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<tr>
<td></td>
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<td>2</td>
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<td>I - Arable land and market gardens</td>
<td>I1 - Arable land and market gardens</td>
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<td>9</td>
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<tr>
<td></td>
<td>I2 - Cultivated areas of gardens and parks</td>
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<tr>
<td>J - constructed, industrial and other artificial habitats</td>
<td>J1 - Buildings of cities, towns and villages</td>
<td>10</td>
<td>10</td>
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<tr>
<td></td>
<td>J2 - Low-density buildings</td>
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</tr>
<tr>
<td></td>
<td>J3 - Extractive industrial sites</td>
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<td>10</td>
</tr>
<tr>
<td></td>
<td>J4 - Transport networks and other constructed hard-surfaced areas</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>J5 - Highly artificial man-made waters and associated structures</td>
<td>10</td>
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Figure S3: Large mammal distribution according in 10 km X 10 km grids (EIONET 2015)
Figure S4: Indicative maps of the habitat preferences of the target species in the study area (see table S1)
**Slope map**

We considered the Digital Elevation Model (DEM) at 100 m resolution (DEM 2013) to calculate the slope. Chamois is a high-altitude species opting for steep slopes as refuge places (see chapter 6). On the other hand, wolves and bears would prefer more mild terrain for their movements to minimize the energy cost (see Chapters 7 & 8). The slope was not considered for the otter connectivity map (Fig. 8).

![Figure S5: Slope derived from a 100m resolution DEM](image)

![Figure S6: Roads in study area (OSM)](image)
**Road network map**

We included the road network in the study area, considering the most recent version of Open Street Map (2022) as chamois is known to avoid roads of any type (Kati et al. 2020b), while main asphalt roads can act as barriers to all large mammal movement (Ibisch et al. 2016, Kati et al. 2020a) (Fig. S6).

**Hydrographic map**

Data of freshwater organism distribution data are largely lacking. We have assembled different geospatial datasets of the hydrographic network of Greece (Geodata 2015), an extended hydrographic network (MEE 2013) with the wetlands dataset (EKBY 2019b) (Fig S7). Freshwater resources are of primary importance for biodiversity and for the targeted large mammal species. They particularly define otters’ habitat, directly dependent on them for habitat and food resources. A freshwater resources map was considered a criterion for evaluating Euclidean distance to water and assigning a value from one to ten to select the best connectivity corridors for large carnivores (wolf, bear), and chamois.

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**Corridor connectivity analysis**

We conducted a corridor connectivity analysis for large mammals within the PP-CCA. The patches to be connected as core areas were the roadless sites of the PP-CCA (Fig. S6). Corridor connectivity analysis aimed at identifying the most suitable corridors for the target species so that their movement between the polygons of the Roadless Areas is mostly uninterrupted and not threatened by human activities. The topographic characteristics (slope and landscape fragmentation), suitable habitats (natural and semi-natural areas with minimal anthropogenic influence), water accessibility during movements (hydrographic network) and the presence of roads are all factors that affect the free movement of the target species between the protected areas.

We followed a multi-factor approach of four criteria for delineating the potential corridor areas for the target mammals. Each factor was then superimposed into a cost surface, identifying the areas where it is most or least costly for the species targeted to move freely.

(a) **Habitat types:** We ranked with scores the habitat types of the EUNIS-MAES habitat classification system from 1 to 10 from the most suitable to least suitable habitat for each of the three target species (bear, wolf, chamois) considering species ecology, after expert opinion.

(b) **Slope:** For large carnivores, a cost surface for the surface slope limiting factor will have high-cost values on steeper slopes and low-cost values on relatively flat surfaces, as the species that prefer mobility in relatively flat-medium...
terrain. This pattern was inversed for the Balkan chamois, preferring steeper slopes and benefited from steep terrain, through an inverse slope scoring (1 to steeper slopes, 10 to flat terrain).

(c) **Roads**: A surface that measures the distance from main asphalt roads will have high-cost values when a particular area of this surface is near a road and a low-cost value when it is considerably away from a road, as all mammals avoid roads that can act as an important barrier for movement.

(d) **Hydrographic network**: A surface closer to the hydrographic network will have lower and hence better scores than an area away from the hydrographic network.

The weighted overlay of all these levels (factors) of information provided a final overall cost raster surface that aims to express the total weighted cost of all individual factors. This cost surface provides input to the corridor analysis that follows below and a thorough evaluation of the wider connectivity area regarding the species involved. The weighted overlay for the large carnivores (wolf and bear), the chamois and the otter separately are inputs to the three different connectivity analyses.

For the large carnivores and chamois, we connected the Roadless areas (Core Areas) using the Weighted Overlay for Connectivity Areas for each species by calculating the accumulative cost for each path between every proximate Core Area. Then, based on Graph Theory ([Urban et al. 2001](#)) the most effective (least cost) path was determined. This path (corridor) connects all Core Areas together in the most efficient way in a continuous line. For the otter, we considered exclusively the hydrographic network and we attempted to connect it with the shortest (low cost) path among freshwater resources, avoiding road barriers. Concerning the project’s target species, three thematic connectivity maps were produced: one for large carnivore corridors among RAs, one for Balkan chamois corridors among RAs and one for the otter (hydrographic network).

### 4. Stakeholder consultation

After having shared the relative map and general information about this study with 12 of the main stakeholders and experts being active in the area, we received feedback from almost all of them (Management Unit of Northern Pindos National Park (NECCA), The Society for the Protection of Prespa, Arcturos NGO, The Consultant Company, HOS, Zagori-Ecomuseum, Dr. Iliopoulos, Dr Mertzanis and Mr. Theodoropoulos). A summary of their comments is following:

**Regarding the study area**, there are several claims about the restriction of its bounders, mainly to the North-eastern sector. There are suggestions that the study area should extent further to the East in order to include important habitats and conservation corridors, e.g., the area of Korissos due to its importance for wolf and ungulates, the wider area to the north-east till the neighboring Natura 2000 sites of Zazari and Chimaditis due to its importance for large carnivores and otter. In addition, the importance of the crucial for the large carnivores mountain connectivity corridor that joins western and central Macedonia through the straits of Kleidi has been underlined. Similarly, there was a suggestion regarding the expansion of the south western point of the study area a little further to west (towards the Greek-Albanian border) in order to include an important habitat for the otter. Finally, another suggestion was related to the determination of the study area (and the PP-CCA) based on the boundaries of the watersheds where exist the most important connectivity corridors.

**Regarding the PP-CCA** there are claims about the narrow connectivity zone between the north and the central-south sectors of the PP-CCA, mentioning that mammal species use a wider area. In addition, important areas for
connectivity relating to large carnivores -e.g., the Aliakmonas plateau- have been left outside of the PP-CCA. In general, the whole part of the study area should be included in the PP-CCA referring to large carnivores.

**Regarding the indicative corridors** there are queries about the direction of them from north to the south of the study area and vice versa and not to other directions, like from the north part of the study area towards further east (outside of the study area). In addition, the analysis used according the applied methodology should provide with graded suitability all the connectivity corridors (within the PP-CCA and the study area) and not only the best ones located within the PP-CCA. In general valleys within and outside the PP-CCA can operate as connectivity corridors and they should have taken into account at least for the brown bear.

**Regarding the hydrological network**, the connectivity corridors for the otter should include a large part of the hydrographic network and as long as the network of connectivity waterways remains available for otters, they can even move between different catchments.

**In conclusion** all stakeholders/experts agree with the importance of the area characterized as PP-CCA based on the applied methodology. In contrast, there are several queries about the boundaries of the study area, mentioning that it should had been extended further, mainly to the north-east. In addition, certain stakeholders/experts suggest that important areas/corridors, which are located outside the PP-CCA -but within the study area- should be included in it, indicating the ecological value of almost all the study area. Finally, ecological field data relating to habitat use are needed to determine the optimal and secondary ecological corridors in the PP-CCA and possibly parts of the rest of the study area.

**A proposal for re-adjustment of PP-CCA borders, based on Stakeholders/experts comments**

After processing the answers collected from the stakeholders and experts, we concluded that the area that emerged as PP-CCA according to the methodology we followed, should be slightly expanded and include the additional areas-zones:

- A polygon in the SW of PP-CCA (Konitsa plain - Aoos river) due to its great importance for: (a) the Egyptian Vulture (*Neophron percnopterus*) (part of the transborder territory in Greece and Albania of one of the last breeding pairs of the species in the Balkans), (b) the otter (*Lutra lutra*) and (c) the operation of this area as a conservation corridor for fish populations towards the upper zones of the Aoos and Voidomatis rivers, including important spawning sites within it, as well as habitats of the endemic fish species of the Aoos river *Oxynoemaheilus pindus*.

- A polygon in the SW (Pogoni municipality) included in the Drinos watershed (a tributary of the wider Aoos/Vjiosa river), due to its importance for: (a) the Egyptian Vulture (*Neophron percnopterus*), (b) the otter (despite the desiccation projects carried out in the area, the species still occur) and (c) the increase of the Greek-Albanian borderline being inside the PP-CCA, especially in the light of a future cooperation between the two countries for the protection of the whole hydrological watershed of the Aoos/ Vjiosa river and its tributaries. However, this polygon is outside of the study area.

- Polygons in the central part of the PP-CCA (Vrachos, Ondria) containing valuable habitats for the brown bear.

- A polygon in the connection zone between the central-southern and northern sectors of the PP-CCA, partially covered by forests and clumps of woody-shrubby vegetation (Archangelos, Hionato, Pteria). Taking action for the implementation of the appropriate management measures this polygon could be improved so as to strengthen the connectivity for large carnivores (bear-wolf) -and possibly other species- between the central-southern and northern sectors of the PP-CCA. Thus, this polygon is expected to contribute as well to the connectivity conservation as an additional and alternative connectivity zone.

- Polygons within the northern sector (Kotas- Antartiko and Korestia) which are used, even occasionally, by large carnivores (bear, wolf).
In conclusion we suggest that “all holes” within the PP-CCA (donut polygons) could be included in the PP-CCA in order to maintain connectivity consistency and continuity within the PP-CCA presenting a more compact map (Fig. S8). However, during future conservation actions focusing on connectivity conservation these areas could easily identified as well as all other areas within the PP-CCA where there is problematic connectivity under the framework of animal ecology and mobility within the PP-CCA. In addition, a special treatment should be carried out for the rivers located at the central eastern part of the study area outside the PP-CCA due to their importance for the otter (Ladopotamos, Aliakmonas, Gioli, Stravopotamos, Velas and Pramoritsa).

**Figure. S8:** PP-CCA after taking into account all stakeholders and experts’ comments.
Figure S9: Renewable Energy Sources projects in the PP-CCA: (a) Hydro-electric, (b) Wind, (c) Solar.
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<th>Municipality</th>
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| Γ-08244 | ΥΔΑΤΟΠΤΩΣΗ ΠΑΡΑΓΩΓΗ ΗΛΕΚΤΡΙΚΗΣ ΕΝΕΡΓΕΙΑΣ ΙΔΙΩΤΙΚΗ ΚΕΦΑΛΑΙΟΥΧΙΚΗ Η ΕΤΑΙΡΕΙΑ | BAROUGKA NESTORIOU | 1.5 | 2-Production | 74.5 |
| Γ-010155 | ΑΝΑΝΕΩΣΙΜΕΣ ΠΗΓΕΣ ΕΝΕΡΓΕΙΑΣ ΗΠΕΙΡΟΥ ΙΚΕ | REMA KRYONERI KONITSAS | 0.49 | 2-Production | 16.1 |
| Γ-010439 | ΚΑΛΕΡΟ LIMITED | REMA ASPROPOTAMOS GREVENON | 1.35 | 2-Production | 60.8 |
| Γ-010515 | ΥΔΡΟΗΛΕΚΤΡΙΚΗ ΙΔΙΩΤΙΚΗ ΚΕΦΑΛΑΙΟΥΧΙΚΗ Η ΕΤΑΙΡΙΑ | KRATERO FLORINAS | 0.1 | 2-Production | 12.3 |
| Γ-010973 | ΥΔΡΟΗΛΕΚΤΡΙΚΗ ΕΛΑΤΟΡΕΜΑ ΙΔΙΩΤΙΚΗ ΚΕΦΑΛΑΙΟΥΧΙΚΗ Η ΕΤΑΙΡΕΙΑ | ELATORREMA FLORINAS | 0.59 | 2-Production | 30.1 |
| Γ-010154 | ΑΝΑΝΕΩΣΙΜΕΣ ΠΗΓΕΣ ΕΝΕΡΓΕΙΑΣ ΗΠΕΙΡΟΥ ΙΚΕ | POURNIA KONITSAS | 0.99 | 2-Production | 32.4 |
| Γ-011424 | ΥΔΡΟΗΛΕΚΤΡΙΚΗ ΙΔΙΩΤΙΚΗ ΚΕΦΑΛΑΙΟΥΧΙΚΗ Η ΕΤΑΙΡΙΑ | STARA REMA FLORINAS | 0.2 | 2-Production | 12.4 |
| Γ-011516 | ΙΝΤΡΟ ΕΛΕΚΤΡΙΚ ΜΟΝΟΠΡΟΣΩΠΗ ΙΔΙΩΤΙΚΗ ΚΕΦΑΛΑΙΟΥΧΙΚΗ Η ΕΤΑΙΡΕΙΑ | EPTACHORI NESTORIOU | 3.7 | 2-Production | 161.7 |</p>
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LITERATURE


Melovski D. et al. 2022a. Feasibility study on enhancing connectivity conservation in the PONT Focus Region: Albania and North Macedonia.

Melovsky et al. 2022b. Feasibility study on enhancing connectivity conservation in the PONT Focus Region: Albania and North Macedonia. Description of the selected Connectivity Conservation Areas


Papaioannou, H., Manolopoulos, A., Kati V. 2022: Methodological design on enhancing connectivity conservation in Northern-Western Greece: a PONT study. Charitakis Papaioannou EE. Funded by PONT, 18 pages


