LIFE ARCPROM

LIFE18 NAT/GR/000768

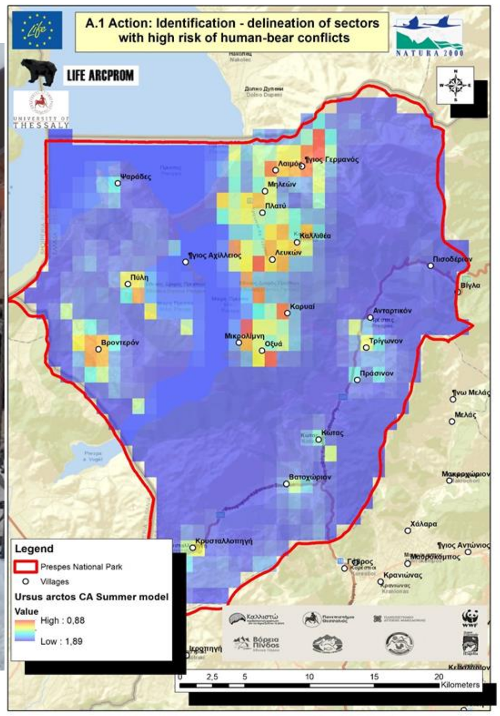
Improving human-bear coexistence
in 4 National Parks of South Europe

ACTION A1

ΑΝΘΡΩΠΟΣ / ΑΡΚΟΥΔΑ
UOMO / ORSO
HUMAN / BEAR

Identification-delineation of sectors with high risk of human-bear conflicts in the project sub-areas

TECHNICAL REPORT WITH THE RESULTS OF QUESTIONNAIRE SURVEYS AND PREDICTIVE MODELLING



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SUMMARY IN GREEK –ΠΕΡΙΛΗΨΗ ΣΤΑ ΕΛΛΗΝΙΚΑ

Βασικός στόχος της παρούσας τεχνικής αναφοράς που συντάχθηκε στο πλαίσιο της δράσης (Α1) αξιοποιώντας τα αντίστοιχα στοιχεία και ευρήματα είναι η ταυτοποίηση και ο χωρικός προσδιορισμός ενεργών σημείων (τομέων) εντός των (2) από τις (3) περιοχές εφαρμογής του έργου (LIFE18NAT/GR/00768) που εμφανίζουν υψηλό ρίσκο σύγκρουσης αρκούδας-ανθρώπινου παράγοντα. **Στην Ελλάδα**: Για την επίτευξη του στόχου συλλέχθηκαν και επεξεργάστηκαν δεδομένα τριών κατηγοριών προκειμένου να τροφοδοτήσουν το κατάλληλο στατιστικό μοντέλο το οποίο εφαρμόστηκε για την ταυτοποίηση των εν λόγω τομέων. Τα δεδομένα προέκυψαν από α) τη διακίνηση στοχευμένου ερωτηματολογίου για την δειγματοληπτική καταγραφή ζημιών αρκούδας στην αγροτική παραγωγή, β)τα περιστατικά επέμβασης της Ομάδας Άμεσης Επέμβασης ενώ γ) οι ζημιές αρκούδας στην αγροτική παραγωγή κατά την τελευταία 20ετία (2009-2020 από τα αρχεία του ΕΛΓΑ) χρησιμοποιήθηκαν για την επαλήθευση των αποτελεσμάτων του στατιστικού μοντέλου. Τα δεδομένα από (α) και (β) χρησιμοποιήθηκαν για την ανάπτυξη και τροφοδότηση του στατιστικού μοντέλου "MaXent" (Maximum Entropy) προκειμένου να προσδιοριστούν και να χαρτογραφηθούν προβλεπτικά οι τομείς με κίνδυνο σύγκρουσης αρκούδας – ανθρώπου και να εκτιμηθεί χωρικά η ένταση και εποχικότητα εντός των (2) περιοχών του έργου. Το προβλεπτικό στατιστικό μοντέλο <Maxent> είναι ένα εργαλείο για τη μοντελοποίηση οικολογικών δεδομένων που απαιτεί δεδομένα μόνο παρουσίας, χρησιμοποιεί συνεχείς ή κατηγορικές μεταβλητές και περιλαμβάνει αποτελεσματικούς ντετερμινιστικούς αλγόριθμους και μαθηματικούς ορισμούς για την παραγωγή του τελικού αποτελέσματος. Η εξαρτημένη μεταβλητή <ζημιές από αρκούδα> χρησιμοποιήθηκε στη μοντελοποίηση Maxent για την πρόβλεψη και τη χωρική αποτύπωση της κατανομής των περιοχών δυνητικής/πραγματικής σύγκρουσης. Οι περιβαλλοντικές μεταβλητές συσχετίστηκαν με τις θέσεις των ζημιών της καφέ αρκούδας προσδιορίζοντας την κατανομή της μέγιστης ομοιότητας, έτσι ώστε η αναμενόμενη τιμή κάθε περιβαλλοντικής μεταβλητής που επιλέχθηκε στο μοντέλο να ταιριάζει με τον εμπειρικό της μέσο όρο, που προσδιορίζεται από τις θέσεις των γνωστών σημείων. Η ερμηνεία των αποτελεσμάτων βασίστηκε στην αξιολόγηση της πιθανότητας σύγκρουσης με ένα εύρος τιμών βαθμονόμησης αυτής της πιθανότητας από 0 έως 1. Το τεστ « Jackknife» χρησιμοποιήθηκε για το φιλτράρισμα του αριθμού των περιβαλλοντικών μεταβλητών σε αυτές που παρουσίασαν σημαντική επιδραστικότητα στο μοντέλο και άρα στο τελικό αποτέλεσμα. Το τελικό χαρτογραφικό αποτέλεσμα οπτικοποιεί την εποχική χωρικότητα και διαβάθμιση των περιοχών με δυνητικό ή/και πραγματικό κίνδυνο σύγκρουσης αρκούδας – ανθρώπου στα (2) Εθνικά Πάρκα (Πρεσπών και Οροσειράς Ροδόπης) αποτελώντας ένα σημαντικό εργαλείο για τον βέλτιστο προσανατολισμό και την στοχευμένη εφαρμογή των διαχειριστικών δράσεων του έργου.

Στην Ιταλία: η παρούσα αναφορά παρουσιάζει προγνωστικά μοντέλα εξάπλωσης αρκούδας, κινδύνους ζημιάς από αρκούδες και ζημιών σε αρκούδες με βάση τα γεωγραφικά δεδομένα της δεκαετίας 2011-2020. Αυτά τα μοντέλα συγκρίθηκαν με αυτά μιας παρόμοιας μελέτης την αμέσως προηγούμενη περίοδο (1996-2010). Η περιοχή μοντελοποίησης ήταν το Εθνικό Πάρκο Maiella (MNP) και οι παρακείμενες περιοχές όπου η παρακολούθηση της παρουσίας της αρκούδας εξακολουθεί να εφαρμόζεται από το MNP (που ορίζεται ως Bear Monitoring Area-BMA). Τα δεδομένα σχετικά με την παρουσία αρκούδας και τα δείγματα περιπτώσεων ζημιάς χρησιμοποιήθηκαν μαζί με μεταβλητές περιβαλλοντικής πρόβλεψης. Επιλέχθηκε ένας αλγόριθμος μέγιστης εντροπίας (Maxent) για τη μοντελοποίηση όπως και στην περίπτωση των ΕΠ Πρεσπών και Οροσειράς Ροδόπης. Χρησιμοποιήσαμε μια σταδιακή εξάλειψη των μεταβλητών στη μοντελοποίηση Maxent για να προσδιορίσουμε τις κύριες περιβαλλοντικές μεταβλητές που είναι προγνωστικές για τις πιθανές περιοχές αρκούδας και τους κινδύνους ζημιάς από και προς τις αρκούδες. Η μοντελοποίηση συμπληρώθηκε από μια

ανάλυση σημειακής πυκνότητας για τον προσδιορισμό του εύρους παρουσίας/εξάπλωσης της αρκούδας και των ζωνών με μεσαίο-υψηλό κίνδυνο ζημιών από αρκούδα. Τα αποτελέσματα περιελάμβαναν πιθανές και ενεργές περιοχές μόνιμης ή/και εποχικής παρουσίας, καθώς και ζώνες μεσαίου-υψηλού κινδύνου ζημιών σε κοτέτσια και μελίσσια. Οι επεξηγηματικές περιβαλλοντικές μεταβλητές που προσδιορίστηκαν από τη μοντελοποίηση ήταν οι τύποι κάλυψης του εδάφους, το υψόμετρο, η γωνία κλίσης, η απόσταση από τον οικισμό και/ή η απόσταση από την υποδομές χιονοδρομικών δραστηριοτήτων (σκι). Οι λιγότερο επιδραστικές μεταβλητές που αφαιρέθηκαν από το σετ ήταν ο αριθμός των κατοίκων στους οικισμούς, η υδρογραφία, η χρήση γης και τα σύνθετα υπόβαθρα δάσους & χρήσεων γης. Η απόσταση από οδικό δίκτυο ως μεταβλητή πρόβλεψης έδειξε διφορούμενα αποτελέσματα που συζητήθηκαν.
Όλα τα αποτελέσματα που θα προκύψουν θα χρησιμοποιηθούν για τον βέλτιστο προσανατολισμό και τη στοχευμένη υλοποίηση συγκεκριμένων δράσεων διατήρησης του έργου

SUMMARY IN ENGLISH

The main objective of this technical report prepared in the framework of action (A1) utilizing the relevant data and findings is the identification and spatial delineation of active points (sectors) within (2) of the (3) project implementation areas (LIFE18NAT/ GR / 00768) showing a high risk of bear-human conflict.
In Greece, in order to achieve the goal, data from three categories were collected and processed in order to feed the appropriate statistical model which was applied for the identification of these sectors. The data came from a) the dissemination of a targeted questionnaire for the sampling of bear losses in agricultural production, b) the incidents of the Bear Emergency Teams involving damage while c) bear losses in agricultural production over the last 20 years (2009-2020) were used for verification of the results from the statistical model. The data from (a) and (b) were used for the development and supply of the statistical model "MaXent" (Maximum Entropy) in order to identify and map the sectors and to evaluate spatially the intensity and seasonality of bear-human conflicts within (2) project areas. The Maxent method is a tool for modeling ecological data that requires presence-only data, uses continuous or categorical variables, and includes efficient deterministic algorithms and mathematical definitions. Brown bear (Ursus arctos) damage areas were used in Maxent modeling to predict and model the distribution of potential / actual conflict areas. The environmental parameters were correlated with the brown bear damage locations by determining the distribution of maximum similarity, so that the expected value of each environmental variable selected in the model matches its empirical average, determined by the locations of the known points. The interpretation of the results was based on the evaluation of the conflict probability with a range of probability scoring values from 0 to 1. The good fit of the model predictions was evaluated from the mean area below the curve (AUC). The "Jackknife" test was used to filter the number of environmental variables in those that showed significant impact on the model. The final mapping result visualizes the seasonal spatiality and scoring of areas potentially at real or potential risk of bear-human conflict and will be used as a guiding tool for the optimal orientation and targeted implementation of project concrete conservation actions.
In Italy, the report presents predictive models of bear ranges, risks of damage-by-bears and damage to bears based on geo-data of the decade 2011-2020. These models were compared with those of a similar study over the preceding period (1996-2010). The modelling area was the Maiella National Park (MNP) and the adjacent territories where the bear presence monitoring is still implemented by MNP (defined as the Bear Monitoring Area-BMA). Data

on bear presence and damage case samples were used together with environmental predictor variables. A maximum entropy algorithm (Maxent) was selected for the modelling as in the preceding study in the MNP and in Northern Greece. We used a step-wise backward elimination of variables in the Maxent modelling to identify the main environmental variables predictive for the potential bear ranges and the risks of damage by and to bears. The modelling was complemented by a point density analysis to establish the occupied bear range and the zones with a medium-high risk of bear damage cases. The results consisted of potential and occupied seasonal and year-round bear ranges as well as medium-high risk zones of damage to henhouses and beehives. The explanatory environmental variables identified by the modelling were land cover types, elevation, slope angle, distance-to-settlement and/or distance-to-ski-infrastructure. Redundant were the number of human residents, the hydrography, the land use and the forest & land use composite layers. Distance-to-roads as predictor variable showed ambiguous results that were discussed.
All the results obtained will be used for the optimal orientation and targeted implementation of project concrete conservation actions.

SUMMARY IN ITALIAN – RIASSUNTO IN ITALIANO

L'obiettivo principale di questa relazione tecnica, preparata nell'ambito dell'azione (A1), è l'identificazione e la delineazione spaziale delle zone ad alto rischio di insorgenza del conflitto uomo-orso all'interno di (2) delle (3) aree di attuazione del progetto (LIFE18NAT/GR/00768).
In Grecia, per raggiungere l'obiettivo, sono stati applicati 3 metodi per la raccolta dei dati utilizzati per sviluppare un modello statistico appropriato per l'identificazione di queste zone ad alto rischio. I dati provengono da a) la diffusione di un questionario mirato ad acquisire informazioni sui danni da orso alla produzione agricola, b) gli eventi relativi agli interventi delle Squadre di Emergenza Orso (BET) relative a episodi di danni da orso mentre c) i danni da orso alla produzione agricola avvenuti negli ultimi 20 anni (2009-2020) sono stati utilizzati per la verifica dei risultati del modello statistico. I dati di (a) e (b) sono stati utilizzati per lo sviluppo del modello statistico "Maxent" (Maximum Entropy) al fine di identificare e mappare i settori e valutare spazialmente l'intensità e la stagionalità dei conflitti uomo-orso all'interno di (2) aree di progetto. Il Maxent è un modello statistico utilizzato per analizzare i dati ecologici di sola presenza, utilizza variabili continue o categoriche e include algoritmi deterministici efficienti e definizioni matematiche. Le aree danneggiate dell'orso bruno (*Ursus arctos*) sono state utilizzate nel modello Maxent per prevedere la distribuzione delle aree di conflitto potenziali/effettive. I parametri ambientali sono stati correlati con le localizzazioni del danno de orso per ottenere una distribuzione di massima similarità, in modo che il valore atteso di ciascuna variabile ambientale selezionata nel modello corrispondesse alla sua media empirica, determinata dalle localizzazioni dei punti noti. L'interpretazione dei risultati si è basata sulla valutazione della probabilità di conflitto con un intervallo di valori di punteggio di probabilità da 0 a 1. Il livello di affidabilità del modello è stato valutato dal parametro "area media sotto la curva" (AUC). Il test "Jackknife" è stato utilizzato per filtrare il numero di variabili ambientali tra quelle che hanno mostrato un impatto significativo sul modello. Il risultato finale del modello è la mappatura stagionale e il punteggio delle aree potenzialmente a rischio reale o potenziale di conflitto uomo-orso e sarà utilizzato come strumento guida per l'orientamento ottimale e l'attuazione mirata delle azioni concrete di conservazione del progetto.
In Italia, la presente relazione tecnica presenta (a) modelli predittivi della distribuzione degli orsi, (b) modelli predittivi dei rischi di danno da parte degli orsi e di danni agli orsi basati su geo-dati relativi al decennio 2011-2020. Questi modelli sono stati confrontati con quelli di uno studio simile nel periodo precedente (1996-2010). L'area di studio è il Parco Nazionale

della Maiella (MNP) e i territori adiacenti dove il monitoraggio della presenza dell'orso è attuato dal MNP (definita *Bear Monitoring Area-BMA*). I dati sulla presenza dell'orso e danni da orso sono stati analizzati alla luce di un insieme di variabili ambientali predittive. Per lo sviluppo del modello, così come già fatto nello studio precedente nel MNP e in Grecia settentrionale, è stato selezionato il metodo Maxent (massima entropia). Per identificare le principali variabili ambientali predittive della distribuzione potenziale dell'orso e del rischio di danno da e per gli orsi, è stata utilizzata la tecnica di esclusione graduale delle variabili dal modello. Lo sviluppo del modello è stato integrato da un'analisi di densità puntiforme per stabilire l'area occupata dell'orso e le zone a rischio medio-alto di danno da orso. I risultati consistono in (a) distribuzione reale e potenziale dell'orso sia a livello stagionale sia per tutto l'anno e (b) zone a rischio medio-alto di danno da orso a pollai e alveari. Le variabili ambientali esplicative identificate dallo sviluppo del modello sono: la copertura del suolo, la quota, la pendenza, la distanza dagli insediamenti e/o la distanza dalle infrastrutture sciistiche. Sono invece risultati ridondanti: il numero di residenti, l'idrografia, l'uso del suolo e gli strati compositi di foresta e uso del suolo. La distanza dalle strade come variabile predittiva ha mostrato risultati ambigui che sono stati discussi.
Tutti i risultati ottenuti saranno utilizzati per l'orientamento ottimale e l'attuazione mirata delle azioni concrete di conservazione del progetto.

PREFACE

Why Action A1

Wildlife management and conservation actions cannot be implemented effectively without the spatial identification of key sectors where the probability of wildlife-human interactions may become crucial for the targeted species conservation status and survival. This is a general rule which always applies but it becomes even more essential when actions are specifically addressing the minimization of human-wildlife conflicts. The presence of the variable "human factor" in an already complex system of wildlife conservation issues, generates additional challenges which can only be handled effectively if detailed knowledge of the spatial dynamics and perspectives of human-wildlife (in our case Ursus arctos) interactions and potential or effective conflicts are depicted with sufficient accuracy.

In the LIFE ARCPROM project Action A1, in synergy with Action A2 (*Assessment of the distribution and numbers of bears in the project areas*), is thus essential to orientate the implementation of concrete conservation as well as communication/awareness raising actions. Even though in the project proposal it is stated that Action A1 will directly contribute to the implementation of Actions C4, C5, C7 & C9, it will actually directly contribute to almost all C actions (Table 1).

Table 1. Contribution of Action A1 on additional concrete conservation actions with respect to those reported in the project proposal.

Action code and main topic	A1 Contribution
C1. Stakeholder consultation and involvement	Individuation of stakeholders to be actually involved in the platform basing not only on the actual bear distribution but also on the distribution "dynamic" observed. This last issue, essential to have a proactive approach, not only applies to project areas where bear range expansion is ongoing but also to those areas where the range is stable but still affected by some variables (e.g. habitat loss/degradation).
C3. Operation of anti-poison units	Individuation of the areas where poison baits could affect bear conservation to a greater extent (e.g. areas with female presence or areas where the genetic variability is lower than others).
C6. Mobilization of volunteers	Choice of the areas where to focus this activity in relation to where bears actually are and to where the human-caused mortality is possibly having an high impact on bear conservation (e.g. low detected genetic variability and genetic distance between individuals could be related to high levels of human-caused mortality).

Project areas background

Action A1 has been implemented in (3) of the project areas, namely: Maiella National Park (MNP), Prespa National Park (MBPNP) and Rodopi Mountain-Range National Park (RMNP). Regarding Pindos NP this action had already been implemented under previous project LIFE ARCPIN (LIFE12NAT/GR/00784). Even though in the three NPs Action A1 has been implemented pursuing the same general scope (see below) and applying the same general methodological frame, there were some differences in the specific methodological tools between Greece and Italy. In order to better understand and interpret A1 methods and results reported in this document, it is thus useful to briefly report here the background in both for Greece and Italy.

In **Greece** the Brown bear Ursus arctos (*) range consists of two (2) major population nuclei geographically separated but with recent signs of a first low level of communication through vagrants from Rodopi to Prespa NP's (Pylidis et al 2021, Tsalazidou et al 2021 in prep. 2021/this project). These two nuclei are located approximately 200 km apart in the north-western and north eastern part of the country and namely in Peristeri-Pindos mountain range and Rodopi mountain complex. Effective species distribution extends over 24,105 km^2 whereas the overall range is > 36,000 km^2 (Mertzanis et al. 2021). The Peristeri-Pindos range bear population represents the southernmost distributional edge of the species range at a European scale, thus of outstanding bio-geographic importance.

The overall brown bear population in the country has shown positive trends at a local scale (mainly in Pindos range) reaching 500-700 individuals minimum (Papamichael et al. 2015, Pylidis et al. 2015, Karamanlidis et al. 2018, Mertzanis et al. 2018, Pylidis et al. 2021, Tsalazidou et al. in prep. 2022,) with an expanding distribution over historical range (Mertzanis et al. 2009). At a biogeographical scale: the western population nucleus is directly connected to the Dinaric-Pindos biological brown bear population (covering 8 countries over the W. Balkans) and numbers 3.070 individuals (the 2nd largest brown bear population in Europe) whereas the RMRNP is connected to the East Balkan biological population which reaches 520 individuals minimum (Kaczensky et al. 2013). The brown bear population sizes in the targeted project sub-areas following also a radical update performed under action A2 are: Prespa Lakes NP: 192 ind. (Tsalazidou et al. in prep. 2022), wider area of Florina regional unit, Nc=161 ind. (Karaiskou et al.2020/LIFE AmyBear project), N. Pindos NP: estimated at Nc= 202 individuals minimum (Tsalazidou et al. in prpe. 2022) and RMNP: 207 individuals (Tsalazidou et al. in prep. 2022).

The aforementioned and recently updated figures (under action A2 of this project) sum an estimated size of circa 600 individuals in the (3) NP's targeted by the project which represents circa 60% of the total brown bear population in the country. Although total Ursus arctos* distribution covers large and continuous areas, both population nuclei are affected by either habitat disruption due to large infrastructure (mainly highways and wind farms massive development – a relatively recent and alarming threat) or to inappropriate land use. In PINDNP sub-area, the eastern border of the area targeted by the project, Ursus arctos* habitat has suffered from 2005 to 2009 severe degradation and disruption due to the construction of the Egnatia highway (Mertzanis et al. 2009). In RMNP sub-area, the eastern part of the area suffers from degradation due the current construction of another Egnatia highway stretch connecting Greece to Bulgaria. Additionally, small land ownership with farmland but also degraded oak forests due to over-exploitation, coupled to forest fires & over-logging are the most crucial factors of effective/potential Ursus arctos* habitat degradation in the sub-areas targeted by the project. Finally, Wind Farms development planning in all (3) National Parks targeted by the project constitute an imminent threat to bear habitat and population integrity.

In **Italy** the project target is the Apennine brown bear (Ursus arctos marsicanus*), an endemic subspecies of the Central Apennines, classified as Critically Endangered in the IUCN red list (Kaczensky et al. 2013, Rondinini et al. 2013). Apennine brown bear (ABB) range in Central Italy

reduced progressively (especially in the last 200 years) because of human persecution and bears now survive in a small, remnant population estimated in 50 (C.I. 45-69) individuals (Ciucci et al. 2015) living in a 5,000 Km^2 area (Ciucci et al. 2017). The main reproductive population survived during the 20^{th} century in an area roughly corresponding to the Abruzzo National Park (PNA), one of the oldest National Parks in Italy (established in 1923) and the only National Park established in Abruzzo before 1991. Clearly, the protection of the territory through the PNA establishment played a role in avoiding ABB extinction and, in the same way, the establishment of the other protected areas (3 National Parks and 1 Regional Park in Abruzzo) in 1991 played a role in favoring bear expansion to its historical range. In the Maiella National Park bears probably never disappeared but only in the last 10-20 years, data on bear presence became more and more abundant. With the augmented bear presence, human-bear conflicts started to happen following more or less the same patterns of other countries where human and bears coexist. However, the Apennine brown bear is not aggressive toward humans and attacks to humans have never been reported in MNP nor in other portions of the bear range. Actually, a recent study (Benazzo et al. 2017), reported that there is DNA region that could be associated with the low degree of aggressiveness so that, maybe, this feature of the Apennine brown bear (with high probability derived by human selection toward non-aggressive individuals) is actually written in its genes. The category "attacks to humans" is thus a type of human-bear conflict that is not present in MNP.
In order to manage the territory in a proactive way (i.e. implement an efficient conservation strategy), it is essential to orientate concrete conservation actions not only basing on existing information but also on the potential situation that managers could face in the immediate future. This is particularly true for MNP where a re-colonization process is ongoing implying a degree of variability in bear distribution and numbers. The implementation of action A1 is thus essential to efficiently work not only on the areas already interested by bear presence and human-bear conflict but also to those areas that could be soon interested by both, ultimately concretely improving the conservation strategy.
Given the fact that bear presence data are relatively recent in MNP and that they have been collected mostly following an opportunistic strategy (see the Report of Action A2 for details), the development of the model had to cope with some issues that could be fixed in the future in order to improve the reliability of results obtained. Nonetheless, the best use of existing data has been done for the development of the model produced in the frame of Action A1 and results provided in this document are essential for the implementation of C actions and, in general, for the implementation of the conservation strategy in MNP.

Scope and objectives of Action A1

Bear-human interference incidents are in most cases generating conflict situations triggering negative attitudes & reactions on behalf of rural communities which often have a direct negative impact on bear population status through illegal acts practices (i.e human caused mortality). In this context of a growing problematic co-existence (enhanced by the results of the current and ongoing economic crisis), it is necessary to spatially identify & quantify the problem in order to better orientate the appropriate conservation actions and measures.

A1 aims at a concrete ranking, mapping & visualization of sectors within the 2 Greek sub-areas of the proposed project (sub-area PINDOSNP was covered under LIFE ARCPIN project) & in MNP in Italy, presenting high risk of human-bear interference which might degenerate into conflict situations detrimental to the target species. It will provide the necessary information in order to prepare the ground for specific concrete conservation actions implementation.

Tasks foreseen under action A1

Identification and delineation of the hot spots with the higher risk of negative bear-human interference will be achieved through compilation, analysis and scoring of all related active factors involving human activity and infrastructure components in relation to bear presence and activity using the following tools which will be developed in cooperation between all the responsible action beneficiaries according to the following steps:

a) Development of a geographic data base (GIS) which will consist of a geo-referenced data input from the area targeted by the project on the following information layers: topographic, administrative, forest vegetation, settlements, road network, agricultural lands etc. These layers with the associated data base will be interconnected to additional field data necessary to the realization of spatial analyses for the identification of the bear-human conflict hot-spots, but also for the production of thematic maps necessary for the visualization of the final result which will be used as a decision making tool in the framework of the related C actions.

b) Collection & mapping of additional field data through interviews using a questionnaire on human activities related to human related food-conditioning factors (i.e. domestic refuses, garbage dumps, farms, small scale cultivations etc.), in order to complete the required database, set necessary for the hot-spot analysis.

c) A statistical analysis using risk assessment tools (i.e. "Hot spot – Getis Ord Gi") will be performed on the aforementioned data. The outcome of this analysis will be a spatial scoring & delineation of hot spots with high risk of human-bear interference which will be colorfully visualized on thematic maps. This spatial identification will facilitate the implementation of the relevant concrete conservations targeting brown bear. Sectors with high risk of human-bear conflicts will be identified using the maximum entropy model (MaxEnt model). The GIS database of conflict events will be analyzed with the socioeconomic and environmental factors to produce risk maps of human-bear conflicts

Table 1. Tasks foreseen in each National Park for the implementation of the 3 methods of Action A1 as reported in the project proposal.

Task	PINDNP	MBPNP	RMNP	MNP
Creation of a Geo Data Base	NO	YES	YES	YES
Questionnaires dissemination	NO	YES	YES	NO
Additional Data	NO	YES	YES	YES
Statistical analyses	NO	YES	YES	YES

A. INTRODUCTION

Conflicts between wildlife and humans are a global problem as humans encroach into wildlife habitats and wildlife increasingly uses human-developed landscapes (Woodroffe et al. 2005a). Wildlife-human conflicts emerge due to diverse causes and span various taxa and continents (Warne & Jones 2003, Michalski et al. 2006, Sitati & Walpole 2006, Van Bella et al. 2007). Although wildlife-human conflicts can pose problems causing damage to property, management of these conflicts can also have deleterious effects on wildlife populations, such as extirpation and range collapse (Woodroffe et al. 2005b). Therefore, wildlife-human conflicts will continue to be a global management priority for many wildlife species.

Wildlife-human conflicts are often clustered in space and time and can cause major economic losses to a few stakeholders in addition to localized wildlife population declines (Thirgood et al. 2005). However, for most species little is known about how conflicts vary spatiotemporally by conflict type. Thus a greater understanding will help to develop strategies to minimize and mitigate conflicts and allow more efficient allocation of resources through targeted management actions.

A central logical principle of conflict resolution is that there is a need for a good understanding of the nature of the specific conflicts. There have been many different attempts to classify the diversity of conflict types that have been recognized associated with conservation in general and with large carnivores in particular. Among the most useful classifications are those developed by Niemela et al. (2005) and Young et. Al (2010). Any given conflict (i.e bears attacking livestock) is likely to contain elements along most of these dimensions, although the relative strength of each dimension will vary importantly with each context and situation.

Depredation on **livestock** is one of the universal impacts that large carnivores have on human interests all across Europe. The extent of depredation varies greatly with husbandry form and with livestock species. (Kaczensky 1999). Sheep and goats are most exposed, with depredation on horses and cattle becoming also fairly common when related to bear attacks. The impacts of depredation go beyond of animals killed, as many are injured, and there is widespread claim that the presence of predators also influences behavior of livestock. The impacts also go beyond a simple economic loss: be it financially compensated or not, the loss is also perceived as an indirect evidence for a lack of respect from the society (usually in favor of large carnivores) towards the farmer's job. (Linnell 2012).

Destruction **of beehives** by bears trying to forage on honey and larvae is a widespread conflict across Europe (Linnell 2012) the area targeted by the project not being an exception. Destruction of property by bears is highly variable, but it can include things as diverse as garbage containers, cans of chainsaw oil, fish ponds, fruit trees, automatic feeders who deliver winter food for wild ungulates (Linnell 2012, Riegler 2012). A more recent study (Bautista et al. 2021) addressed the multiscale nature of wildlife damage occurrence by considering ecological and management correlates interacting from household to landscape scales. Taking brown bear (Ursus arctos) damage to apiaries in the North-eastern Carpathians as our model system/case study, this research showed that brown bear tendency to avoid humans and the habitat preferences of bears and beekeepers determine the risk of bear damage at multiple scales. Damage risk at fine scales increased when the broad landscape context also favoured damage. Furthermore, integrated-scale risk maps resulted in more accurate predictions than single-scale models. The results of this study suggest that principles of resource selection by animals can be used to understand the occurrence of damage and help mitigate conflicts in a proactive and preventive manner.

The intensity of damage to livestock, beehives, crops, and orchards is positively related to their density, their proximity to important carnivore habitats (e.g., breeding areas) as well as their vulnerability, which is determined by the effectiveness of prevention measures and landscape characteristics. Thus, extensive livestock farming systems are at a higher risk of carnivore depredation compared to less extensive systems, aggravated by the lack of efficient damage prevention measures. For instance, herds that move from lowland winter pastures to higher altitude mountainous areas during the summer sometimes graze without continuous human supervision, especially in the case of cattle. Inadequate preventive methods lead to high depredation by carnivores and the conflict between humans and wildlife is intensified (Blanco et al. 1992, Ciucci and Boitani 1998, Coza et al., 1996, Iliopoulos et al., 2009). As a result, some farmers use illegal practices to reduce losses, such as poisoned baits or poaching of predators. Understanding and predicting wildlife-habitat relationships are the foundations of wildlife management (Hirzel et al. 2006, Pearce and Boyce 2006). Human-bear conflicts cause financial losses, and in mountain less favourite agricultural areas (such as Greek project area) conflicts with bears can affect local economy. Failure to take practical measures against conflicts may reduce villagers and farmers tolerance of bears and reduce conservation efforts.

Vehicle **collisions** have a two-way impact. While they often cause injury or death of the large carnivore involved, they may also cause substantial damage to vehicles and may even endanger drivers and passengers.

The **danger of injury and death** is so low as to defy quantification, although both bears and wolves have been documented to attack, and even kill, people under special circumstances (Swenson et al. 1999). Regarding brown bears more specifically, a recent study (Bombieri et al. 2019) investigated patterns of brown bear attacks on humans occurring between 2000 and 2015 on a worldwide scale, with the main aim of improving the knowledge on this type of confict and, consequently, providing useful information that could help reduce the occurrence of negative human-bear encounters. In particular this research achieves to : (i) provide a first global-scale perspective of the phenomenon; (ii) describe temporal and spatial patterns of these incidents; (iii) describe main attack circumstances, highlighting common features and local peculiarities in attack scenarios between geographical areas with diferent histories of human coexistence with this species (e.g. North America vs. Europe); and (iv) explore the efect of various factors, such as bear and human densities, as well as differences in geographic location and management practices, on the number of attacks.
Two main assumptions were used: (a) higher numbers of attacks occurred in those countries/jurisdictions where both bear and human densities are higher, due to the consequent higher encounter probability; and (b) fewer attacks occurred in those countries where bears are legally hunted, due to potential removal of bold individuals.

The finidings of this study can be summarized as follows:
At a global scale, attacks were more frequent in those countries/jurisdictions where human density is lower and bear density higher. Because human density is a measure of the degree of human encroachment into bear range, the results suggest that attacks are less frequent where human developments and activities extend more into bear areas, and more frequent in countries where recreational activities in bear areas are more common.
This result might also suggest that bears and people have learnt to coexist better in highly humanized regions, whereas those people who are more at risk of attack are visitors of high bear-density areas, where bears are less accustomed to encountering people, because of lower human density and, consequently, bears and people might be less used to avoiding each other.

Additionally, there was no significant difference in the number of attacks between 'hunting' and 'non-hunting' countries, which does not support the assumption (b) that "fewer attacks occurred in countries where bears are legally hunted".
The main conclusion of this comprehensive study is that negative encounters with brown bears are extremely rare and mainly non-fatal. However, to increase both human and bear safety, and promote coexistence, it is crucial to gain a deeper understanding, and promote public knowledge of the riskiest circumstances that may trigger an aggressive response by brown bears. To this aim, strong connection and collaboration between researchers, managers and education tools such as mass media and schools should be established to promote correct and scientific-based information about bears among the large public.
This first worldwide approach showed that, although similar patterns in attacks exist across the distribution range of brown bears, specific local contexts might prove to be crucial in explaining particularly high or low attack numbers. We therefore believe that, although it is important to have a global picture, additional studies at a local scale, especially in those countries where information is still scarce, will help identify additional factors related to local situations which will provide wildlife managers with specific information on how to effectively deal with this issue

Despite the objective risks being low, the perception of this risk and fear is still widespread in many areas, especially where wolves and bears recolonize after long periods of absence.

Conflicts between different conservation goals may also occur. In several areas predation by wolves and / or lynx has been implicated as an additional factor threatening endangered ungulate populations, such as wild forest reindeer in Finland (Kojola et al. 2004) and some of the small chamois populations in Italy and the Balkans. Furthermore, a large proportion of threatened European habitats and their associated species are linked with systems where livestock grazing and mowing are important to maintain an open landscape. To the extent that carnivore depredation on livestock serves as a driver to decrease grazing they may lead to a decrease in the biological and cultural values of these traditional / cultural landscapes (Macdonald et al. 2000). Another issue can also be the conflict between conserving large carnivores and the genetic diversity represented by rare livestock breeds (Hall & Bradley 1995). Rare breeds tend to be associated with small scale production in marginal areas, exactly the areas where large carnivores often have the greatest impacts. (Linnell, 2012).
Particularly in landscapes, which are highly altered by human activity, bears and other species come into conflict situations with humans. Such conflicts are a major risk for any wildlife populations worldwide (Woodroffe E 2000, Treves & Karanth 2003), but especially for large carnivores (Ambarli et al.2008, Kaczensky 1999).

With only restricted and patchy parts of natural habitats left for bears to live according to their ecological and biological requirements, as it is the case in most parts of Europe, conflicts between local communities and bears are often the result and consequence, threatening most of the European brown bear populations, but also posing a potential threat to people and their sources of income (Camarra 1999, Mertzanis 1999, Nyholm & Nyholm1999, Spassov & Spiridonov 1999).

B. REPORT OF ACTIVITIES IN GREECE

1. Methods

1.1. Data collection with questionnaire survey/interviews

A survey of the four main categories of human-bear interaction which were described above and mainly focusing on losses in agricultural production was performed by the method of live interviews using a semi-structured questionnaire. Conducting interviews using a semi-structured questionnaire is a research method used mainly in the social sciences but fitting appropriately in this type of surveys.
Unlike their fully structured questionnaire method which follows a more rigorous questions structure that does not allow any deviation from the main topic, the semi-structured questionnaire (and the corresponding form of interviews) is more "open", allowing the entry of new data and ideas during the interview. The semi-structured questionnaire allows the interviewer to move more flexibly in a context of topics to be explored.
However, even in the case of the semi-structured questionnaire, the specific topics should have been identified in advance (especially in the case of research projects).
It is advisable for the researchers preparing the interviews to have grouped the topics and questions in such a way that the information extracted by the interviewee intersects with similar questions. This stage of preparing the questionnaire is especially important when the interviewees' reference group wants a special approach because on the one hand they are not used to this way of interacting with the researcher and on the other hand they have specific reflexes regarding the type and time range of the questions.
This flexibility offered by this type of questionnaire helps the researcher to adapt the questions in the best possible way to the appropriate context and circumstance as well as to the reference groups that constitute the sample.
Interviews using a semi-structured questionnaire are widely used in surveys mainly for the collection of qualitative data, without of course excluding the quantified processing of the resulting data.
In the context of action A1 and the interviews conducted, a multi-thematic questionnaire was used in (3) versions depending on the human-bear interaction category and the respective social producer group as follows: a) one questionnaire addressing farmers, b) one questionnaire addressing livestock raisers and c) one questionnaire addressing beekeepers versions of this questionnaire are listed in annex (1) of this report. The interviews were conducted by personnel from Callisto (CB), MBPNP (see photos 1-4) and RMNP (see photos 5-8).

1.2. Creation of a GeoData base in GIS

GIS tools and multivariate statistical techniques have allowed the development of predictive distribution models in ecology during the last two decades (Guisan and Zimmermann 2000, Elith and Burgman 2002, Scott et al. 2002). A lot of potential distribution models have been developed and are currently used in wildlife ecology studies such as logistic regression (Mladenoff et al. 1999, Glenz et al. 2001), generalized additive models (Guisan and Zimmermann 2000) and classification tree analysis (Jerina et al. 2003).
Moreover, many robust statistical approaches are developed, and they are available to model the species distribution in relation to the habitat variables (Elith 2002, Elith et al. 2006). Many of these methods need presence and absence data. The lack of recorded presence does not mean equal absence. However, whilst presence data may be established by direct

observation, absence data are notoriously difficult to obtain accurately. Therefore, an analysis method is needed that relies only upon the recorded presences.
Moreover, machine learning algorithms such as Maximum Entropy Modelling (MaxEnt) (Phillips et al. 2006, Phillips, S. J. and Dudik 2008), Random forests (Breiman 2001), Classification and Regressions Tress (CART) (Breiman et al. 1984) have been shown to outperform the traditional regression-based approaches. Maximum Entropy Modelling (MaxEnt) has been proposed to solve exactly this problem.

Therefore, if the aim is to draw ecological conclusions from these analyses, the choice should follow a number of criteria which can be highlighted as follows:

- Geographical Information System (GIS) digital layers from the study area (environmental parameters)
- The biological importance of environmental parameters for the species.
- Statistically significant relationship between parameters and species presence.

  The CORINE Land Cover (CLC) consists of an inventory of land cover in 44 classes. CLC uses a Minimum Mapping Unit (MMU) of 25 hectares (ha) for areal phenomena and a minimum width of 100 m for linear phenomena.

1.2.1.GIS environmental layers stored in the GIS data base:

For the preparation of the GIS data base (13) different information layers describing different environmental (biotic and abiotic) as well as anthropogenic factors have been selected as follows:

- Elevation -altitude
- Aspect classification
- Distance from villages
- Distance from main roads
- Distance from forest roads
- Distance from farms
- Distance from rivers
- CORINE Land Cover (CLC)-land uses-habitat types
- Habitats/Habitat types
- Bovine-Cattle density
- Goat flocks density
- Mean annual temperature
- Precipitation classification

1.3 Statistical Modelling and mapping:

The Maximum Entropy algorithm (Phillips et al. 2006, Merow et al. 2013), is one of the most widely used predictive modeling tools, which is based on information on known locations of species presence. In the MaxEnt modelling, the pixels of the study area present the area where the distribution of the MaxEnt probability is defined. Pixels with occurrence records constitute the sample points and the features are environmental parametres. We have selected maximum entropy (MaxEnt) modeling because of its multiple advantages a) requires presence-only data, b) utilises both continuous and categorical data and c) includes efficient deterministic algorithms and mathematical definitions (Phillips et al., 2006).

Basic steps in the analysis are:

- Presence locations of human bear conflict
- GIS Database development -environmental Parameters
- Identify a model to evaluate the similarity of the presence positions
- Prediction of potential distribution in whole area

In total, 34 brown bear (*Ursus arctos*) +72 (through questionnaires survey) potential conflict areas (bear presence records) were collected in the field over three seasons (autumn, spring, summer) in Prespes NP by personnel from MBPNP. Data on brown bear (*Ursus arctos*) presence were collected in the field using hand-held Global Positioning System Garmin units. Likewise, a total of 56 brown bear (*Ursus arctos*) +83 (through questionnaires) conflict areas (bear presence records) were collected in the field over three seasons (autumn, spring, summer) in Rodopi NP by the personnel from RMNP. Again here data on brown bear (*Ursus arctos*) presence were collected in the field using hand-held Global Positioning System Garmin units.

Models validation was performed with the use of data on bear damage over a 4y period (2018-2020). These data have been provided by the Hellenic Farmers Insurance Organization (ELGA) to Callisto CB following relevant requests.

1.3.1. Environmental variables definition and processing:

ArcGIS V.10.1 GIS software (ESRI; Redlands, Ca, USA) was employed for description and analysis of spatial information. Altitude and distance from rivers were extracted from a digital elevation model (DEM) (https://land.copernicus.eu/imagery-in-situ/eu-dem/eu-dem-v1.1). Livestock densities sheep/goat/cattles densities were taken from FAO (http://www.fao.org/land-water/land/land-governance/land-resources-planning toolbox/category/details/en/c/1236449/). Land uses (habitat types) and human population densities were derived from the Corine Land Cover 2000 database Copernicus EEMP (https://land.copernicus.eu/pan-european/corine-land-cover/clc2018) and from GIS data base from two National parks. The normalized difference vegetation index (NDVI), an indicator of the greenness of the biomes per month and two climatic variables were derived from the Copernicus European earth monitoring program (https://land.copernicus.eu/global/products/ndvi). Other environmental parameters were developed with ArcGIS tools and routines.

ArcGIS 10.1 GIS software (ESRI, Redlands, CA, USA) was also used to create topographic layers and human disturbance layers. In total 24 GIS layers (*environmental parameters*) was developed for the analysis. These data sets were converted to a common projection, map extent and resolution prior to use in the modelling program.

Table 2. Environmental variables used in the analysis.

1.3.2 Spatial Analysis:

Variable	Code in output tables	Value	Source
Climatic variables (n=2) (one related to temperature, one related to precipitation)	Matemp/precipitation	continuous	Copernicus
Altitude (m)	alt	continuous	DEM-Copernicus
Distance to rivers (m)	distancetorivers	continuous	ArcGIS-DEM
Distance to main road network (m)	distancefrommainroads	continuous	ArcGIS
Distance to forest road network (m)	distancefromforestroads	continuous	ArcGIS
Goat density (small ruminants km^{-2})	goatden	continuous	FAO
Sheep density (small ruminants km^{-2})	sheepden	continuous	FAO
Bovine density (large ruminants km^{-2})	cattleden	continuous	FAO
Land use/habitats	habitattypes1	categorical	Corine CLC
Land use/habitats	Habitattypes_	categorical	GIS Data Bases-National Parks
NDVI index	April-May-June-July-August-September-October-November/ndvi	continuous	Copernicus
Distance from villages (m)	distancefromvillages	continuous	ArcGIS-DEM
Slope	Slope	continuous	ArcGIS-DEM
Distance from livestock farms	farmsdistance	continuous	GIS Data Bases-National Parks
Human population density (people km^{-2})	popden	continuous	GEoDatabase

Maxent method is a machine learning tool for modeling ecological data that requires presence-only data, utilizes both continuous and categorical data and includes efficient deterministic algorithms and mathematical definitions (Phillips et al. 2006). Brown bear (*Ursus arctos*) conflict areas (damages) were used in Maxent modelling (Maxent software version 3.4) (Phillips et al., 2017) to predict and model the bears conflict area distribution. The environmental parameters were correlated with the locations of brown bear damages by identifying the distribution of maximum similarity, so that the expected value of each environmental variable matched its empirical average, determined by the locations of the known points. The logistic output was used for the interpretation of the results which assessed the probability of presence with a range of values from 0 to 1. The goodness of fit of the model predictions was evaluated by the mean area under the curve (AUC) of the receiver operating characteristic (ROC) curve. Jackknife test was used to eliminate the number of environmental variables to those that exhibited a substantial contribution to the model. The Jackknife procedure was used to reduce the number of environmental variables to only those that showed a substantial influence on the model.

2. Results

2.1. Questionnaires survey in Prespa National Park:

In Prespa National Park, interviews were conducted with livestock raisers, beekeepers and farmers of crop production. Interviewees sample partition is shown in (Figure 1). The interviews were conducted during on-site visits mainly to livestock units, apiaries within the National Park jurisdiction area following consultation with the candidate interviewees. General data on the conducted interviews are presented in Table (3).

Fig. 1: Interviewees sample partition (n=73) in Prespa National Park project sub-area.

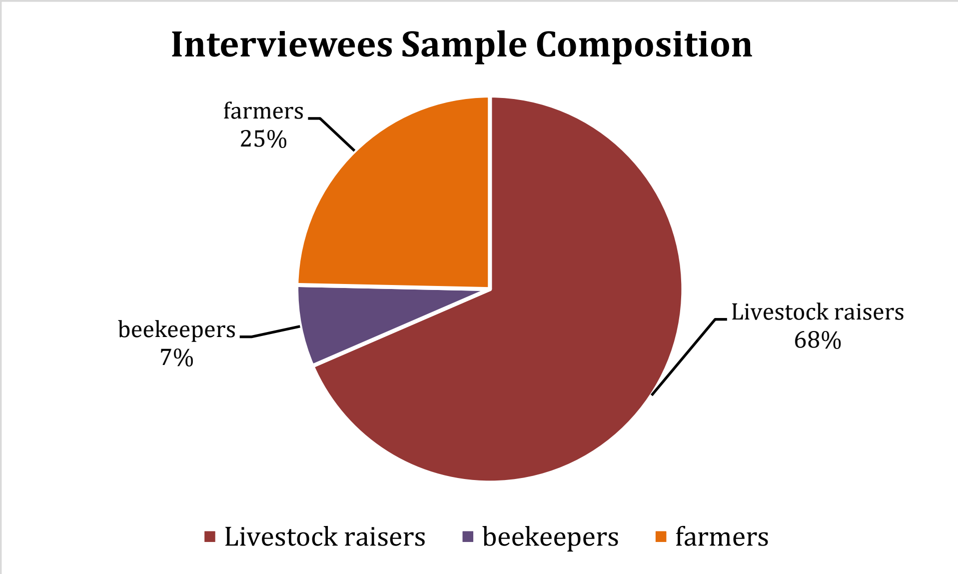
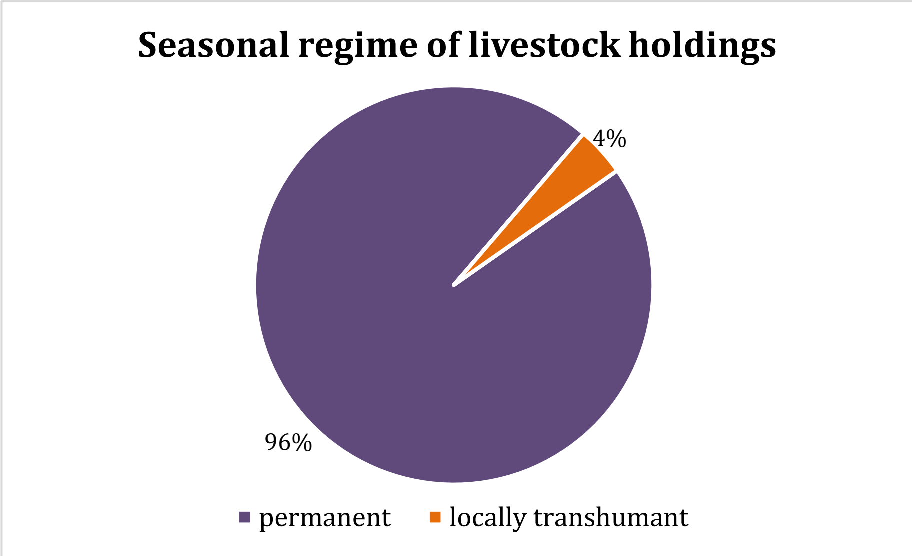


Table (3): Number of livestock or crop farms for which interviews were conducted by type of exploitation

Category	Type of farming	number	%
Livestock raisers (N=50)	Adult bovines	6	8.2%
	Adult bovines and calves	12	16.4%
	Goats	1	1.4%
	Bovines and sheep	1	1.4%
	Bovines and goats	1	1.4%
	Sheep and goats	20	27.4%
	Bovines + sheep & goats	5	6.8%
	Cattle and buffalos	1	1.4%
	Porcins	1	1.4%
	Equiids	1	1.4%
	Sheep, goats and equiids	1	1.4%
Beekeepers (N=5)	beehives	5	6.8%
Farmers (N=18)	beans	14	19.2%
	Beans and trifolium	3	4.1%
	Beans and vine yards	1	1.4%

The questionnaire survey took into account the seasonal movement of breeders. As shown in Figure 2, the livestock farming in the area is almost entirely seasonal (96% of producers), which means that most livestock farms are permanent establishments that are used all year round. Only 2 producers (4%) make local movements, moving the herd to a different location during the summer.

Fig.2 : Seasonal regime of livestock holdings in Prespa National park project sub-area.

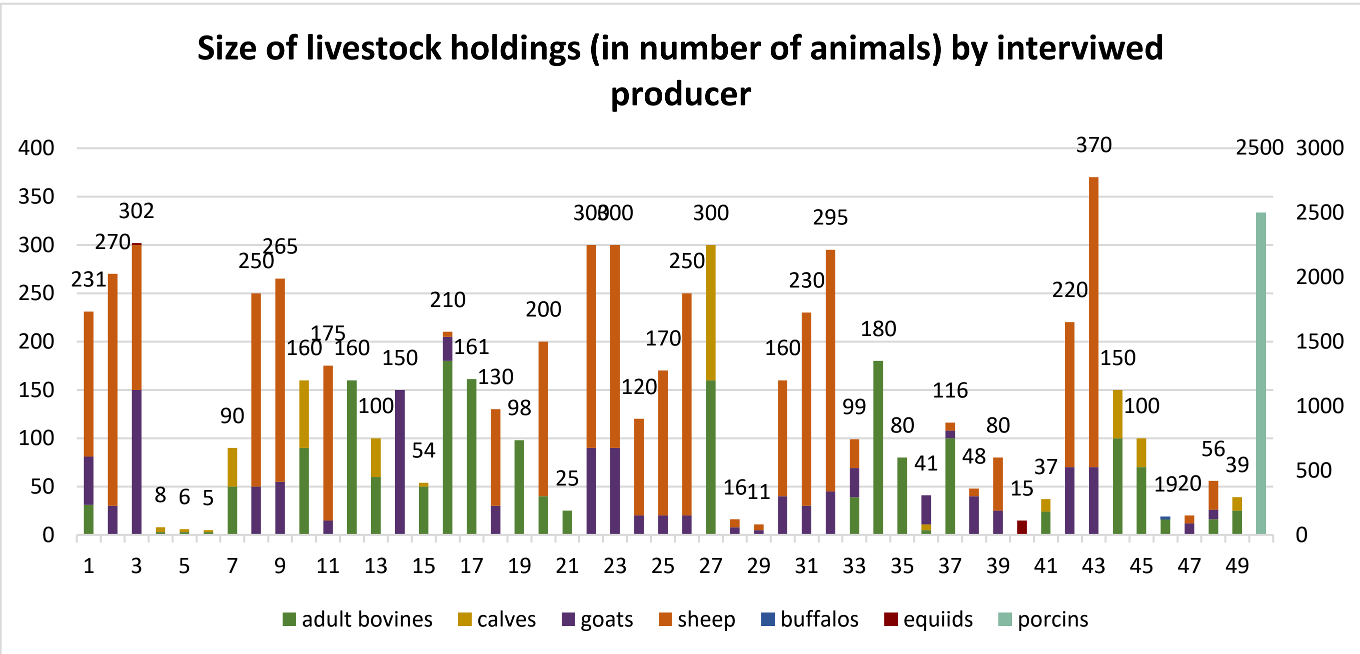


Regarding the size of livestock holdings, it was expressed in two ways:

a) number of livestock animals per species and

b) number of animal units.

The Animal Units coefficient (AU/Greek codification=ZM), as defined by the Hellenic Agricultural Insurance Organization (ELGA), is used as a common tool in order to evaluate the different components regarding size of livestock farms and livestock flocks related to different species, ages and numbers of livestock. This specific coefficient value varies depending on the type of livestock. Consequently, every adult sheep and goat corresponds to 0.15 livestock unit (AU/ZM), every adult bovine (cattle) to 1 (AU/ZM) and one calf to 0.4 (AU/ZM). Initially, the capacity of the livestock units was estimated in terms of number of



livestock animals per species for each producer (Figure 3, Table 3) and per species for the different types of holdings. Table (4) shows the livestock units of the sample divided into 7 categories according to the type of farmed animal.

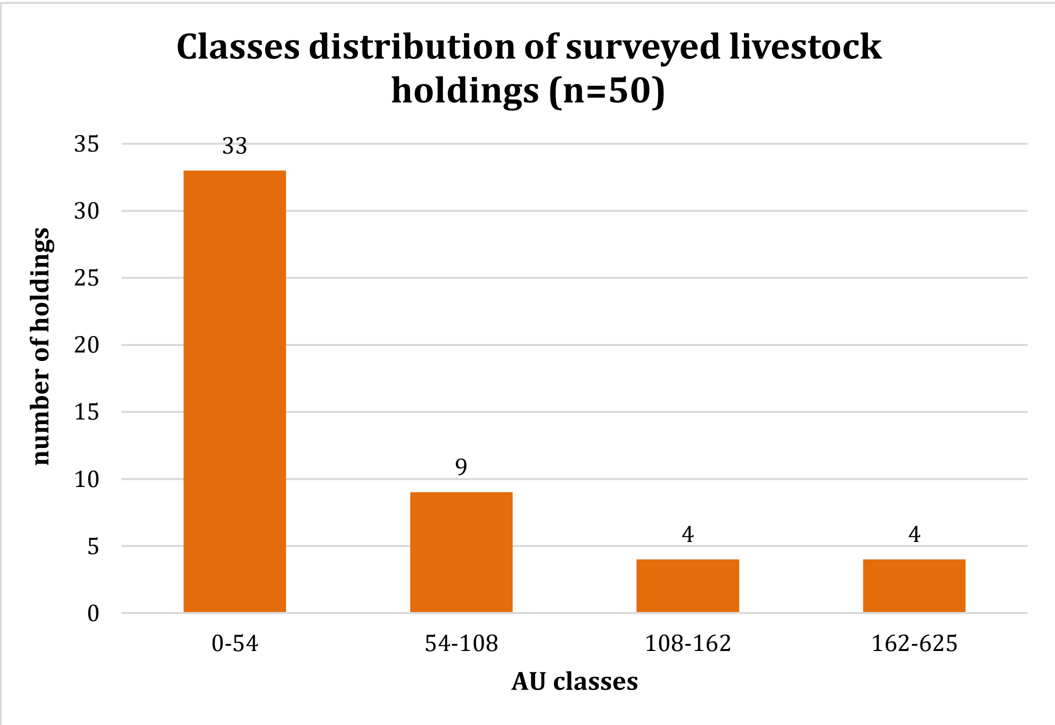
Table 4: Size of livestock capital per producer (N = 50) and number of farmed animals per species.

	Bovines (adults)	Calves	Goats	Sheep	Buffalos	Equiids	Porcines
1	31		50	150			
2			30	240			
3			150	150		2	
4	3	5					
5	3	3					
6	3	2					
7	50	40					
8			50	200			
9			55	210			
10	90	70					
11			15	160			
12	160						
13	60	40					
14			150				
15	50	4					
16	180		25	5			
17	161						
18			30	100			
19	98						
20	40			160			
21	25						
22			90	210			
23			90	210			
24			20	100			
25			20	150			
26			20	230			
27	160	140					
28			8	8			
29			5	6			
30			40	120			
31			30	200			
32			45	250			
33	39		30	30			
34	180						
35	80						
36	5	6	30				
37	100		8	8			
38			40	8			
39			25	55			
40						15	
41	24	13					
42			70	150			
43			70	300			

44	100	50					
45	70	30					
46	16				3		
47			12	8			
48	16		10	30			
49	25	14					
50							2500
TOTAL	**1769**	**417**	**1218**	**3448**	**3**	**17**	**2500**

The capacity, and therefore the size of the livestock holdings, was also estimated using the Animal Units coefficient as described above. The sampled (50) livestock units were grouped and classified into 4 Animal Units (AU) scored classes as follows: a) 0-54 AU, b) 54-108 AU, c) 108-162 AU και d) 162-625 AU. In the classification process, one unit was excluded which was disproportionately large in relation to the other (4) classes (625 AM - 2500 pigs), which was finally integrated in the larger class. Typically, 66% of the units belong to the first size category, (class 0-54 AU).

Fig. 4: Percentage distribution of livestock farms (N = 50) in size classes as they are expressed in insurance/animal units (AU).



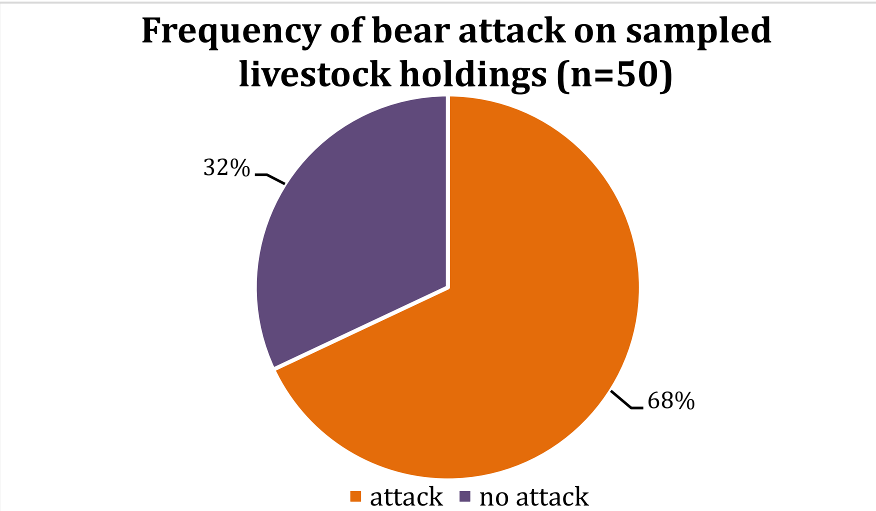
➢ **Livestock losses related to bear depredation**:

Regarding the losses of livestock capital from the brown bear, through the interviews data were collected regarding the annual number of lost animals for the years 2010-2021 due to bear attacks and depredation.
It should be noted that the results relate to losses reported by the producers themselves and the analysis carried out in the present survey can only be used in a comparative way between the producers.
Table 5 presents the livestock losses and bear attacks for all holdings and by category of livestock for the evaluation period 2010-2021. The table does not include crop losses as it was not possible to collect quantitative data on the number of attacks and the magnitude of the loss. The rate of bear attacks over the entire sample of livestock holdings is shown in fig. 5

Table (5): Livestock losses over a 10y period from bear attacks in Prespa NP project sub-area.

		2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Livestock raisers	**Number of attacks**	3		1		3	4		6	7	17	33	1
	Bovines	9				3	9		6	21	30	23	
	Goats											5	
	Sheep					3					3	5	3
	Sheep and goats	10							13	25	37	22	
	Equiids			2						2			
	TOTAL	19		2		6	9		19	48	70	55	3
Beekeepers	**Number of attacks**										2	1	
	Number of beehives										10	10	

Fig.5: Frequency of bear attack incidents upon the surveyed livestock holdings.(n=50***)***

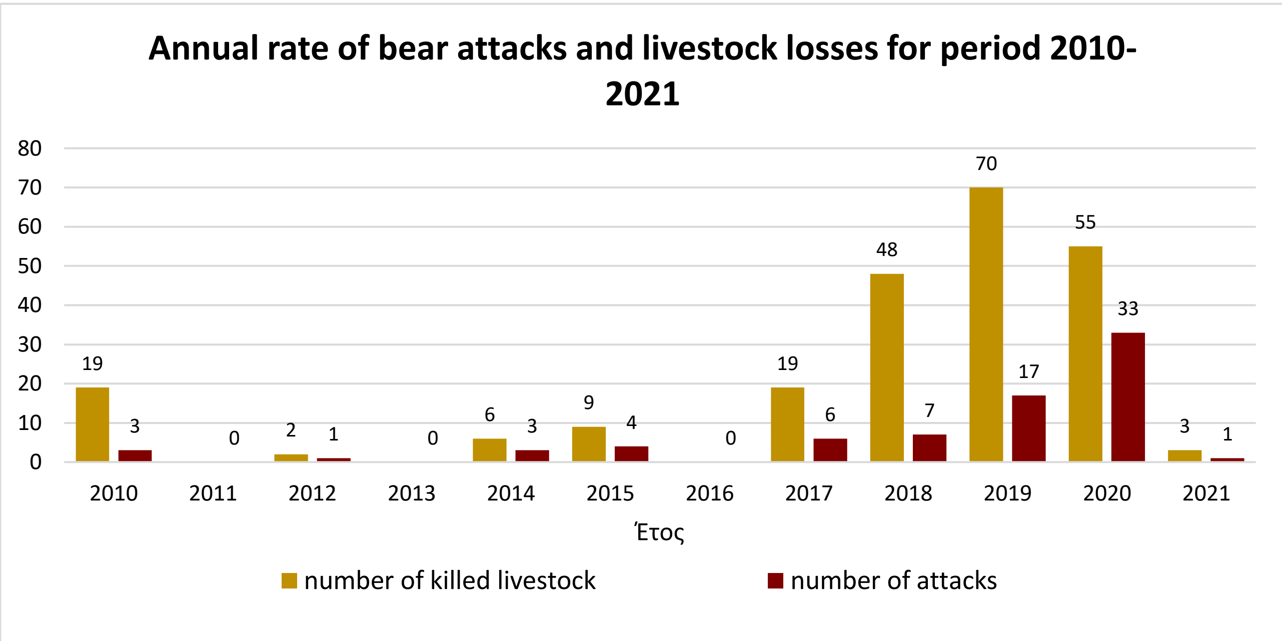


Through interviews with livestock breeders, it became possible to collect data on the magnitude of livestock capital losses from bears attacks but also on the frequency of bear attacks on livestock facilities. Table 6 summarizes some statistics on the number of annual attacks for the period 2010-2021 in relation to the location of the attack (at pasture during grazing or in stable/holding). The number of attacks refers only to attacks where a livestock animal was killed while data on attacks in which no information on the location of the attack was available were not taken into account. In the cases of bear attacks in the stable (holding) the animals were either inside or just outside.

Table 6 Figures on annual bear attacks for the period 2010-2021 in relation to the location of the attack.

	Number of attacks		Number of killed livestock	
Location of attack	Min-max	average	Min-max	average
Pasture (N=34, 45%)	0-27	7	0-39	13
Stable (N=15, 20%)	0-8	3	0-33	11

The results show that a relatively small percentage of attacks (20%) take place at thye holdings (stables). It is worth noting, however, that although the attacks at the stables are less both throughout the season and for each year separately, the total number of depredated livestock is comparatively similar between the two locations, making the attacks at the stable almost as destructive as those occurring at the grazing grounds. This may be due also to the fact that at the stable livestock is even more grouped.
However, this finding should be evaluated with caution as there is no data on the relative positions of a significant percentage of attacks (35%, N = 26).
Figure 6 shows the total number of attacks and depredated livestock for each year over the 10y period the period 2010-2021. In recent years there has been a significant increase in both the number of attacks and losses (with the exception of 2021 for which data are incomplete as interviews were conducted in 2020 and the first half of 2021). As these data are derived only from the statements of the interviewed producers, they need cross validation with the official data collected by of ELGA, in order to further investigate the existence of depredation rate positive trend at the local level.
Fig. 6 : Annual rate of bear attacks and livestock losses (n=50) – 2010-2021



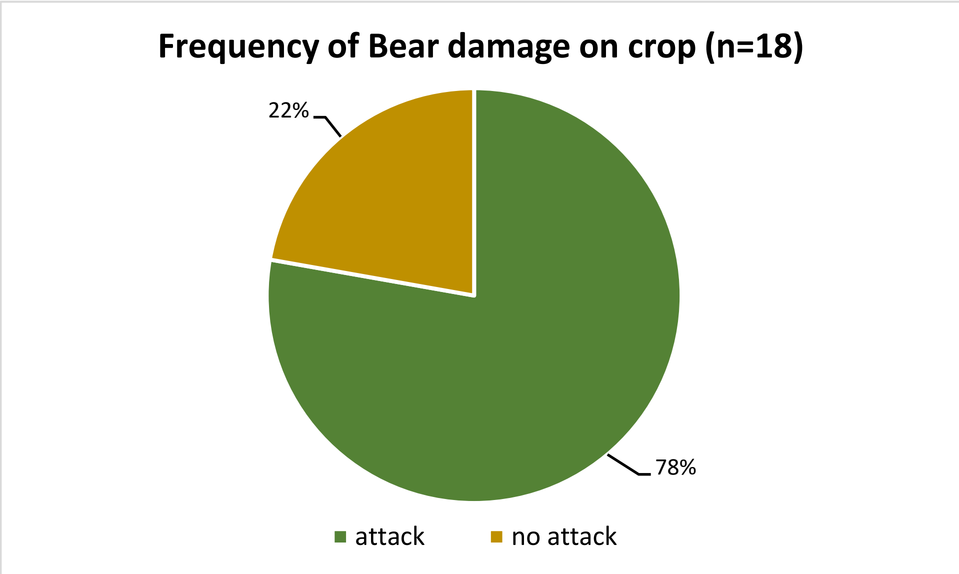
➢ **Attacks on apiaries**

Within Prespa National Park, of the five (5) beekeepers interviewed, (2) had capital losses with by destroyed beehives after a bear attack. In both cases, there was a destruction of 10 beehive boxes, a number that corresponds to half the beehive boxes in each of the two locations. Both producers procured and then installed electric fences. From the interviews, another bear attack on a apicultural unit was recorded, which, however, took place in a previous period and thus is not evaluated as a case in the present report.

- **Damage on crop production**

The majority of the farmers in the National Park area who participated in the interviews, have suffered some loss from bear visits to their crops (Figure 7). However, the frequency of visits from other wildlife species (i.e. wild boars which are at numbers) and the difficulty in assessing the damage in quantitative terms, makes difficult to present more elaborated figures.

Fig.7: Frequency of bear damage on crop production in Prespa NP (n=18)



- **Protection/preventive measures**

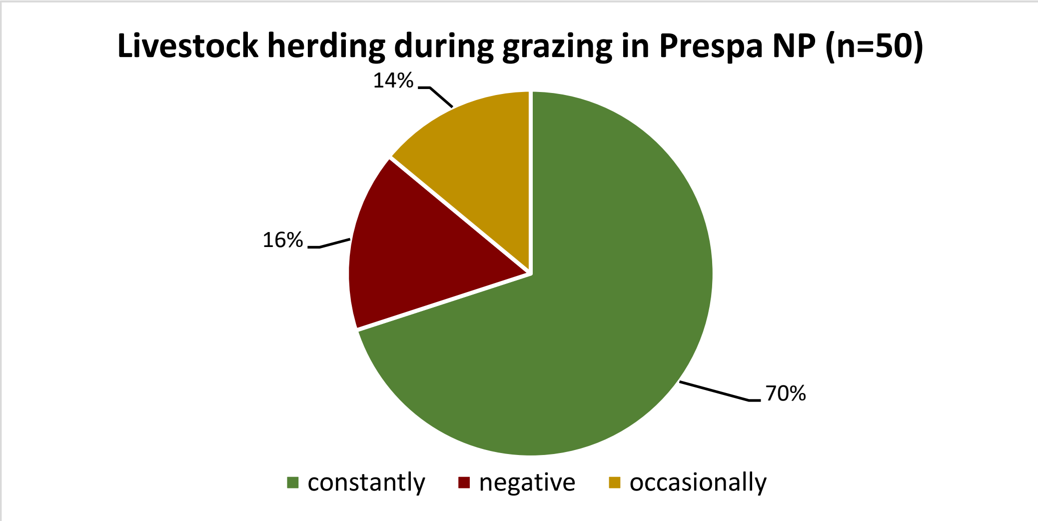
Use of shepherds for livestock herding is among the most common measures. Table 6 shows the number and percentage of holdings in the various categories, depending on the number of shepherds involved in guarding and supervising the herd. In the vast majority of cases (92%, n=50), there is an involvement of additional staff, in addition to the producer owner, regarding the care and supervision of the herd, either by family members or by a third person hired for this purpose.

No of shepherds	Number of holdings	% of holdings
1	8	16%
2	20	40%
3	19	38%
4	1	2%
5	2	4%

The care and surveillance of the herd is a key parameter that largely determines the losses rate and frequency from large carnivores' attacks (including the brown bear). Figure 8 shows

the frequency of herd guarding-monitoring of by a shepherd during grazing. On the positive side, is the fact that the majority of holdings (70%), is under constant supervision during grazing either by the owner of the livestock unit or by an employee (shepherd).
A small percentage (14%) of herds have partial supervision which means that the herd spends some hours or days of the year alone grazing without human surveillance. Finally, 16% of the herds are left unattended during grazing, which makes them more vulnerable to wildlife attacks.

Fig 8.: Livestock surveillance frequency during grazing (n=50)



- **Flocks overnight**

Regarding herds overnight, it is observed that during winter season, the majority of the herds (83%) are gathered and driven to spend the night in a fenced holding facility or a stable facility (Figure 9). This ratio is reversed during the summer season, when the majority of herds are concentrated in an outdoor area, either inside or outside a fence, while only a small percentage (23%) is driven to a closed and more secured facility (Figure 10).

Fig. 9: Herds overnight regime during winter season (n=50):

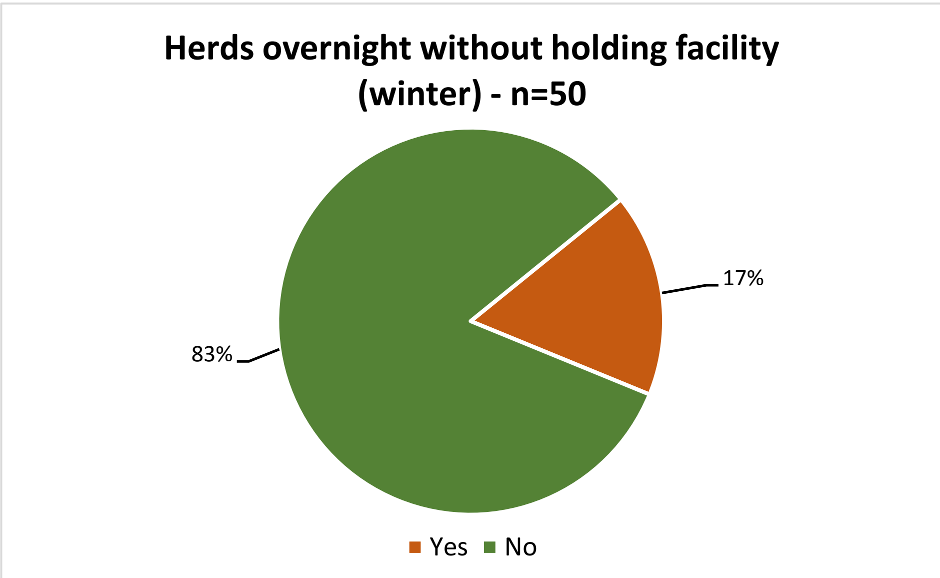
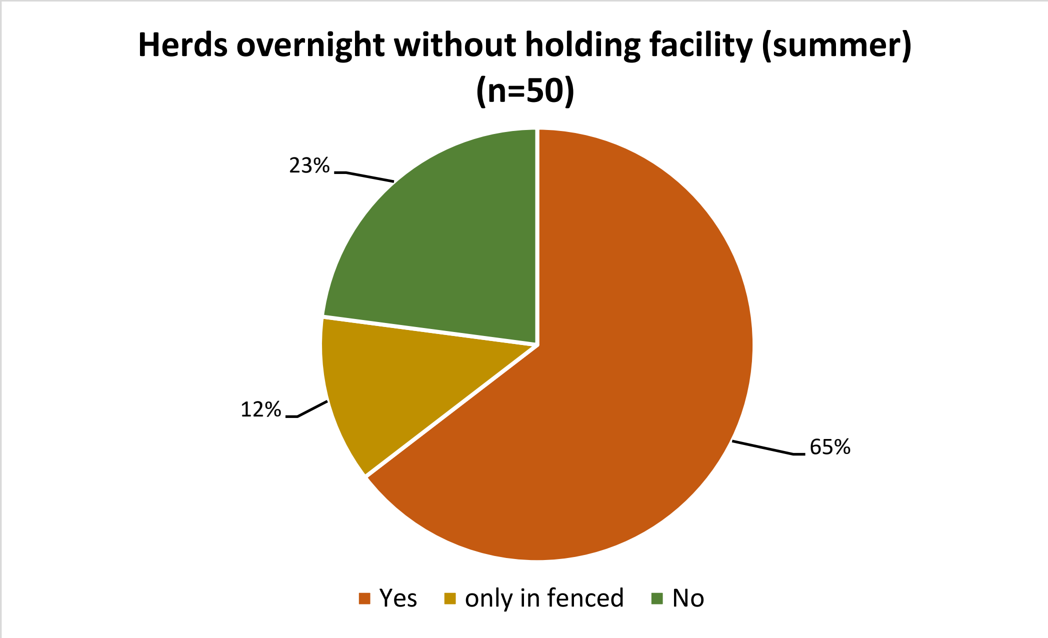


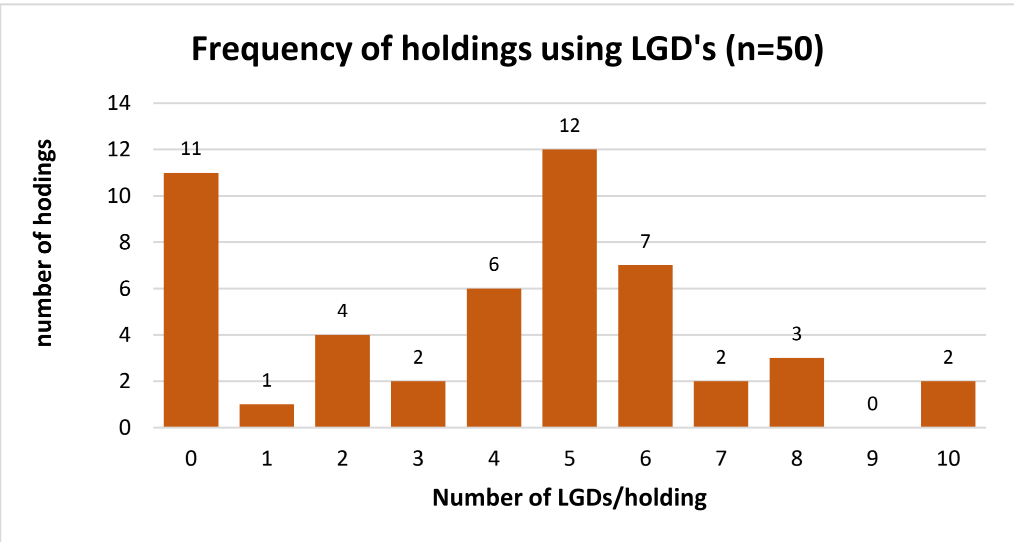
fig.10: Herds overnight regime during summer season (n=50).



➢ **Use of Livestock guarding dogs (LGD's):**

The use of livestock guarding dogs (LGD's) is one of the most important and common preventive measures to deal with large carnivore attacks and livestock depredation incidents. It seems that the vast majority of the interviewed livestock raisers (78%) have adopted this traditional preventive measure and use LGD's for their flocks protection while the number of LGD's by livestock exploitation varies considerably with most livestock breeders having 4-6 LGD's in their flock (fig. 11).
According to fig. 11 it is important to note that in eleven (11) livestock holdings LGD's are not used at all, a fact that makes these livestock units and flocks more exposed and vulnerable to potential large carnivore-bear attacks.

Fig 11: Use of LGD's as a preventive measure in the surveyed livestock holdings



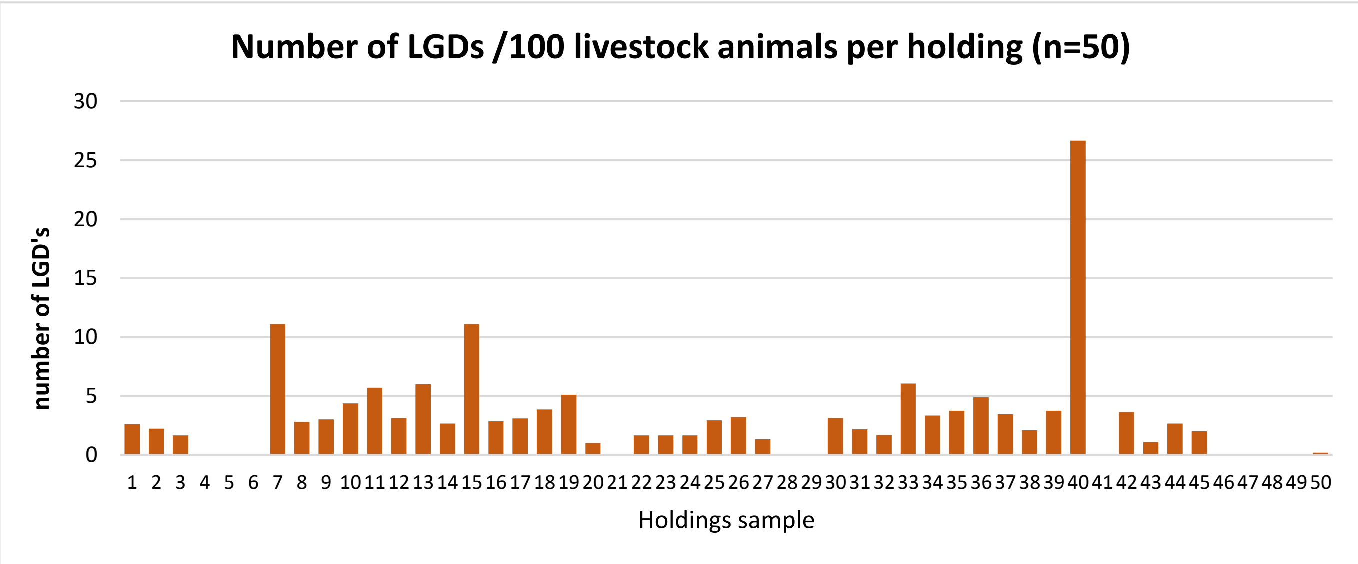
By processing the data collected through the interviews, and regarding the number of LGD's / livestock holding, it was estimated in three different ways: a) as the absolute number of LGD's per holding, b) as the number of LGD's per 100 livestock animals and c) as the number of LGDs per insurance unit (or Animal Unit – as described above). Table 7 presents the above figures for all livestock farms covered by the questionnaire survey.

Table 8: Figures on LGD's used in livestock holdings covered by the survey.

	Magnitude range	Number of LGDs	Number of LGDs/100 animals	Number of LGDs / AU
Number of holdings (N=50)	Min – max	0-10	0-27	0-0.38
	Average value	4	3	0.09

The above ratios should be evaluated as a whole, including other parameters (such as LGDs quality and training other proactive measures and deterrent mechanisms, human presence, etc.), in order to draw a conclusion about their effectiveness in protecting the herd. In Figure 12, we observe that the number of LGDs/ 100 animals varies considerably with most breeders maintaining a ratio where less than 5 LGDs to every 100 animals. It has been proved in practice that the number of dogs is not always proportional to the flock protection efficiency.

fig.12: Variation of LGDs numbers per interviewed livestock holding.



- **Other preventive measures used by farmers/livestock raisers**:

During the survey and regarding the use of preventive measures, livestock breeders were asked if they use additional preventive measures apart from the traditional ones (i.e. LGD's, herd surveillance by hired shepherd and flock overnight in fenced location). The results are presented in Figure 13.

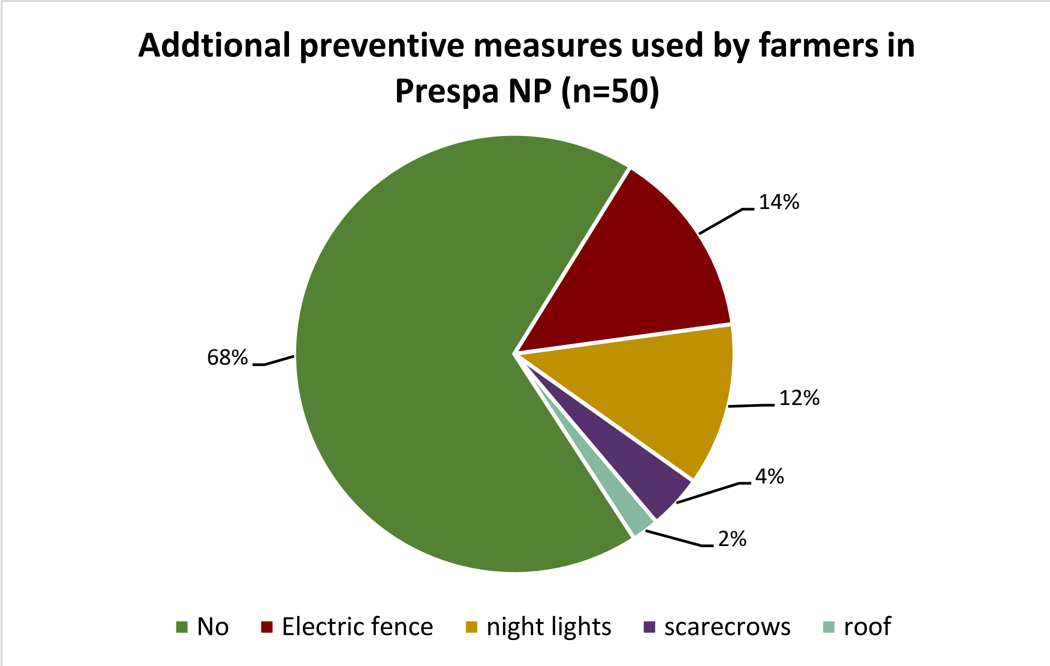
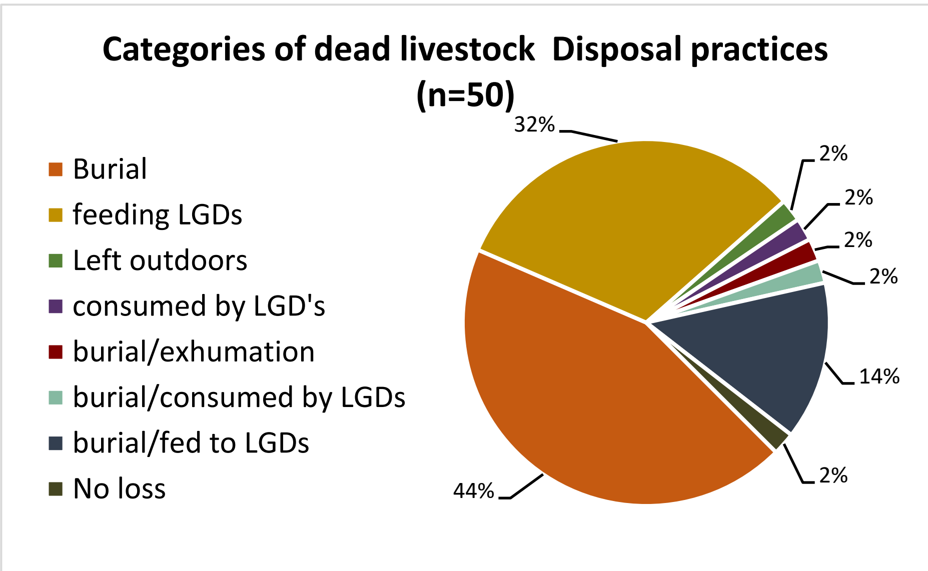


Fig. 13: categories of additional preventive measures used by interviewed farmers in Prespa NP.

According to fig. 13, we note that the largest percentage of breeders (68%) do not use any additional and/or modern preventive measure. The most popular prevention measure used is the installation of electric fences, followed by the use of night lighting in order to prevent/deter wild animals from approaching the overnight place of the herd.

- **Disposal of dead livestock animals**

Bears have a very good sense of smell and, like other carnivores, can detect a decaying corpse from a distance of many kilometers. Any dead animals dumped outdoors can be a source of attraction for carnivores and predators/scavengers, such as bears and wolves. Removing, burying or burning corpses, instead of dumping them outdoors, reduces the chances of attracting predators. In the frame of this survey, the answers recorded by the breeders in the area of the National Park are positive regarding appropriate disposal, as almost all producers stated that in some way they manage the dead animals instead of leaving them outdoors in the pasture. The most popular practice is the burial of corpses, which is combined to other practices such as feeding of corpses to the LGDs (Figure 14).



- **Losses of herding dogs from poisoned baits**

One of the most important problems faced by breeders in many parts of Greece is the loss of their LGDs from poisoned baits. These losses are seriously hindering and jeopardizing the efforts for the propagation of LGD's use among livestock raisers and thus dispose of an efficient "tool" against large carnivores' attacks. Nearly half of the interviewed livestock raisers (**42%**) said they lost at least one LGD from poisoned bait consumption in 2010-2021. In total, 85 LGDs died from poisoning in the last decade while on average 4 LGDs were lost per holding (range = 1-12).

The incentives for the use of poisoned baits, according to the producers, mainly include:

A) Local conflicts: poisoned baits are placed either by other producers or by other locals due to personal conflicts.

B) Conflicts with hunters: poisoned baits are placed by hunters targeting shepherd dogs that may attack and injure / kill hunting dogs.

C) Illegal placement of poisoned baits to fight other carnivores such as fox, wolf or bear.

In cases where the illegal practice of poisoning was perceived by breeders, the type of poisoned bait used was mainly pieces of meat (minced meat, offal, fish) while in other cases the breeders realized from the symptoms (as e.g. foaming) that their LGD's had consumed some poisonous substance but were unable to locate the source. In some cases, the poisoning was secondary as it was caused by the consumption of another animal, which in turn had consumed a poisoned bait.


Photos 1-4: Questionnaire dissemination and interviews in Prespa National Park.

2.2 Questionnaire survey in Rodopi National Park:

In RMNP, interviews were conducted with livestock raisers, beekeepers and farmers of crop production. The interviews (n=83) were conducted during on-site visits mainly to livestock units, apiaries within the RMNP jurisdiction area following consultation with the owners. Map (1) shows the spatial distribution of the interviewees locations and figure 16 presents the frequency of interviewed farmers categories. Interview process is illustrated on photos 5-8.

***Map 1.**: Distribution of the interview locations (green dots) in farm units in RMNP project sub-area.*

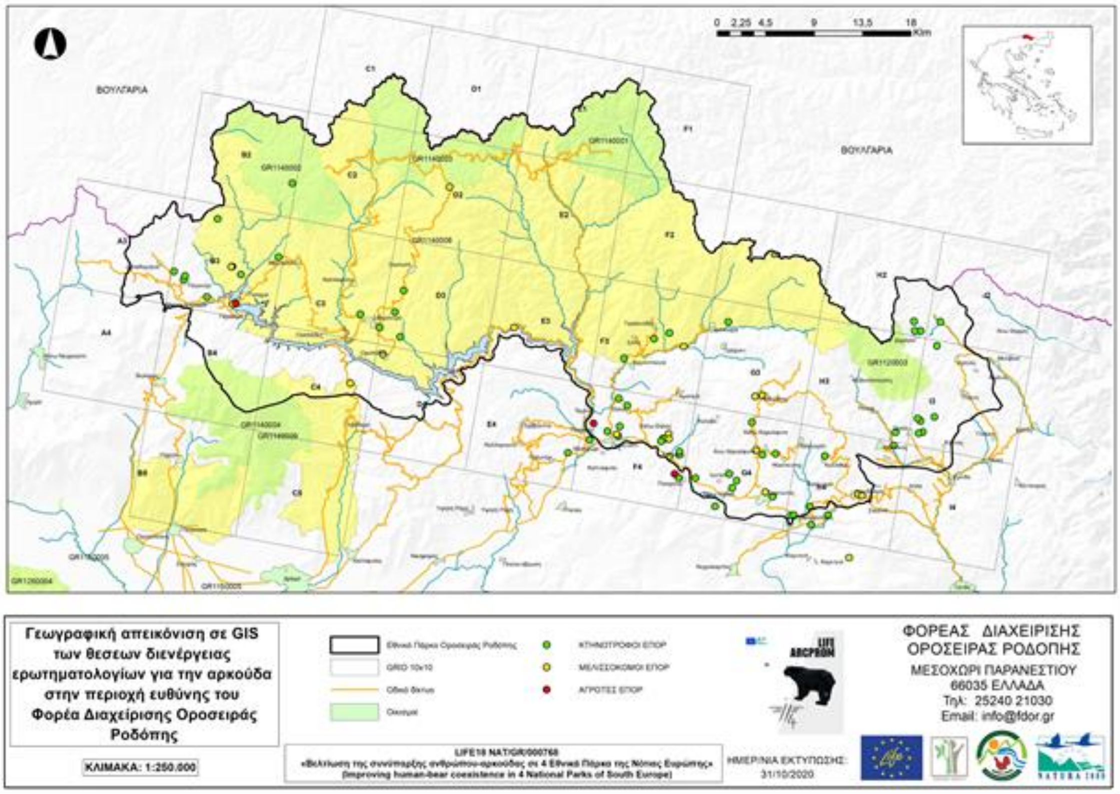
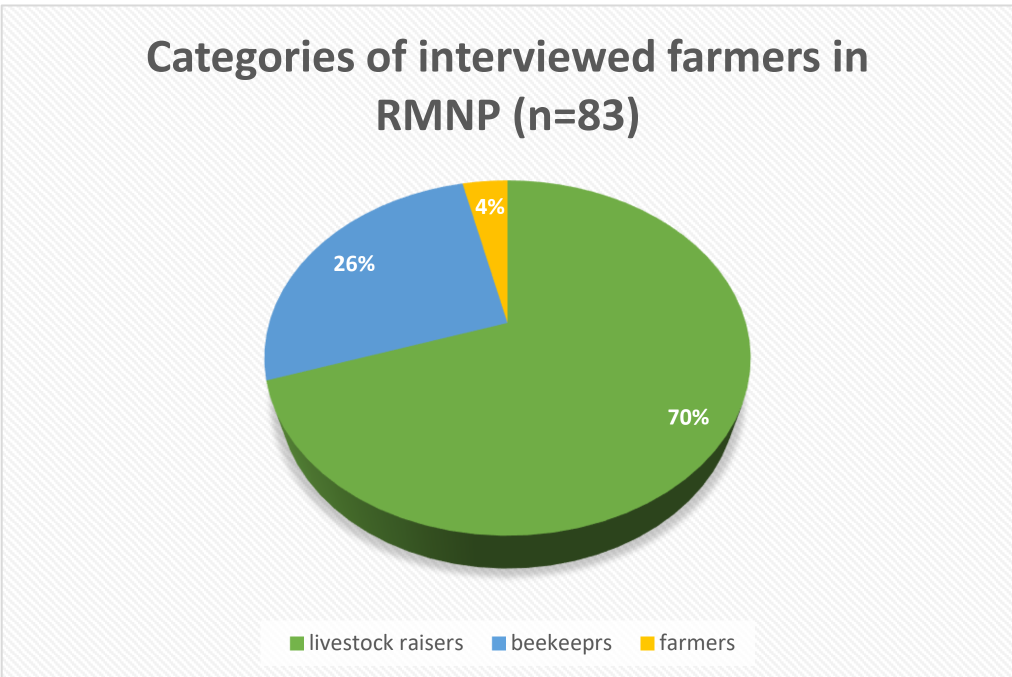


Figure (16): Categories of interviewed farmers (n=83) in Rodopi Mountain Range NP.



General characteristics and figures regarding the interviewees' farm units are presented in table (9), while more detailed figures and data on livestock raising units are presented on table (10)

Table (9): *Composition of interviewees samples and figures on types of exploitations in RMNP.*

Livestock raisers (n=58)	
Bovines (adults)	24
Bovines (adults and calves)	10
Bovines (calves)	1
Goats	6
Sheep	5
Goat + sheep	6
Bovines + goats & sheep + buffalos and porcines	1
Bovines and goats	1
Bovines and sheep	3
Goats/sheep and bovines	1
Total	58
Beekeepers (n=22)	
Farmers (n=3)	

Table (10) *: detailed figures on livestock units composition as reported from questionnaires survey.*

Survey area	Rodopi Mountain Range National park
Number of interviews	**83**
Type of livestock exploitation	

Type of livestock	(%)	N
Bovines & Buffalos	72,4	42
Sheep and goats (mixed or separated)	25,9	7
Goats/sheep (only mixed)	27,6	8
Goats	39,7	23
Sheep	1,7	1
Bovines and goats	13,8	8
Bovines and sheep	1,7	1
Sheep/goats + Bovines	5,2	3
Porcins	1,7	1

Photos 5-8: *During interviewing of farmers in RMNP by RMNP and Callisto personnel*

The questionnaires survey took into account the seasonal movement of livestock breeders. As shown in figure (17), livestock farming in the RMNP area is mainly permanent regime (41% of livestock raisers cases), which means that most livestock farms are permanent facilities that are used all year round.

A certain percentage of livestock raisers (59%) make local movements (local scale transhumance) and more specifically, some producers move locally during the summer season - usually within the same Municipality unit - to locations and grazing areas at higher altitudes with rudimentary summer facilities. This type of facilities is usually insufficiently protected against large carnivores attacks especially when it comes to small livestock (sheep and goats) which are gathered during the night hours.

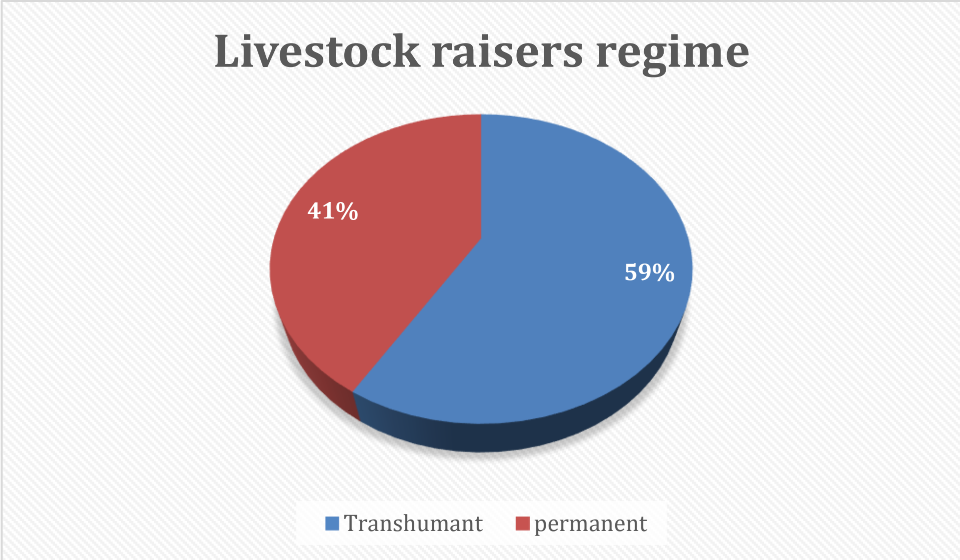
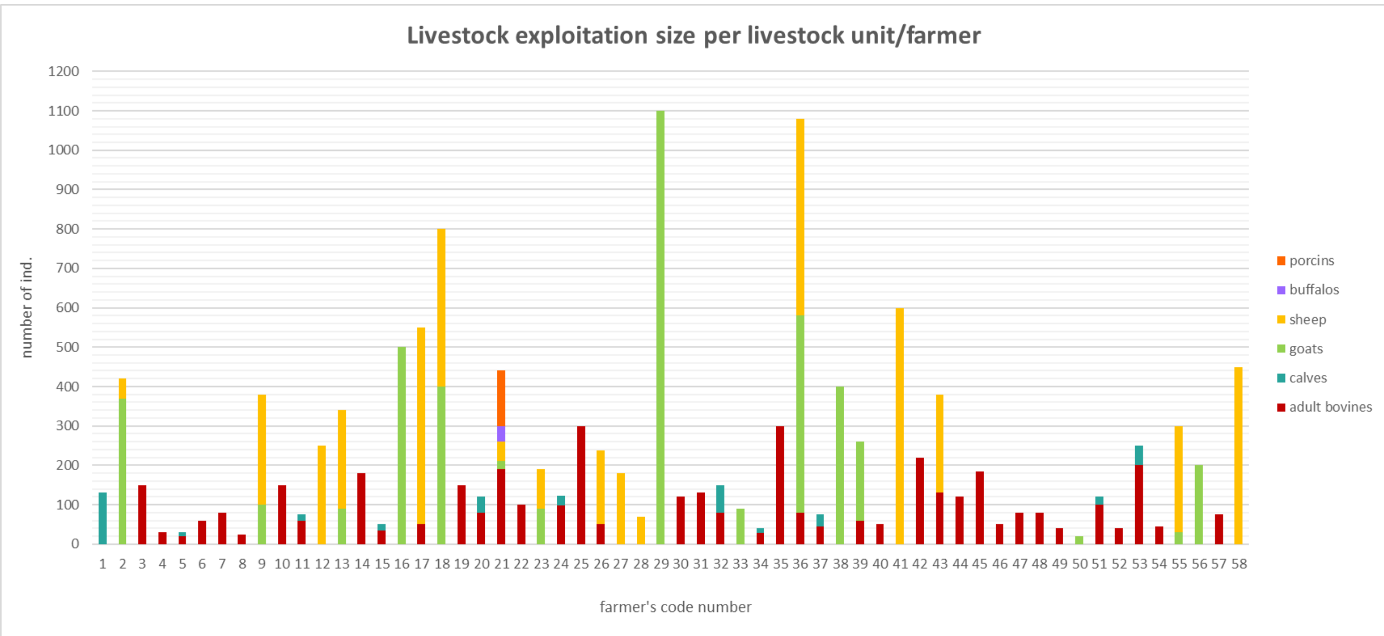


Fig (17) . Livestock raisers regime in Rodopi National Park project sub-area. (n=83)

The size of the livestock holdings was expressed in two ways:
a) number of livestock animals per species and
b) number of animal units.
The Animal Units coefficient (AU/Greek codification=ZM), as defined by the Hellenic Agricultural Insurance Organization (ELGA), is used as a common tool in order to evaluate the different components regarding size of livestock farms and livestock flocks related to different species, ages and numbers of livestock species. This specific coefficient value varies depending on the type of livestock. Consequently, every adult sheep and goat corresponds to 0.15 livestock unit (AU/ZM), every adult bovine (cattle) to 1 (AU/ZM) and one calf to 0.4 (AU/ZM). Data processing regarding the size of livestock units is shown on figure (18) where the capacity of the livestock units was estimated in number of livestock animals per species for each interviewed livestock raiser. Then, the livestock units of the sample were divided into 6 categories according to the type and total numbers of farmed animals (tables 11 & 12).

Fig 18: Livestock capital size per livestock holding unit (n=58)



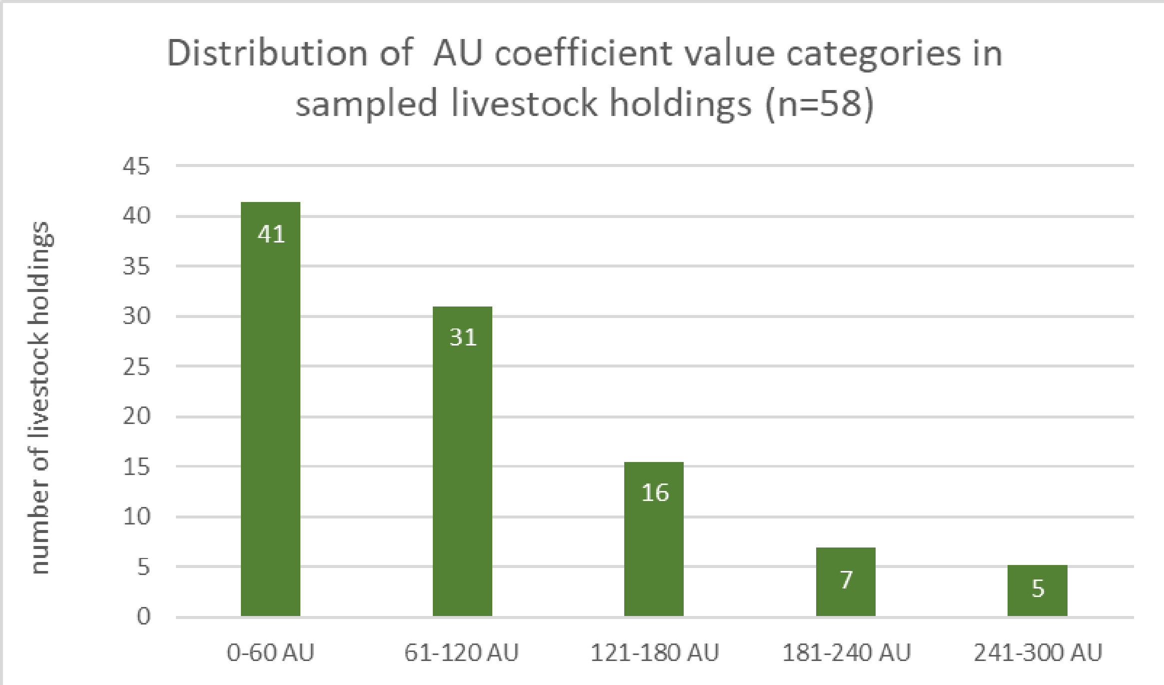
Livestock holding category	N	Values/numbers	Πρόβατα	Αίγες	Βοοειδή	Βουβάλια	Χοίρους
Mixed sheep & goats	6	Min-max	50-400	30-400			
		average	225	180			
Sheep	5	Min-max	70-600				
		average	310				
Goats	6	Min-max		20-1100			
		average		373			
Cattle (adults + calves)	35	Min-max			10-300		
		average			82		
Mixed sheep and cattle	3	Min-max	187-500		50-130		
		average	312		77		
Mixed goats & cattle	1	Min-max		200	60		
		average		200	60		
Mixed sheep/goats/cattle	1	Min-max	500	500	80		
		average	500	500	80		
Mixed sheep/goats/cattle/buffalos /Porcines	1	Min-max	50	20	190	40	140
		average	50	20	190	40	140

	Total number
Bovines	3767
Calves	416
Goats	4110
Sheep	4387
Buffalos	40
Porcines	140

Tables (11 & 12) : composition of surveyed livestock units (n=58) in terms of livestock species and numbers per livestock farm and total number of farmed livestock per species.

The capacity, and therefore the size of the livestock holdings, was also estimated using the Animal Units coefficient as described above. The sampled (58) livestock units were grouped and classified into 5 Animal Units (AU) scored classes as follows:
a) 0-60 (AU)
b) 61-120 (AU)
c) 121-180 (AU),
d) 181-240 (AU)and
e) 241-300 (AU).
Circa 88% of the sampled livestock holdings corresponds to the first (3) categories, with the largest percentage (41%) relating to holdings of class 0-60. (fig. 19).

Fig 19.. Distribution of livestock holdings size in the surveyed area (n=58) given in AU coefficient values.



- **Losses in agricultural capital from the bear**

Regarding the losses of livestock capital from brown bear depredation (photos 5,6) the questionnaires collected data on the annual number of animals lost over a 9y period from 2012 to 2020 (with an additional record from the year 2001) in a sample of 58 breeders and 22 beekeepers. No losses have been recorded/reported on crop production.
Regarding livestock breeders in order for the data to be processed correctly, it was necessary to make the following assumptions for producers with coded numbers S13 and S56 who had given a vague answer as to the year of loss of the animals and to S8 for whom the information is not confirmed.
For producer S13, a combination of data from the Case Record Database from the Rodopi Mountain Range NP Management Agency and the ELGA official data base was used and its damage was recorded in 2016 according to the data recorded in the data base. For producers S8 and S56 it was preferred not to use their information as it could not be confirmed.

Fotos 5 & 6: bear damage on beehives and porcine in Rodopi Mountain Range NP.

Of the 58 interviewed livestock breeders, 32 reported attacks by bears (ν1 = 52), while of the 22 interviewed beekeepers, 15 reported bear damage (ν2 = 15). The absolute number of total bear attacks is shown in Table 13. The same table calculates the absolute number of animal losses per year with losses of 166 livestock animals and 113 bee colonies (beehives).

	Total number of bear attacks		Total losses	
years	Livestock raisers	beekeepers	Livestock	beehives
2001	1		1	
2012	1		1	
2013	1		1	
2014	3		3	
2015	2		5	
2016	2	1	14	4
2017	2	4	2	25
2018	14	2	37	26
2019	8	3	33	40
2020	18	5	69	18
Σύνολο	52	15	166	113
GD total	**67**		**279**	

Table 13: absolute number of total bear attacks and absolute numbers of animal losses per year in the interviewed farmers.

- **Attacks on livestock facilities**

Questionnaires and interviews with livestock producers provided information about the size of livestock capital loss from bears depredation but also about the frequency of bear attacks in livestock facilities.

As the different species need different grazing and husbandry conditions, it was chosen by all the holdings (goats, sheep, goats, sheep, cattle & sheep-cattle) to separate the owners' flocks of sheep and cattle to make it easier to quantify the losses. Thus the holdings were clustered as follows: GOATS / SHEEP 3 flocks, GOATS 3 flocks, SHEEP 2 flocks, Cattle 23 flocks and BEES 15.

Therefore, the bear effect was estimated over a total of 31 herds and the average annual number of attacks per producer was estimated at 1.43 attacks (0-18 attacks, SD 0.67), while the average annual loss in number of animals per herd was 4.46 animals (range 0-69 animals, SD 7.58) with some fluctuations in variability according to fig 20.

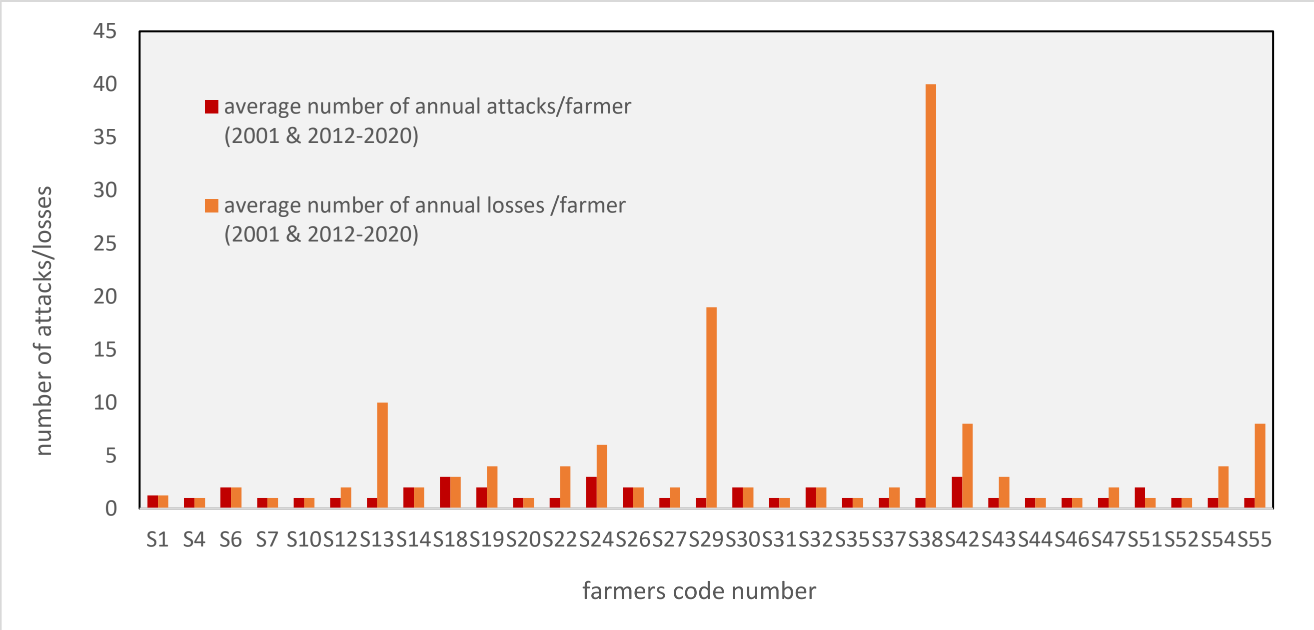
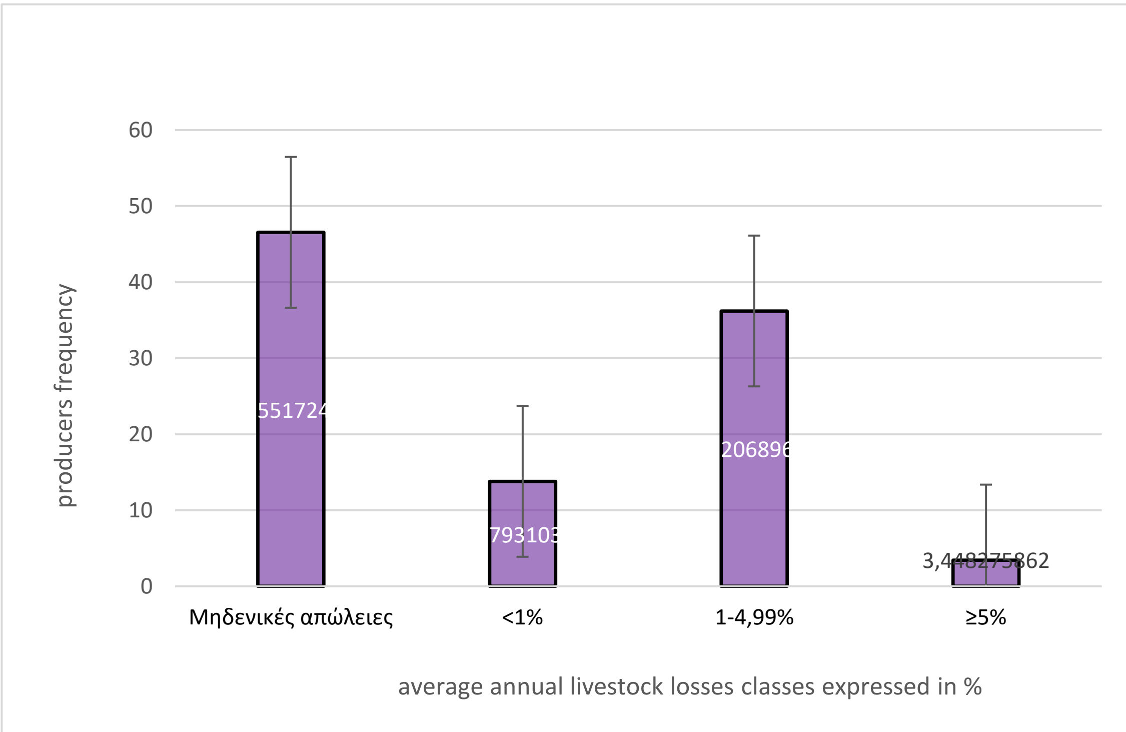


fig 20. Average annual bear attacks and livestock losses for interviewed livestock raisers (n=58)

Figure 21 shows that a percentage of 3.45% of livestock breeders suffer losses which correspond to numbers higher than or equal to 5% of the total livestock capital by producer. The majority percentage of producers (46.55%) reported zero losses, followed by 36.21% of producers with losses ranging between 1 - 4.99%.
Of all the livestock species, the cattle herds present the highest losses, which is logical as cattle represents the largest percentage of livestock exploitation type in the area of RMNP. This can be also crosschecked from the proportion of livestock farms in the sample, 72% of producers are engaged in cattle breeding (while the remaining 28% run other types of livestock farms/holdings).

Fig. 21: Average annual livestock losses per interviewed livestock breeder (n=58)



- **Bear Attacks on apiaries**

Twenty-two (22) beekeepers were interviewed during the questionnaire survey in RMNP, (3) of which had small sized beekeeping units (~25 beehives) while the rest had larger units ranging to > 1000 beehives. Only 2 out of 22 beekeepers declared a sedentary status (non-transhumant) while all the rest follow seasonal movements following the blossoming periods. Of the 22 interviewed beekeepers, fifteen (15) suffered bear damage while the remaining 17 did not (fig. 22).

According to the Livestock Insurance Regulation of ELGA (Government Gazette 1669 / B / 27-7-2011) the bee swarms are compensated following damage due to natural causes with a minimum threshold of five (5) bee swarms. In addition to the damage to the bee swarms, the partial or total destruction of the beehive box is also equally considered as part of the damage and therefore fully compensated as well. (art. 6 par. 1a of the same Government Gazette).

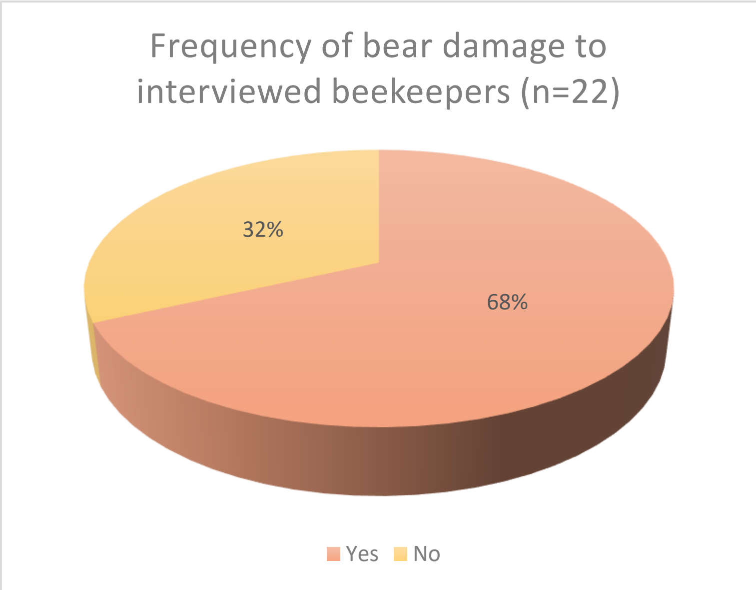


Fig.22: Frequency of bear damage to beehives among the surveyed beekeepers (n=22)

- **Farmers attitudes towards national damage compensation system**.

In general, based on the questionnaires outcome, there is a general dissatisfaction on behalf of farmers regarding the operation of ELGA and more specifically regarding the compensation procedure and criteria. This outcome is depicted in fig. 23 showing that the largest percentage of interviewed producers (47%), are not satisfied with the way ELGA operates whereas 24% did not give a concrete answer, and 21% feel moderate satisfaction in relation to the aforementioned institution and just 9% of all producers (mainly livestock breeders) expressed a moderate satisfaction attitude with the exception of just one who was fully positive.

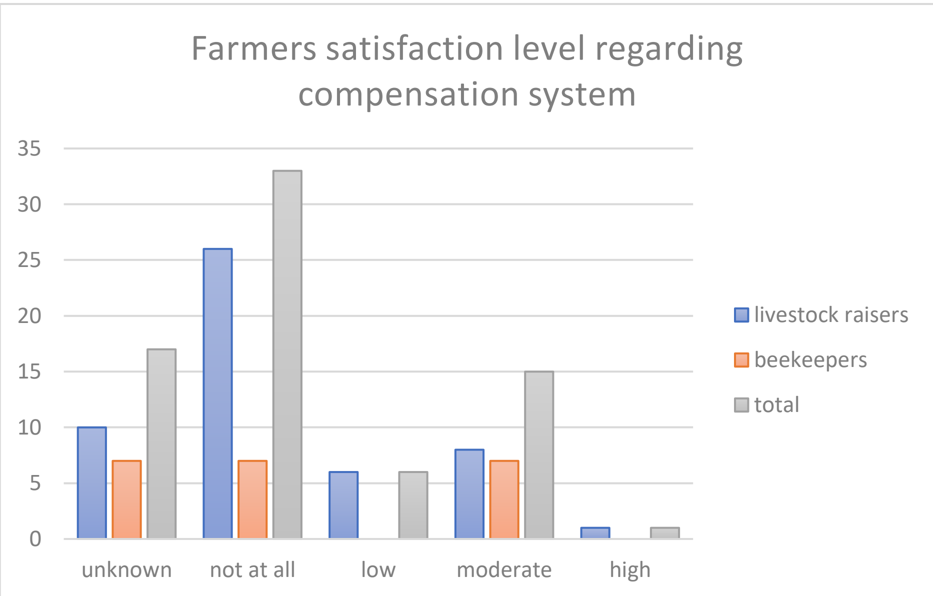
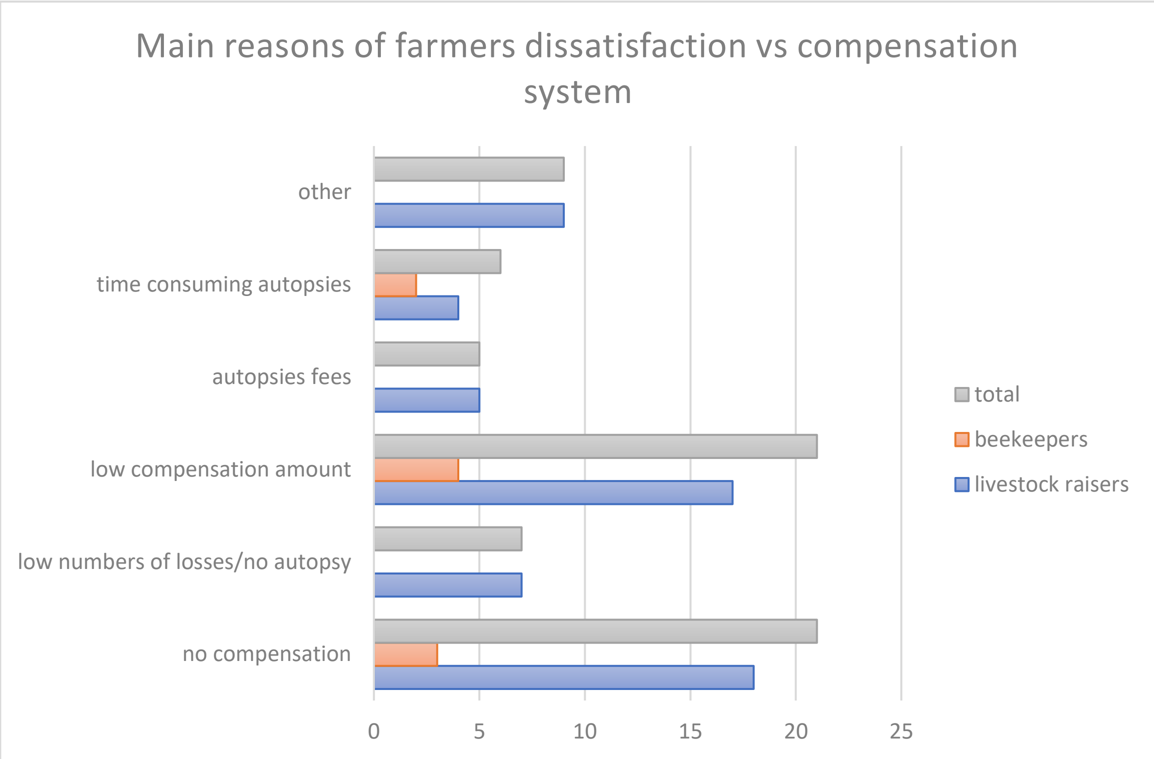


Fig.23: Farmers attitudes towards national damage compensation system,

The main reasons for this dissatisfaction are shown in fig. 24. The largest percentage of dissatisfaction in mainly wrongly related to the fact/farmers perception that ELGA does not compensate at all. Dissatisfaction still persists even in the case of effective compensation because of the small compensation amount. Some of the reasons for non-compensation from ELGA as recorded from the collected testimonies through the questionnaires are related a) to the young age of the depredated livestock b) to non-eligible age categories c) if the depredated animal is found days later and has been eaten by dogs, c) to the fact that the animal is not found in one piece d) to causes of death other than disease or wildlife attack e) to the official deadline is (48h after the damage) expiration f) to the producer's lack of insurance fees payment g) to total losses that exceed annual threshold.

Fig. 24: Main categories of dissatisfaction reasons among all farmers categories vs the current damage compensation system.



- **Protection measures**

Taking appropriate measures to guard and protect the herd is the only way to avoid the negative effects of wildlife attacks, especially bears, on livestock and the consequent escalation of the conflict between producers and wildlife. Questionnaires dissemination allowed the collection of important information on preventive and proactive measures used by the producers in the RMNP area, which can be briefly described as follows:

- **Herd surveillance**

Guarding and monitoring of the herd is one of the traditional and most effective ways to protect the herd. The intensity of custody-supervision depends on local conditions and needs of livestock farms. The vast majority of holdings (52.59%) are constantly supervised during grazing either by the owner of the livestock unit or by a relative or hired shepherd, 31.90% keep the herd occasionally in the pasture, 7.76 % of producers keep their herd only in the sheepfold while only a small percentage of 3.45% choose the constant surveillance of the herd both in the sheepfold and in the grazing by a third person. The largest percentage of producers (56.90%) choose 2 persons to guard the herd the flock. It is followed by a 22.41%

employing 3 people in custody, 10% of the livestock breeders choosing 1-2 people for flock surveillance and the remaining 10% chose from 3 to 5 persons for flock surveillance.

- **Animal overnight: Type of installation - surveillance**

According to the interviewed producers in order to protect their livestock flock during the nigh hours, they gather them either in stables or in makeshift facilities or only inside fenced areas. Both in winter and summer most producers chose stables for the flocks overnight. Only in summer, in case a stable is not available, a larger percentage of producers prefer either to avoid animals overnight outdoors or to use a temporary facility.

Of the fences used for keeping livestock gathered overnight in winter, there is a higher preference to be kept in yards, while in summer in more makeshift facilities. While there is not much seasonal difference between summer and winter regarding the stay of breeders with their animals overnight, the overnight supervision of livestock is preferred to be done by their owners. The only difference observed is that in summer season a larger percentage of producers loosen the overnight surveillance and leave the animals unattended.

Regarding the overnight stay of the animals outside the premises, a practice that usually concerns the calves, the results showed that the largest percentage of producers, especially in winter, does not follow this practice and stables their animals normally. The percentages vary in the summer when the percentage of producers who will leave small animals out of the premises increases.

- **Disposal of dead livestock**

Breeders have traditionally disposed of dead livestock by dumping them outdoors, a common practice that is often used even today. Dead animals have long been a major part of the diet of many predators, birds and carnivores. Currently and mainly for public health reasons, the common practice is to remove and bury or burn the corpses, thus reducing the chances of attracting predators.
According to the results of the interviews, the producers in a larger percentage choose the burial of the corpses (50%). This is followed by the burning of animals at a rate of 26% and this is helped by the "Program for collection and management of productive animals" which is promoted in the region of Eastern Macedonia and Thrace, without financial burden to producers. A percentage of 16% choose to feed the dead animal to their dogs, 14% discard the animals outside the stable, in the pasture, while a very small percentage of 2% discard the dead animals in streams.

- **Use of Livestock guarding dogs (LGDs)**

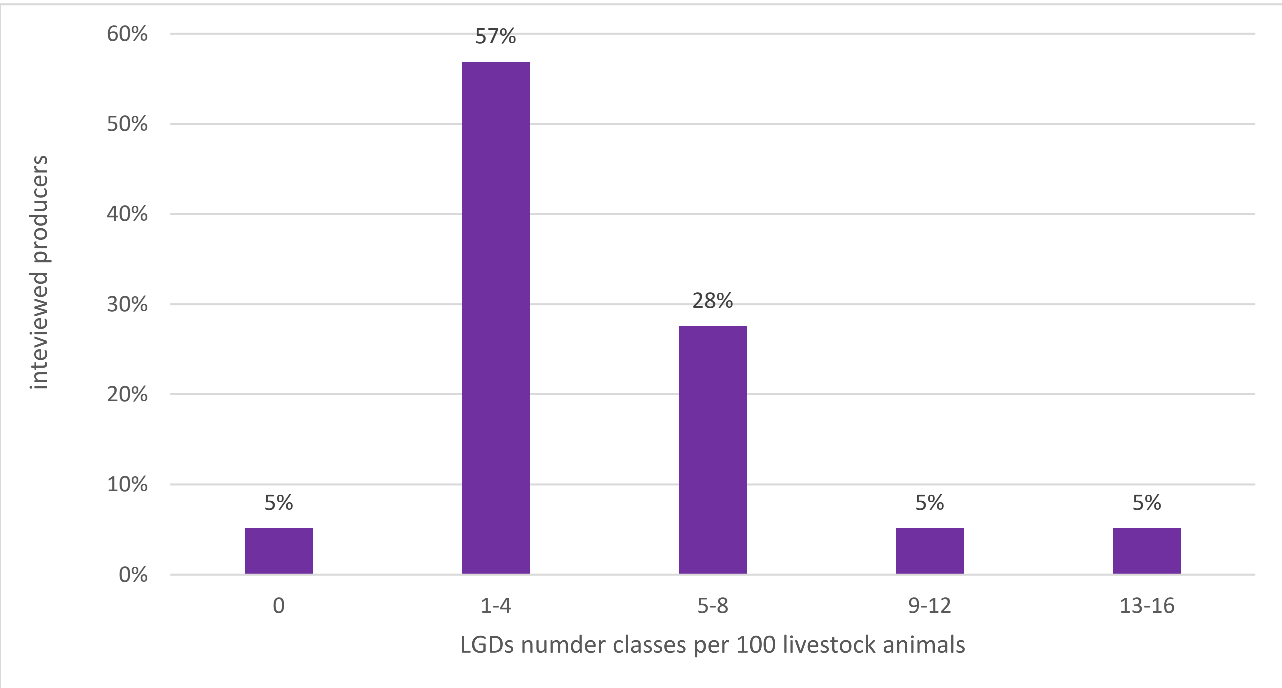
Livestock guarding dogs (photos 7 & 8) are one of the most important preventive measures against attacks by large carnivores. Of the total producers, only three do not have dogs to protect their animals, while one did not answer the question. Based on the data collected through the interviews, the number of LGDs / livestock unit was estimated as: a) absolute number of LGDs, b) number of LGDs per 100 livestock, and c) number of LGDs per animal unit. Table 14 shows the number of LGDs / livestock holding for all types of holdings.

Type of farming		LGDs numbers/holding	LGDs number /100 livestock animals	LGDs number/animal unit (AU)
Total holdings (v=58)	Min	0	0	0
	Max	30	16	0,39
	average	7,36	5	0,09

Table 14. number of LGDs / livestock holding for all types of holdings.

Photos 7 & 8: two different types opf LGDs from the traditional breeds in RMNP.

Figure 21 shows that the largest percentage of producers own from 1-4 LGDs per 100 livestock animals for the effective protection of their flocks from large carnivores' attacks.



Of the total 425 LGDs available to the interviewed breeders, the largest percentage are male animals (Figure 22). It is a general preference of breeders due to the perception that they are more focused on their duties which is the protection and surveillance of the herd. This is probably due to the fact that females in a possible pregnancy will need to abstain from their activities for as long as the puppies need to be raised. Also worrying is the fact that breeders have only a small percentage (4%) of puppies, which makes the herd guarding system unsafe, as in a possible mass poisoning of the breeder's LGDs they have little alternatives with younger ones to fill the gap.

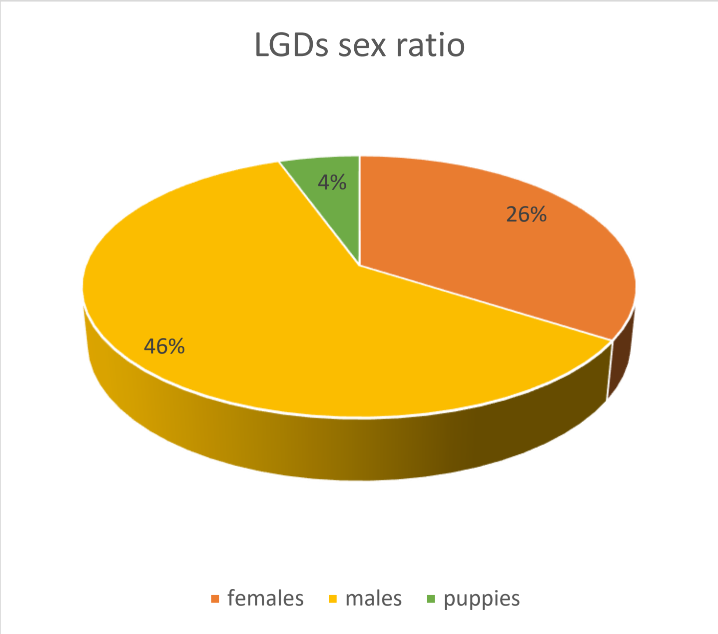
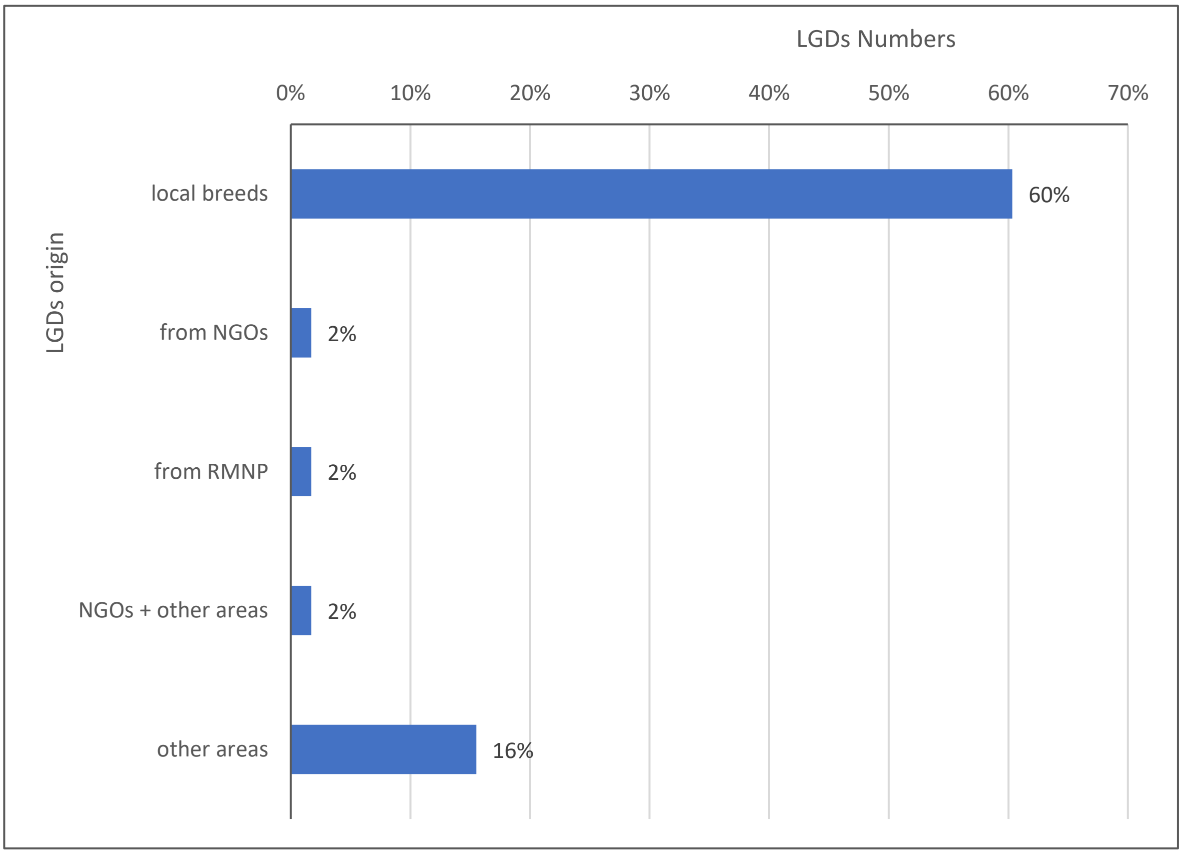


Fig. 22: LGDs Sex ratio among the surveyed livestock raisers.

The interviewed producers use LGDs from different origins (fig. 23). The largest percentage of producers (60%) use local LGDs breeds (traditional) which probably has to do with the fact that in this way breeders are more confident about the breeders of the puppies they receive and therefore the genetic, phenotypic and behavioral characteristics of their LGDs when they grow up and become operational. A smaller percentage of LGD's breeds comes from other parts of Greece.

Fig 23: LGDs breeds origins among the interviewed livestock raisers in RMNP (n=58)

- **Losses of herding dogs from poisoned baits**



One of the most serious problems that breeders face on top of livestock animal losses from diseases, wildlife attacks or other causes, is the loss of their LGDs from the use of poisoned baits (PB). The percentage of stockbreeders who have experienced incidents of PB use with LGDs victims in their herds represents half of the interviewed livestock raisers (52%) a fact that shows how the problem remains serious.

The motives and causes that drive the use of poisoned baits are not clear and cannot always be elucidated. A large percentage remains unknown (45%). In the recorded cases, a large percentage is also motivated by the extermination of competing species and local conflicts (with hunters, loggers, etc.) (~12% both incentive categories). Other motives that have been recorded are the extermination of stray dogs, the use of pesticides, etc.

Of the 58 breeders interviewed, only five knew the type of poison used (offal, pieces of meat, sausage, paraffin capsules with cyanide, meat with glasses and offal). The majority was unaware of the types of baits used illegally.
It is noteworthy that based on the outcome from the report on the Status of Use of Poisoned Bait in the National Park of the Rhodope Mountain Range, for the period 2009-2020 prepared by the Management Authority of the Rhodope Mountains, together with data recorded in the year 2021, the losses of dogs are recorded at high numbers (> 115). These dogs include all categories: stray, LGDs and hounds.

- **Other preventive measures**

Regarding other preventive measures, breeders and beekeepers were asked for the use of additional preventive measures in addition to the more traditional ones (LGDs, overnight surveillance, fencing etc.).
The largest percentage of breeders (52%) do not use any other preventive measure, while among beekeepers the most common precautionary measure is electric fencing (77%).

Regarding the other categories of preventive measures mentioned by the interviewees are the following:

- electric fencing at a rate of 34% among all interviewed producers (breeders and beekeepers),
- certain types of lighting with deterring effects: 17% of all producers,
- radio sound used only by beekeepers (14%),
- propane cannon used only by 9% of breeders
- other types of shooting guns noise for intimidation used by only 3% of stockbreeders
- dogs other than LGDs (2%)
- and in one case breeder manufactured an improvised mechanism: an electric powered water cannon.

2.3. Creation of the GeoData base (UTH)

The different steps and stages for the Geo Data base elaboration are as follows.

- Definition and classification of the different information layers sourced from Corine Land Cover Classes (CLC) – at 3 levels (tables 15 and 16).

Table (15). CORINE Land Cover (CLC) classes-3 Level

CLC_CODE	LABEL1	LABEL2	LABEL3
111	Artificial surfaces	Urban fabric	Continuous urban fabric
112	Artificial surfaces	Urban fabric	Discontinuous urban fabric
121	Artificial surfaces	Industrial, commercial and transport units	Industrial or commercial units
122	Artificial surfaces	Industrial, commercial and transport units	Road and rail networks and associated land
123	Artificial surfaces	Industrial, commercial and transport units	Port areas
124	Artificial surfaces	Industrial, commercial and transport units	Airports
131	Artificial surfaces	Mine, dump and construction sites	Mineral extraction sites
132	Artificial surfaces	Mine, dump and construction sites	Dump sites
133	Artificial surfaces	Mine, dump and construction sites	Construction sites
141	Artificial surfaces	Artificial, non-agricultural vegetated areas	Green urban areas
142	Artificial surfaces	Artificial, non-agricultural vegetated areas	Sport and leisure facilities
211	Agricultural areas	Arable land	Non-irrigated arable land
212	Agricultural areas	Arable land	Permanently irrigated land
213	Agricultural areas	Arable land	Rice fields
221	Agricultural areas	Permanent crops	Vineyards
222	Agricultural areas	Permanent crops	Fruit trees and berry plantations
223	Agricultural areas	Permanent crops	Olive groves
231	Agricultural areas	Pastures	Pastures
241	Agricultural areas	Heterogeneous agricultural areas	Annual crops associated with permanent crops
242	Agricultural areas	Heterogeneous agricultural areas	Complex cultivation patterns
243	Agricultural areas	Heterogeneous agricultural areas	Land principally occupied by agriculture, with significant areas of natural vegetation
244	Agricultural areas	Heterogeneous agricultural areas	Agro-forestry areas
311	Forest and semi natural areas	Forests	Broad-leaved forest
312	Forest and semi natural areas	Forests	Coniferous forest
313	Forest and semi natural areas	Forests	Mixed forest
321	Forest and semi natural areas	Scrub and/or herbaceous vegetation associations	Natural grasslands

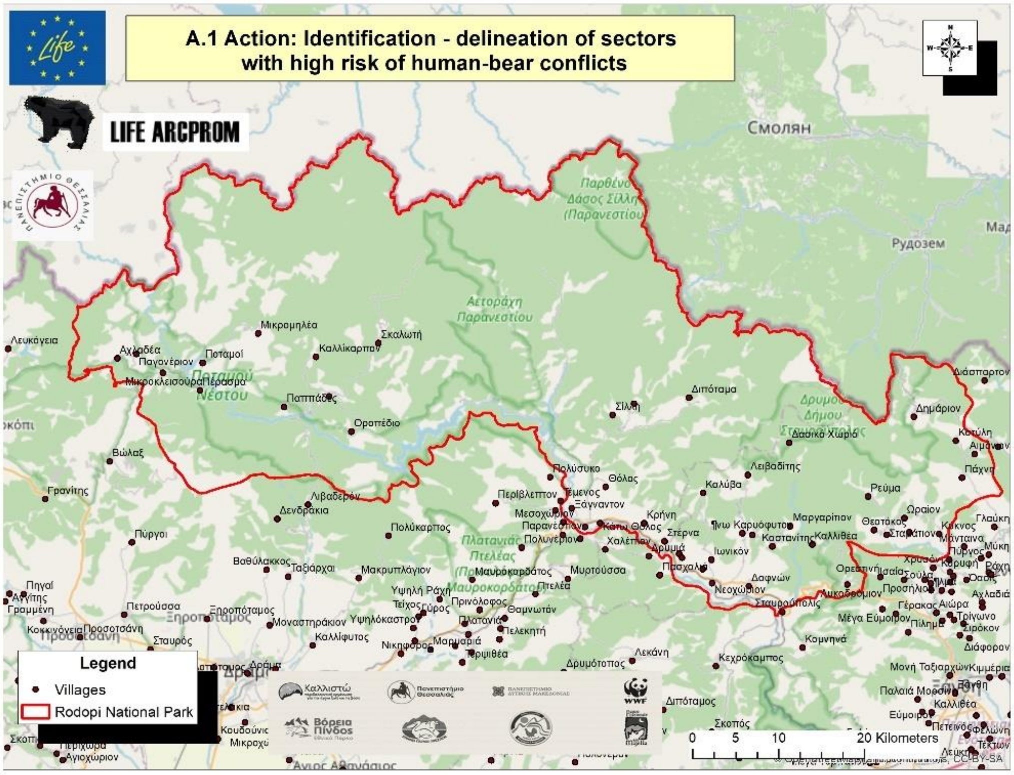
CLC_CODE	LABEL1	LABEL2	LABEL3
322	Forest and semi natural areas	Scrub and/or herbaceous vegetation associations	Moors and heathland
323	Forest and semi natural areas	Scrub and/or herbaceous vegetation associations	Sclerophyllous vegetation
324	Forest and semi natural areas	Scrub and/or herbaceous vegetation associations	Transitional woodland-shrub
331	Forest and semi natural areas	Open spaces with little or no vegetation	Beaches, dunes, sands
332	Forest and semi natural areas	Open spaces with little or no vegetation	Bare rocks
333	Forest and semi natural areas	Open spaces with little or no vegetation	Sparsely vegetated areas
334	Forest and semi natural areas	Open spaces with little or no vegetation	Burnt areas
335	Forest and semi natural areas	Open spaces with little or no vegetation	Glaciers and perpetual snow
411	Wetlands	Inland wetlands	Inland marshes
412	Wetlands	Inland wetlands	Peat bogs
421	Wetlands	Maritime wetlands	Salt marshes
422	Wetlands	Maritime wetlands	Salines
423	Wetlands	Maritime wetlands	Intertidal flats
511	Water bodies	Inland waters	Water courses
512	Water bodies	Inland waters	Water bodies
521	Water bodies	Marine waters	Coastal lagoons
522	Water bodies	Marine waters	Estuaries
523	Water bodies	Marine waters	Sea and ocean

Table (16). CORINE Land Cover (CLC) classes

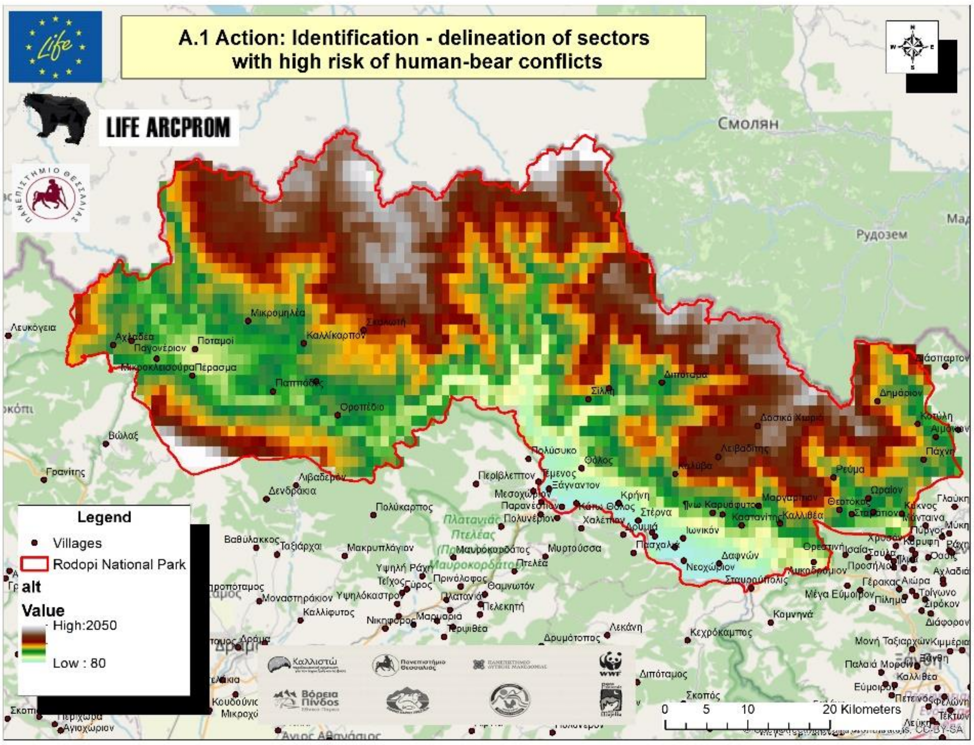
Value	LABEL3	CODE_18
1	Continuous urban fabric	111
2	Discontinuous urban fabric	112
3	Industrial or commercial units	121
4	Road and rail networks and associated land	122
5	Port areas	123
6	Airports	124
7	Mineral extraction sites	131
8	Dump sites	132
9	Construction sites	133
10	Green urban areas	141
11	Sport and leisure facilities	142
12	Non-irrigated arable land	211
13	Permanently irrigated land	212
14	Rice fields	213

Value	LABEL3	CODE_18
15	Vineyards	221
16	Fruit trees and berry plantations	222
17	Olive groves	223
18	Pastures	231
19	Annual crops associated with permanent crops	241
20	Complex cultivation patterns	242
21	Land principally occupied by agriculture, with significant areas of natural vegetation	243
22	Agro-forestry areas	244
23	Broad-leaved forest	311
24	Coniferous forest	312
25	Mixed forest	313
26	Natural grasslands	321
27	Moors and heathland	322
28	Sclerophyllous vegetation	323
29	Transitional woodland-shrub	324
30	Beaches, dunes, sands	331
31	Bare rocks	332
32	Sparsely vegetated areas	333
33	Burnt areas	334
34	Glaciers and perpetual snow	335
35	Inland marshes	411
36	Peat bogs	412
37	Salt marshes	421
38	Salines	422
39	Intertidal flats	423
40	Water courses	511
41	Water bodies	512
42	Coastal lagoons	521
43	Estuaries	522
44	Sea and ocean	523

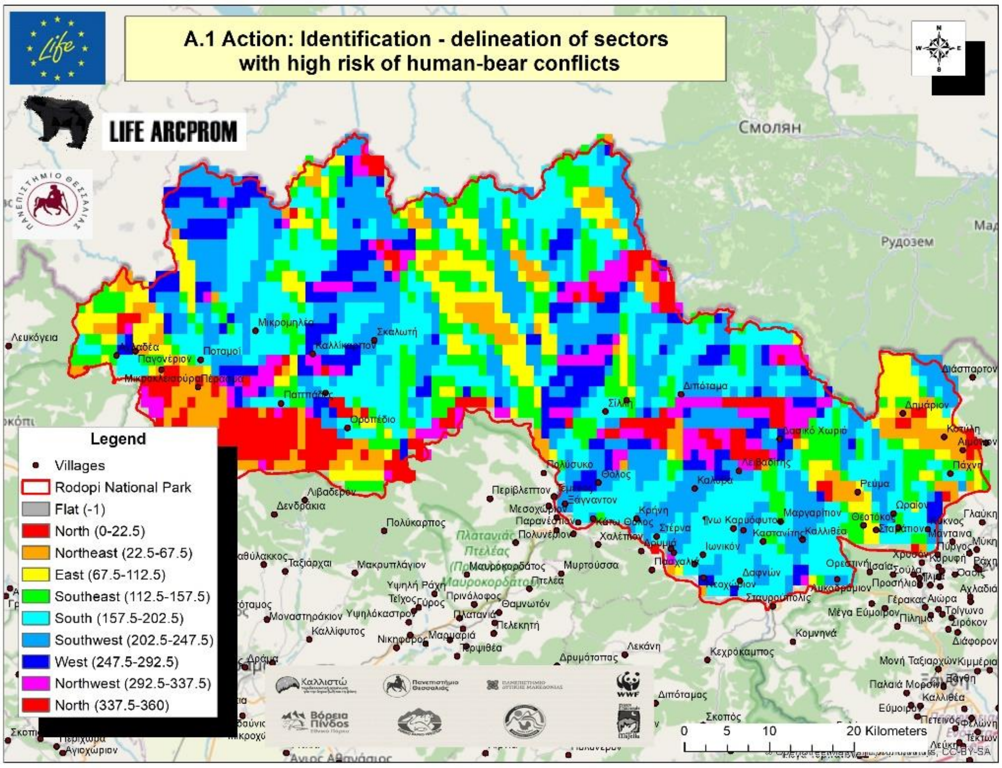
- GIS layers processing, storage in the Geo Data base and elaboration of the mapped and scored version of the selected environmental variables classification, necessary for the statistical analyses in Rodopi and Prespa National Parks project sub-areas (maps 2-14 for RMNP and 16-25 for MBPNP).



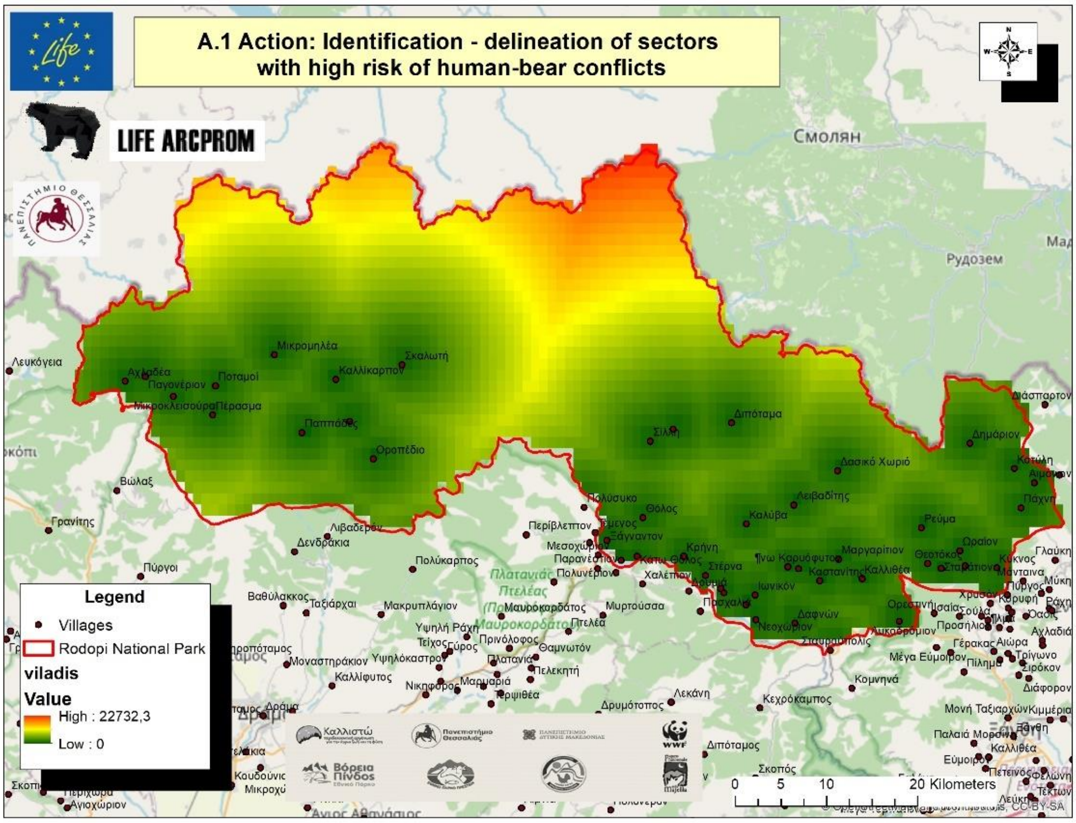
Map 1. Rodopi National Park area



Map 2. Elevation -altitude classification in RMNP

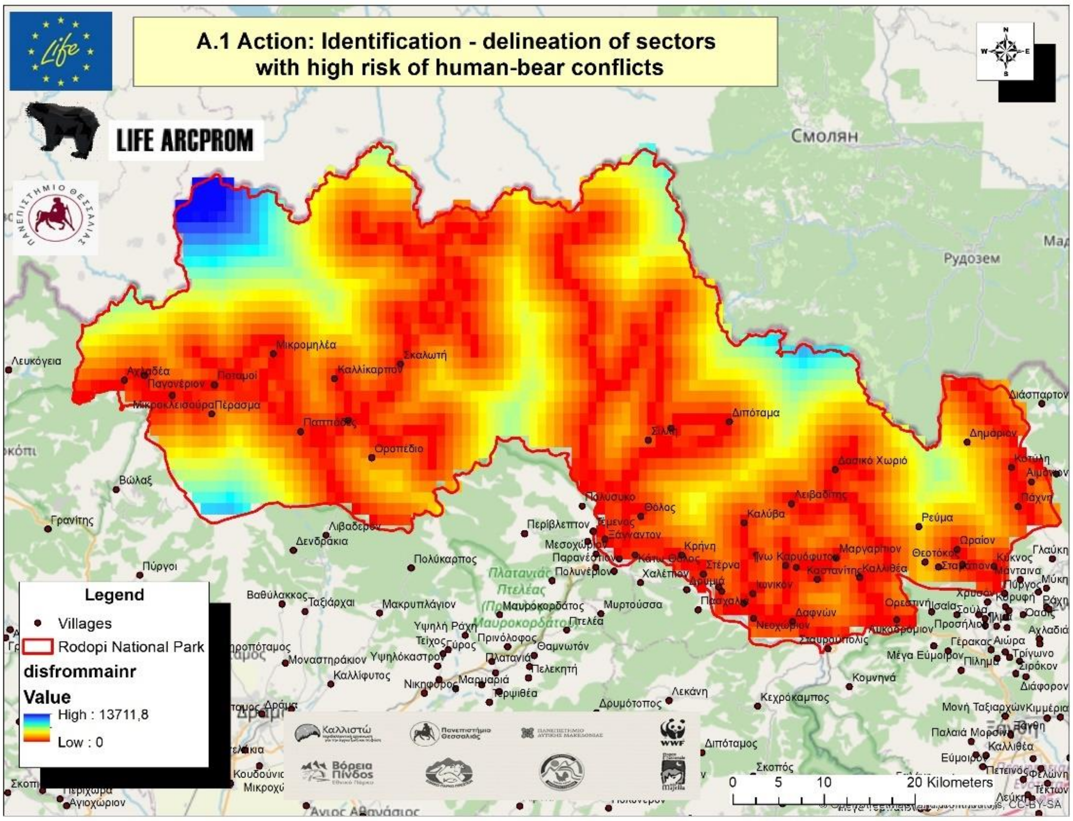


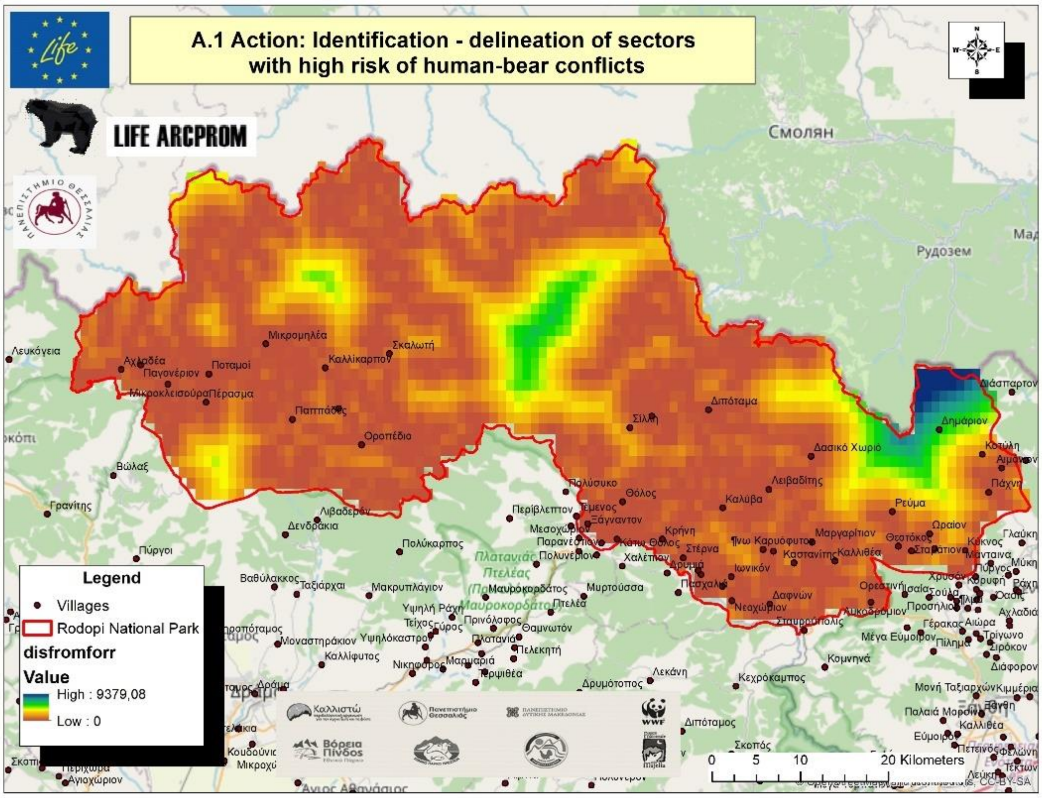
Map 3. Aspect classification in RMNP



Map 4. Distance from villages classification in RNMP

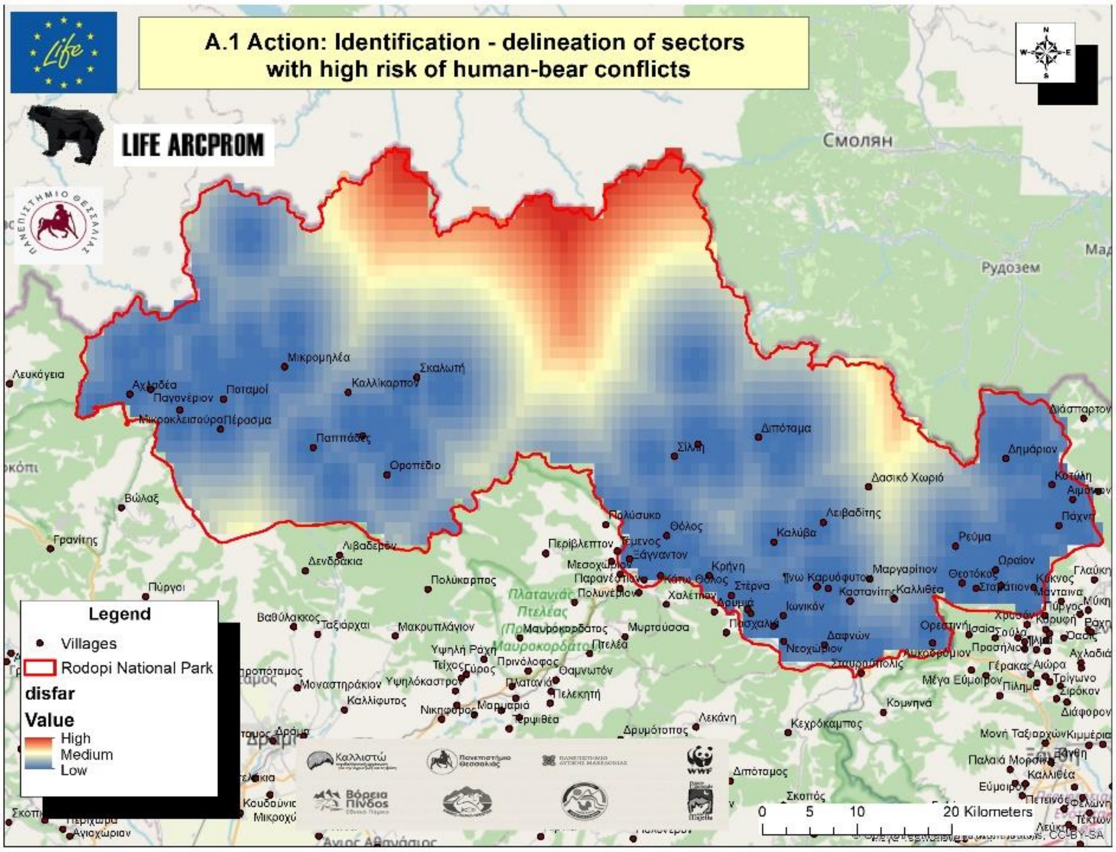
Map 5. Distance from main roads classification in RMNP

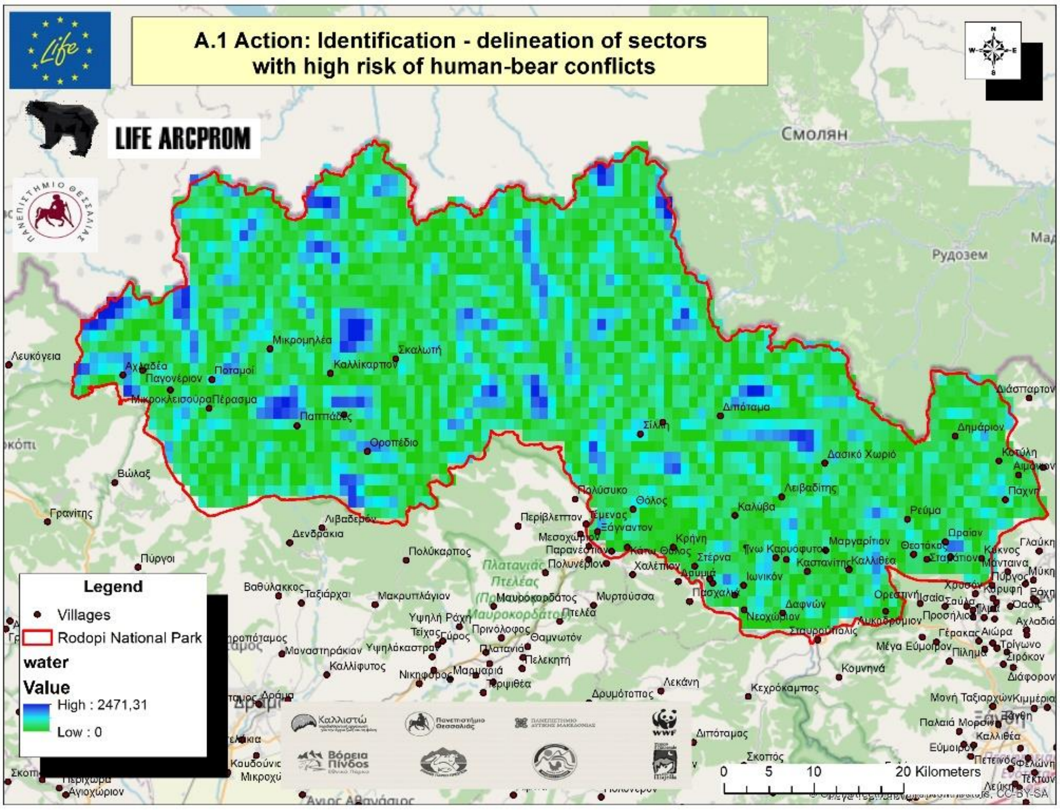




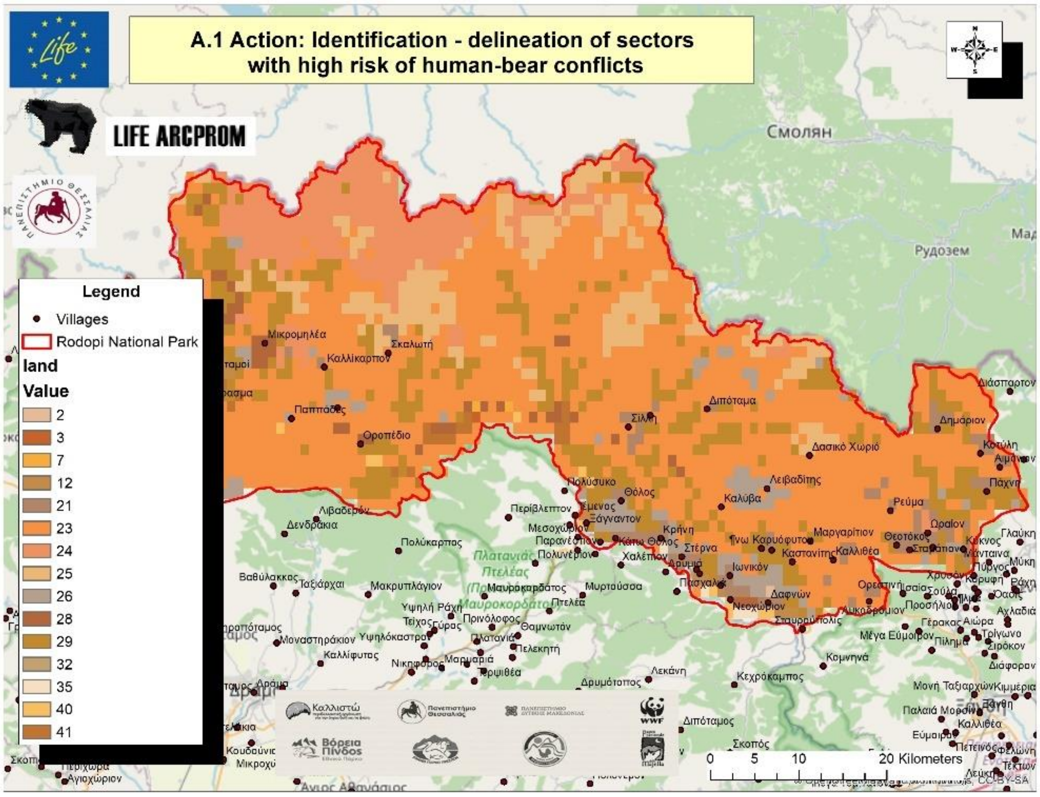
Map 6. Distance from forest roads classification in RNMP

Map 7. Distance from farms classification in RMNP



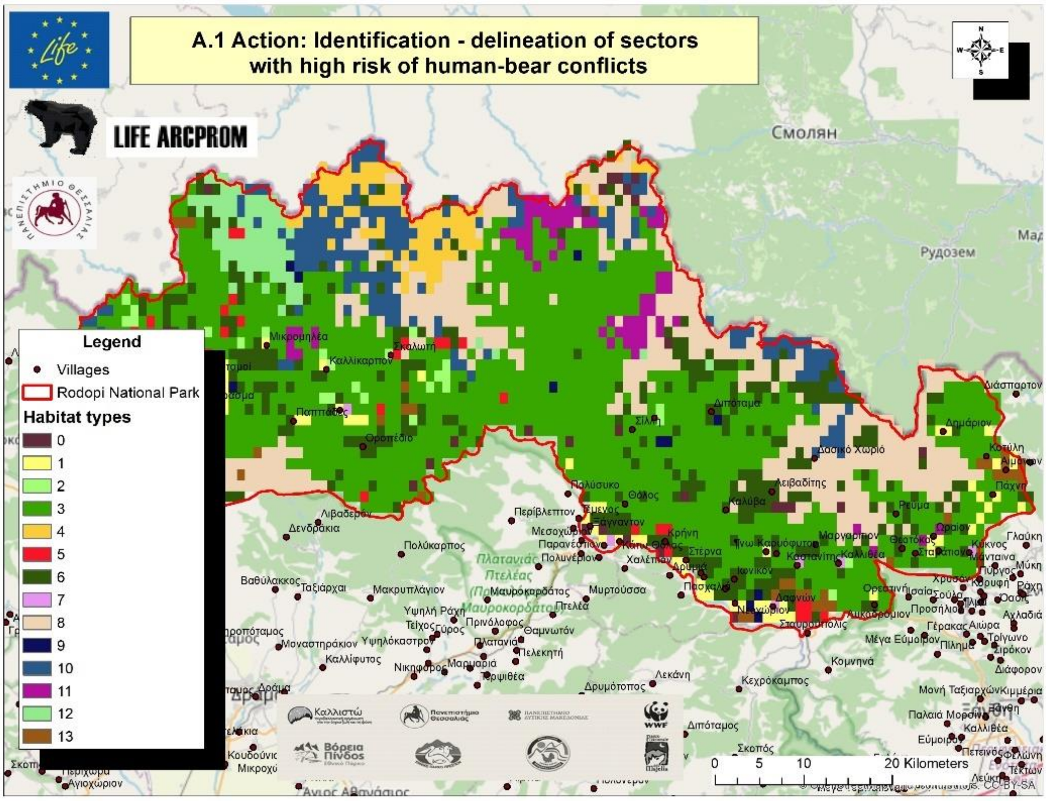


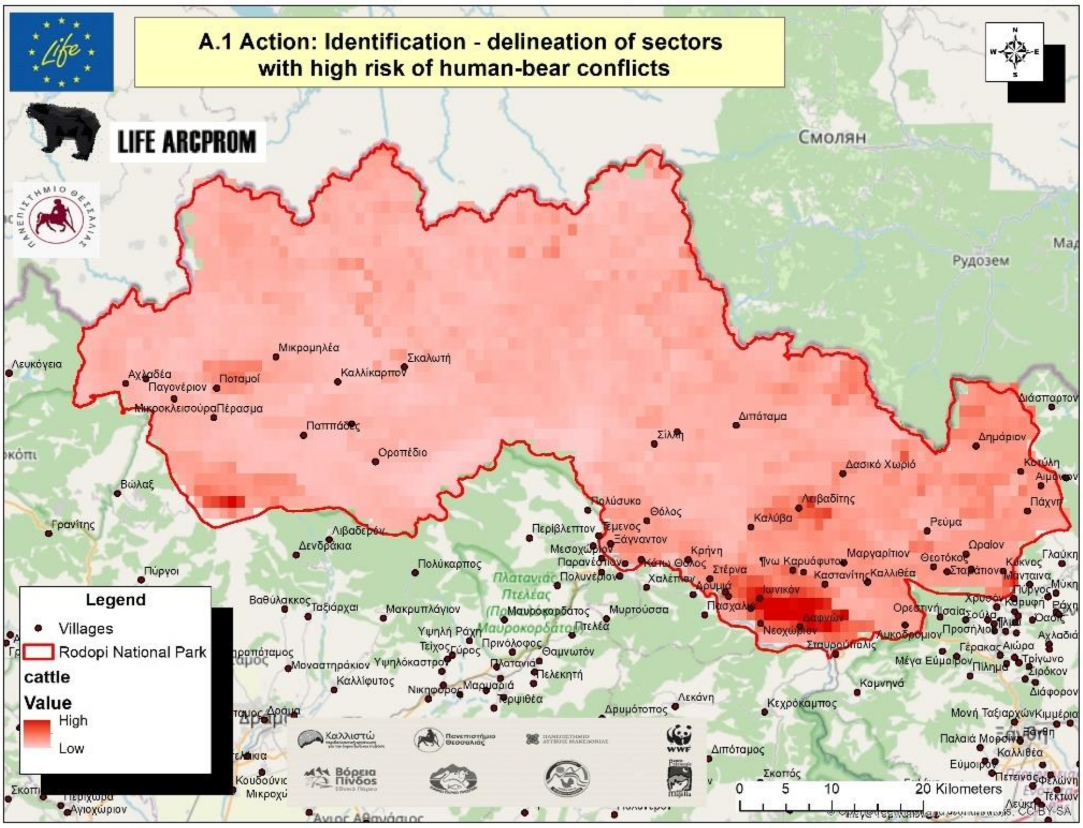
Map 8. Distance from rivers classification in RNMP



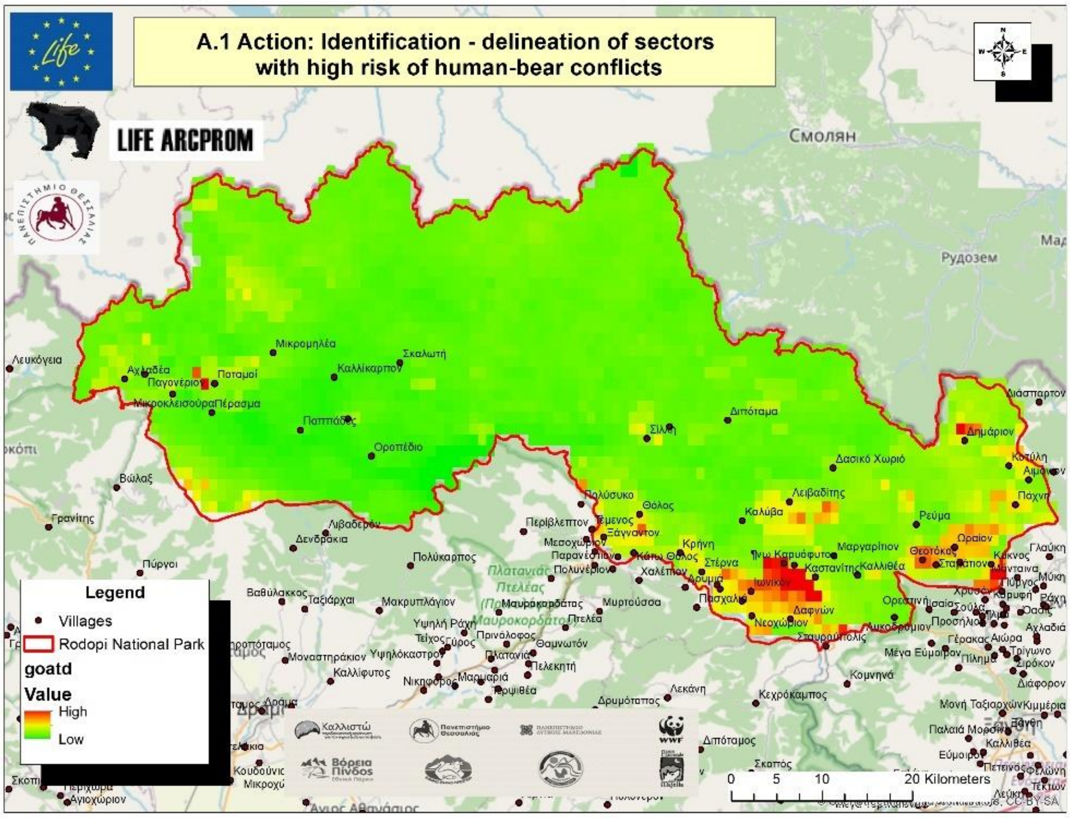
Map 9. CORINE Land Cover (CLC)-land uses-habitat types classification in RNMP

Map 10. Habitat/habitat types classification in RNMP

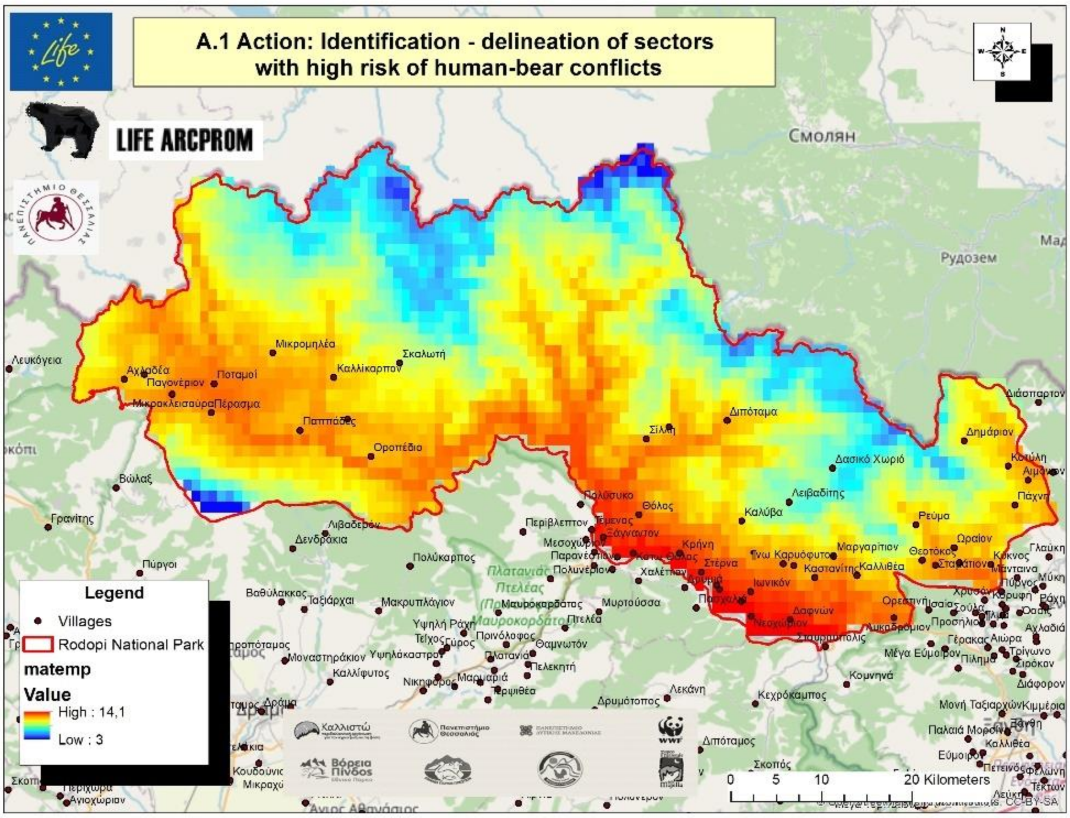




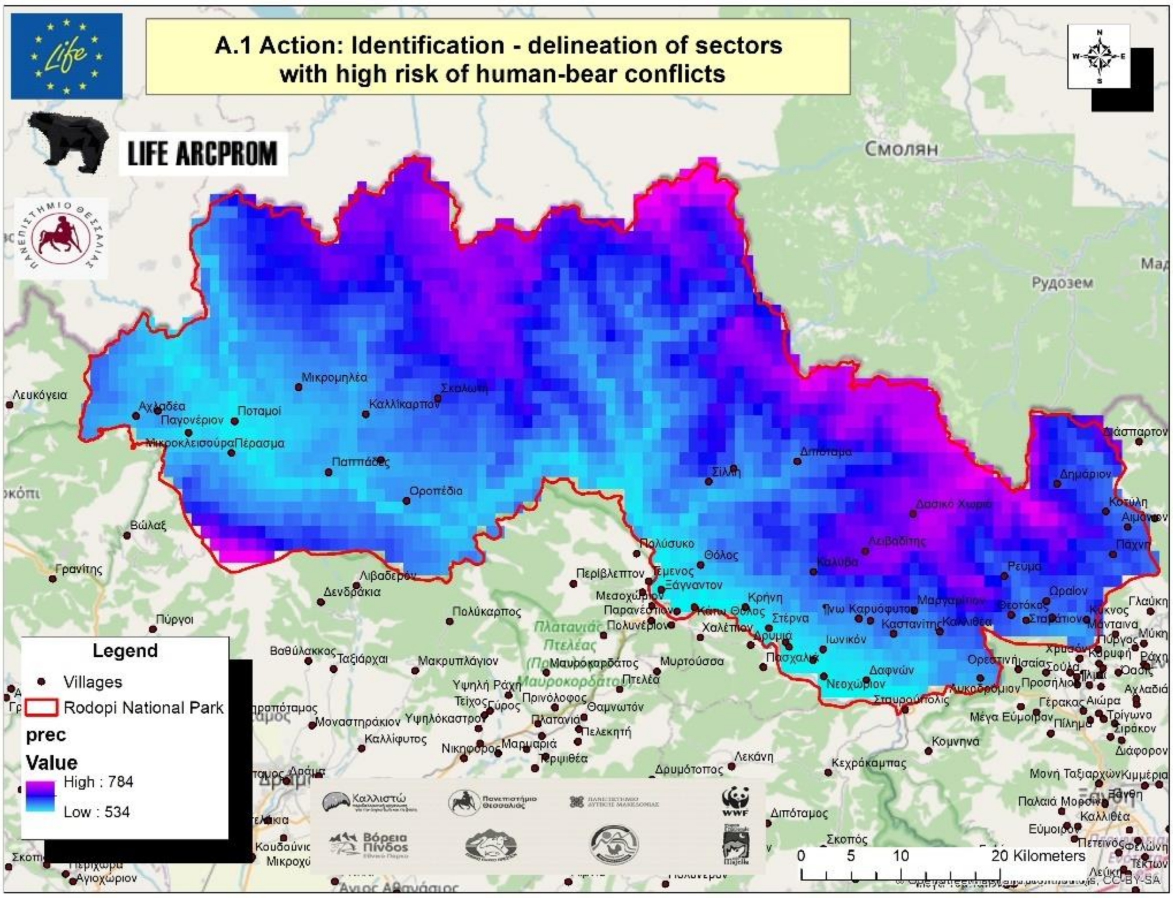
Map 11. Bovine-Cattle density classification in RNMP



Map 12. Goat flocks' density classification in RNMP

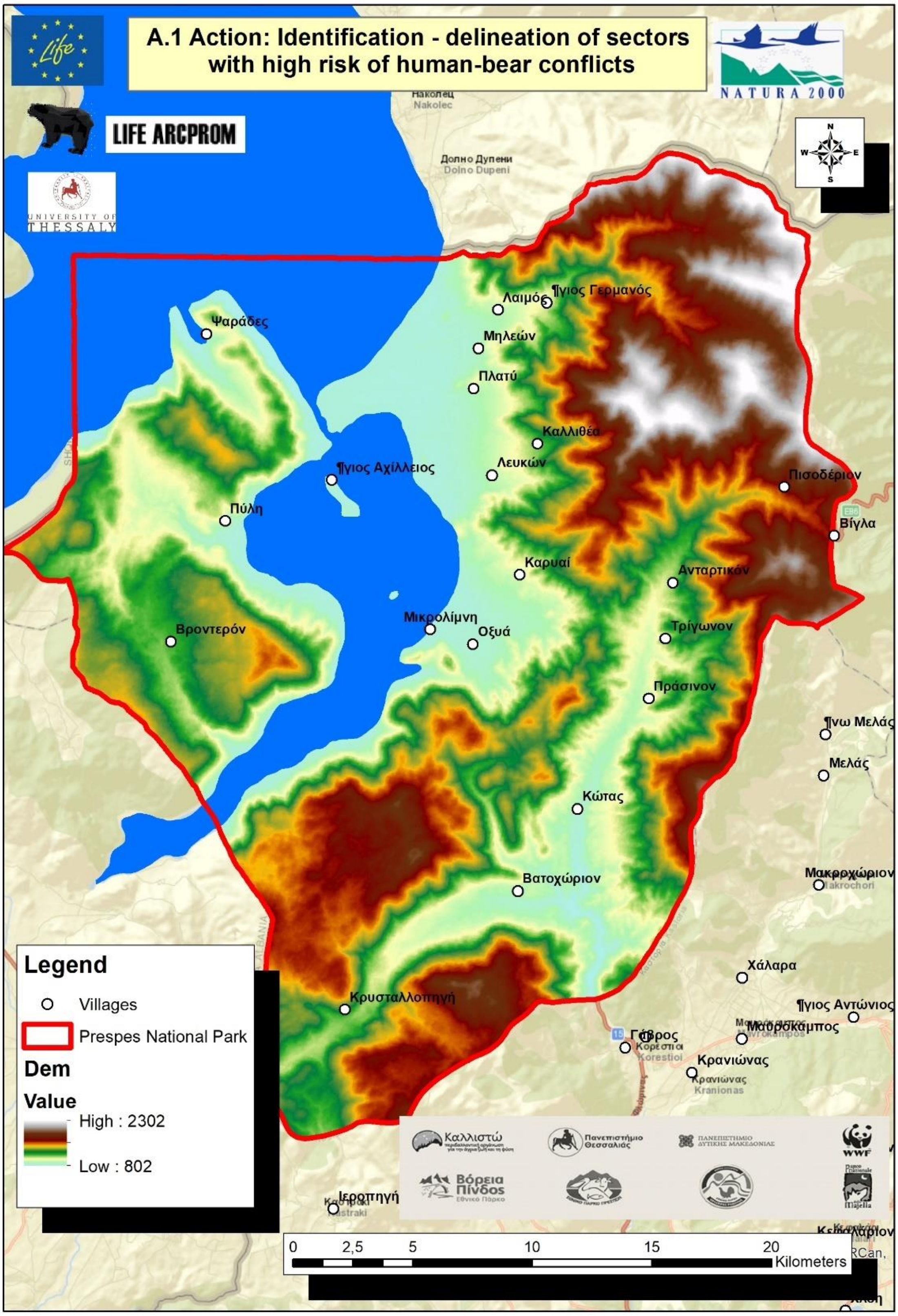


Map 13. Mean annual temperature classification in RNMP

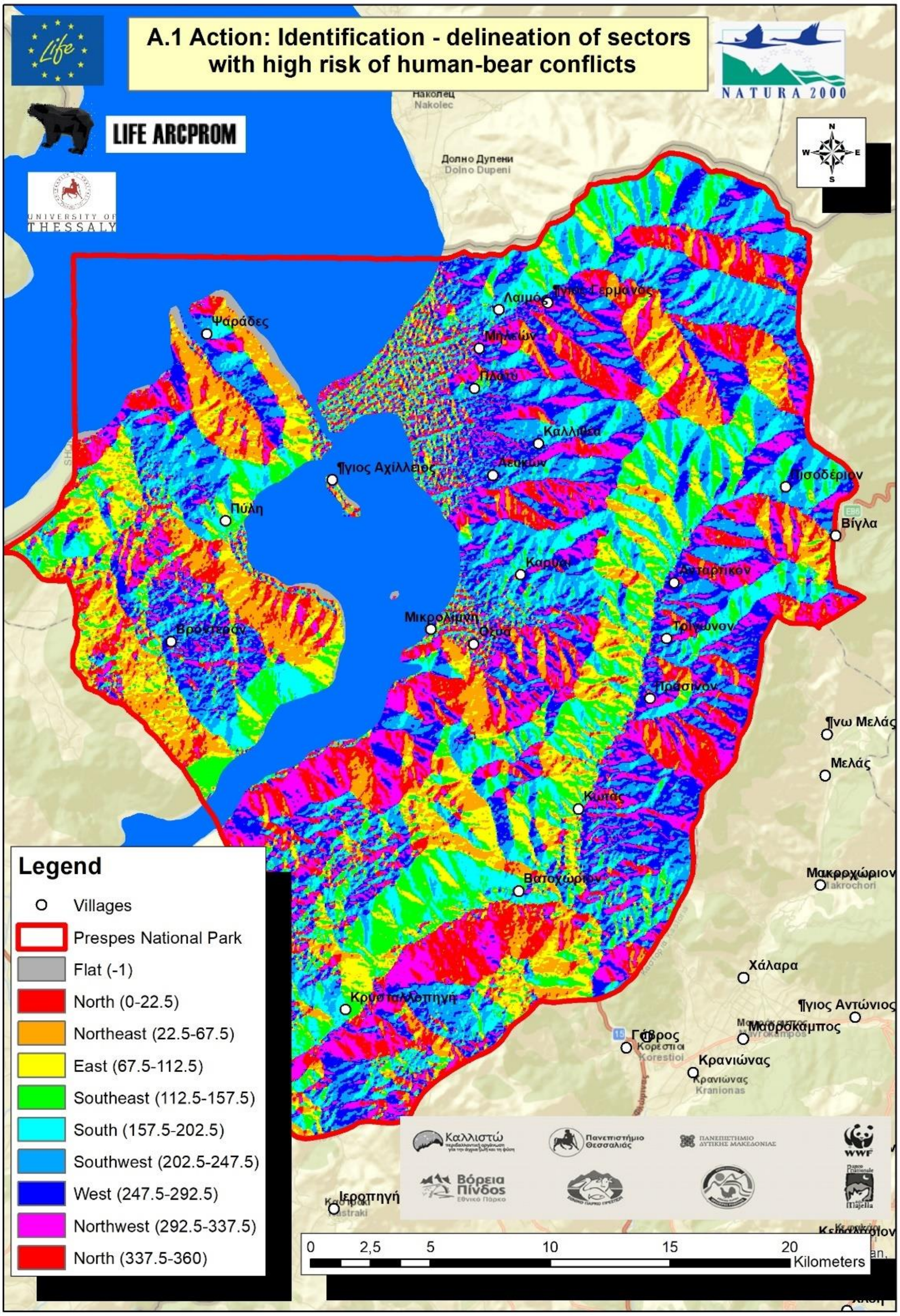


Map 14. Precipitation classification in RNMP

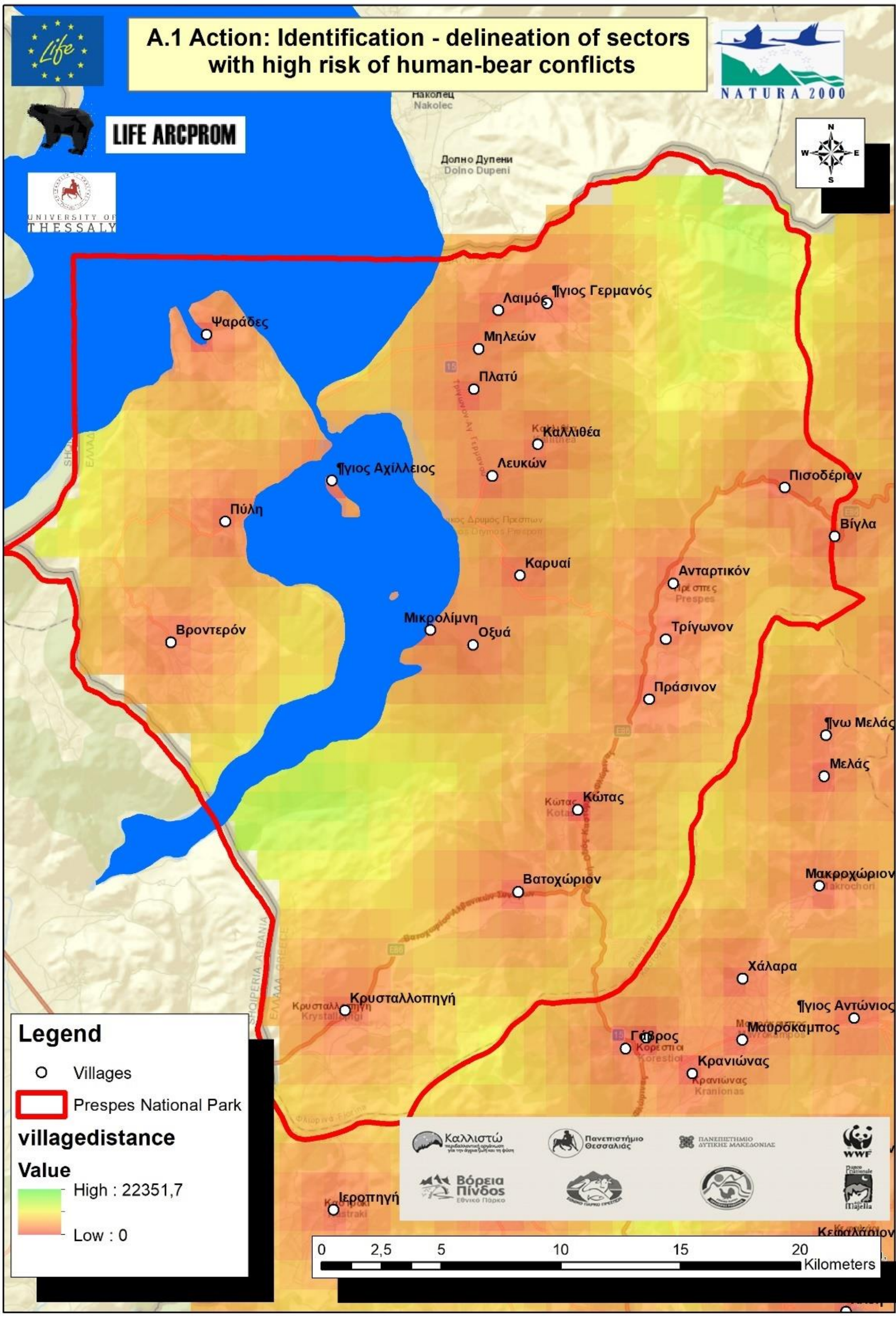
Map 15. Prespes National Park area



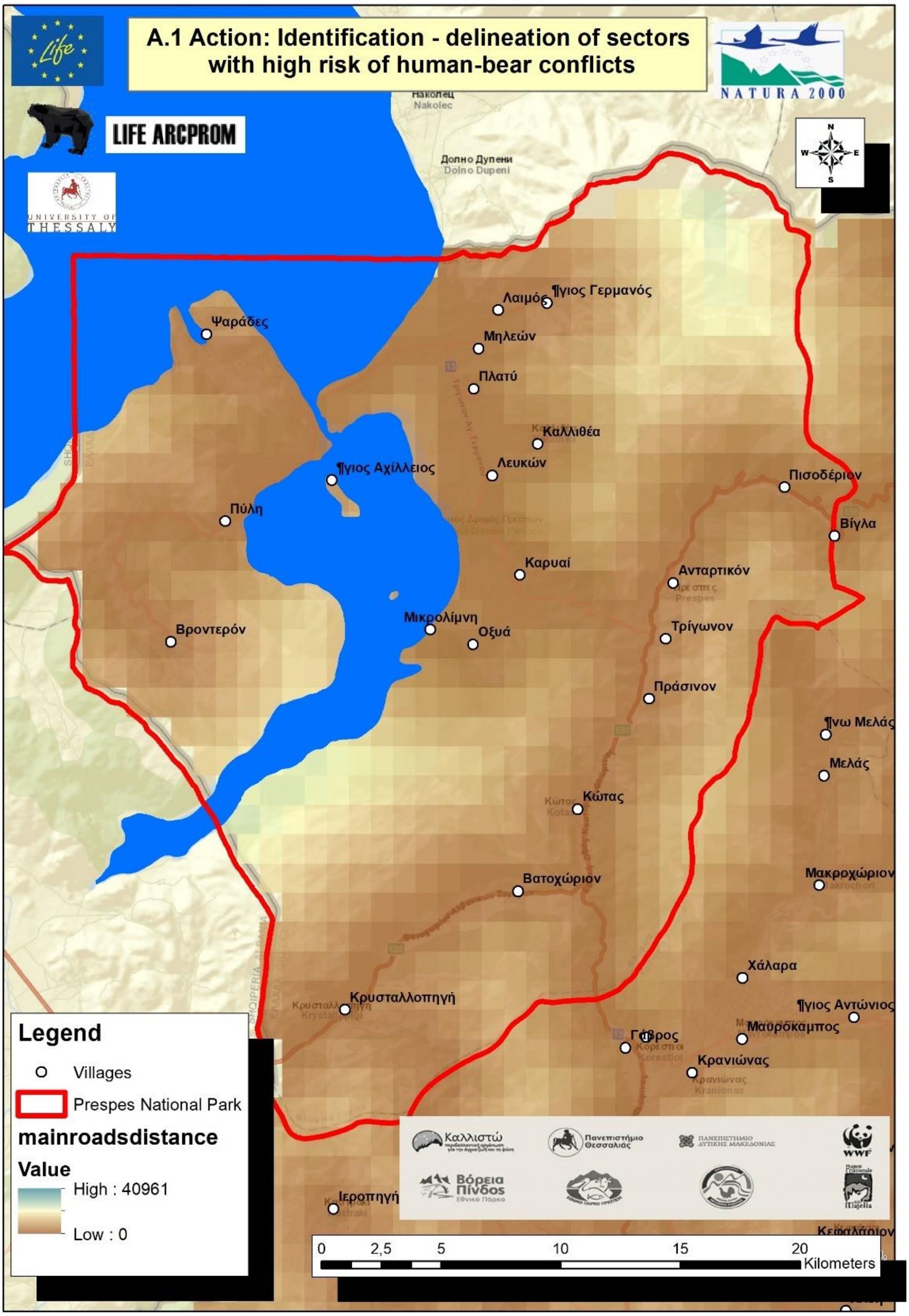
Map 16. Elevation -altitude classification in MBPNP



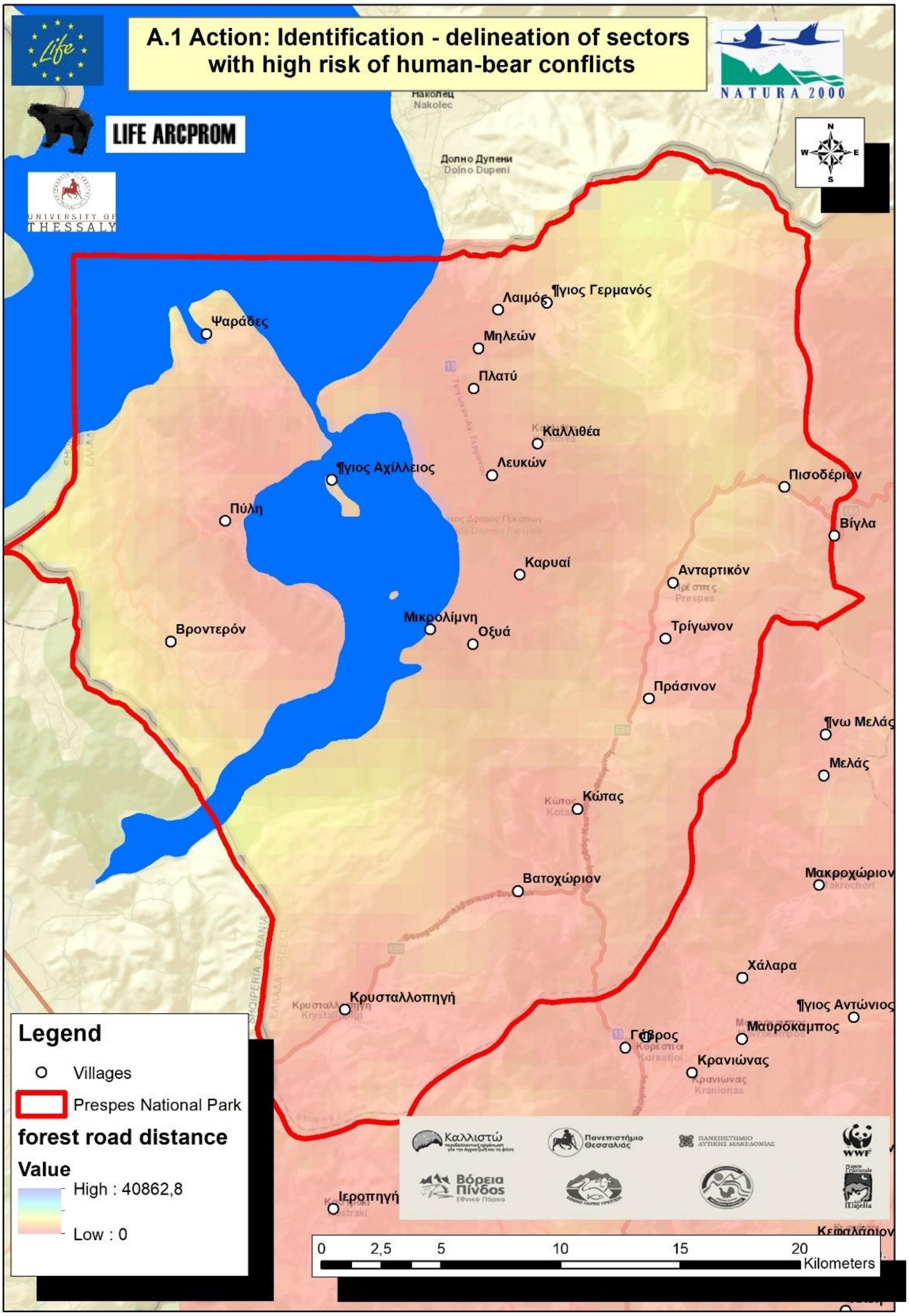
Map 17. Aspect classification in MBPNP



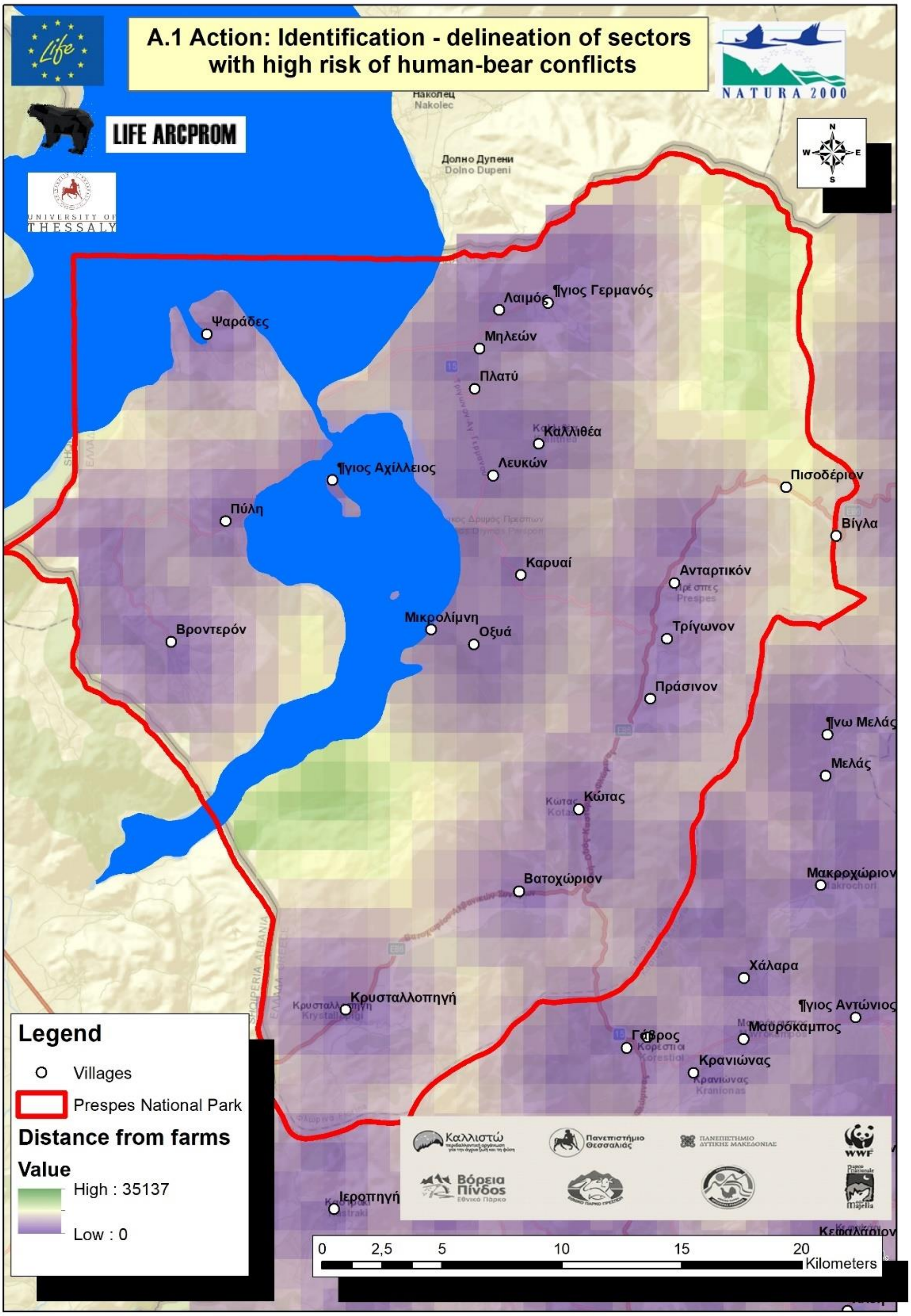
Map 18. Distance from villages classification in MBPNP



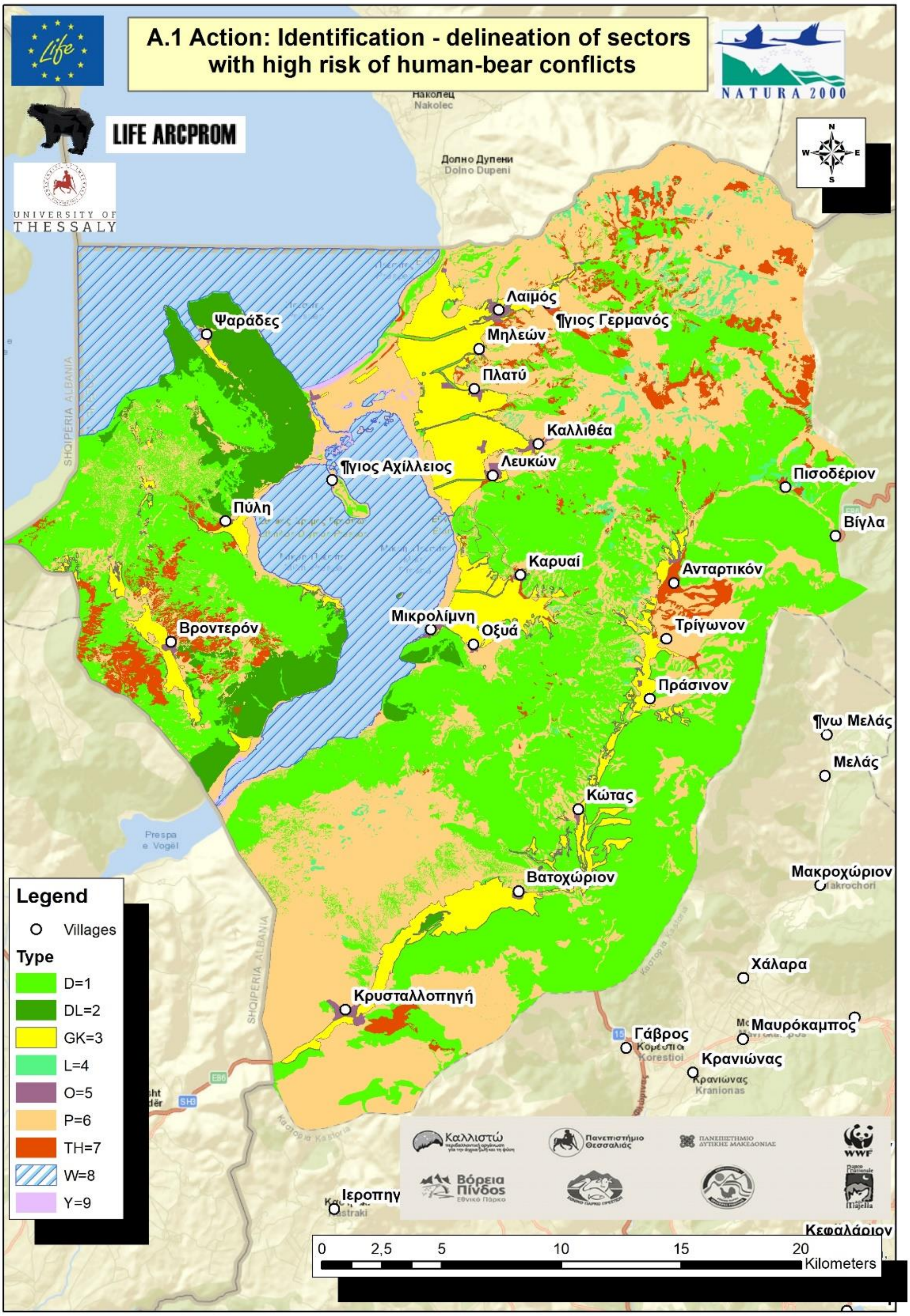
Map 19. Distance from main roads classification in MBPNP



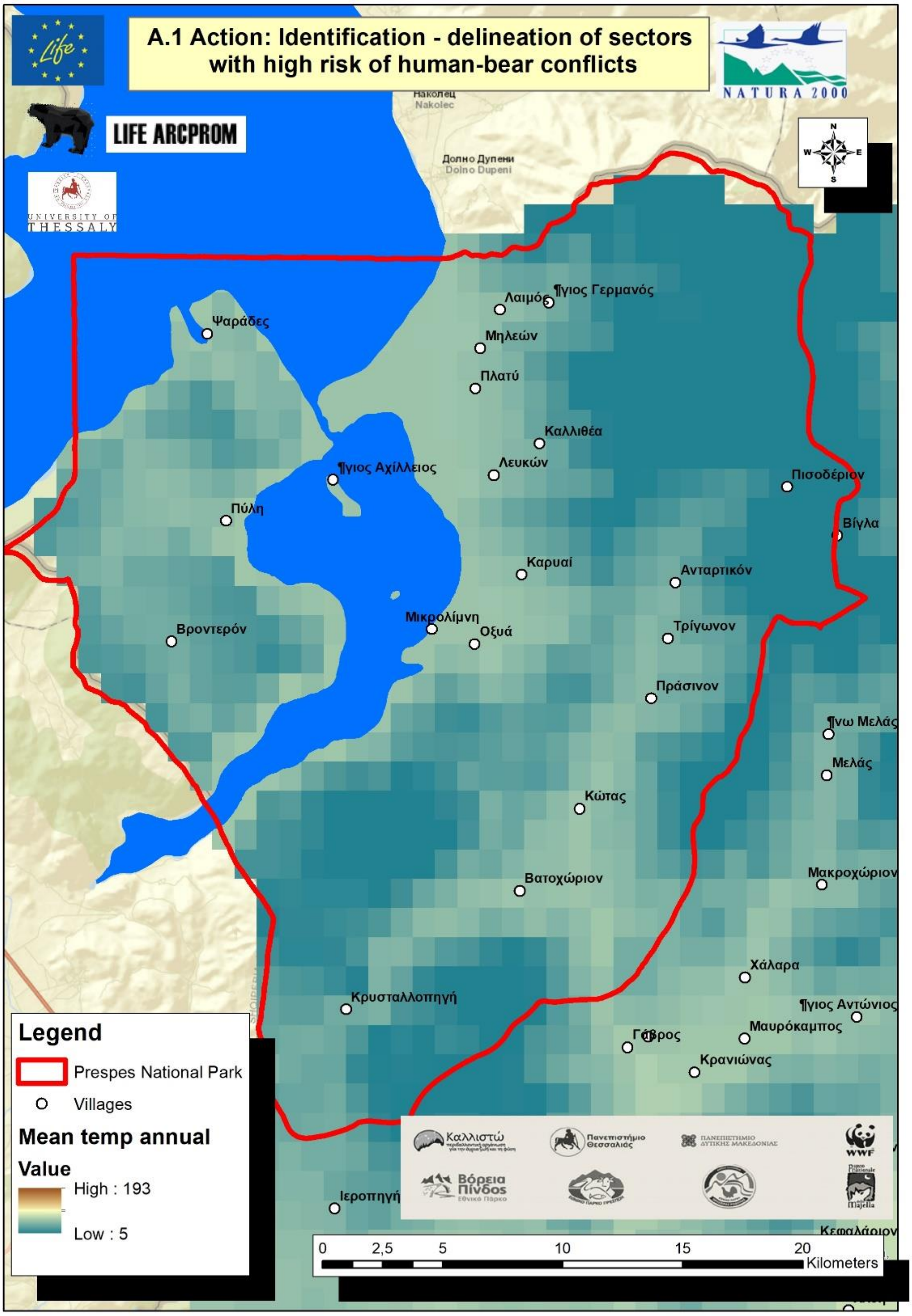
Map 20. Distance from forest roads classification in MBPNP



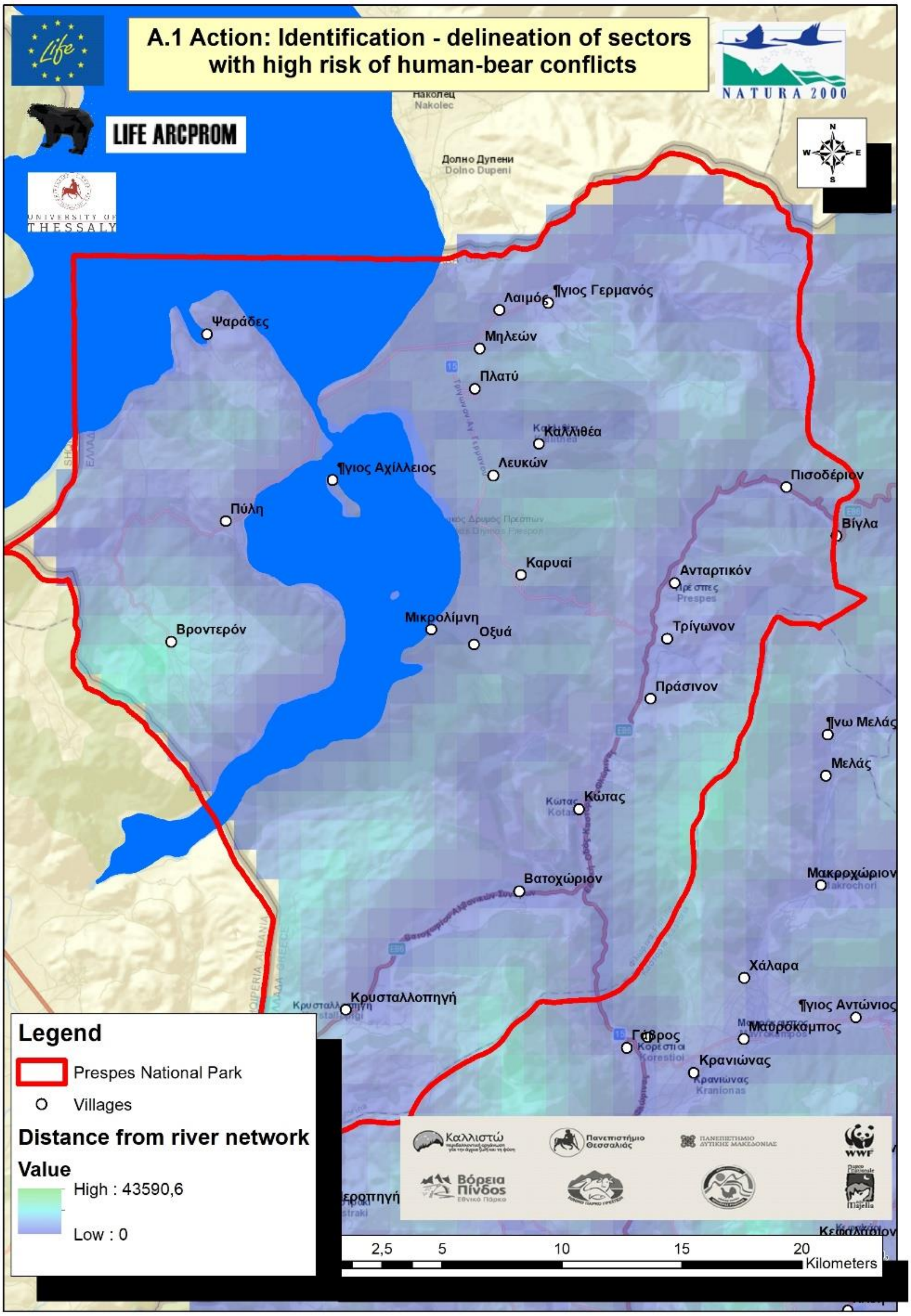
Map 21. Distance from farms classification in MBPNP



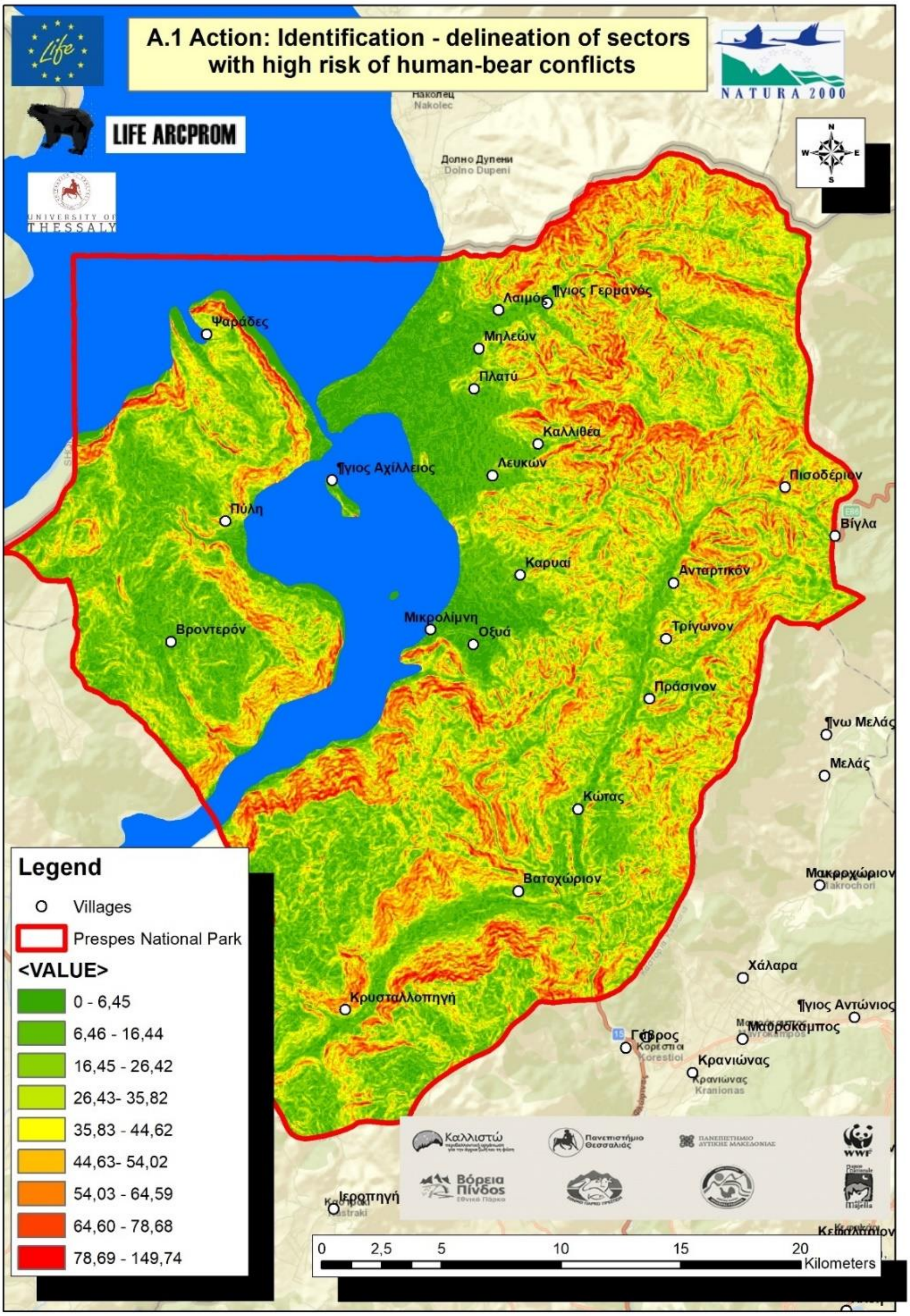
Map 22. Land uses-habitat types classification in MBPNP



Map 23. Mean annual temperature classification in MBPNP



Map 24. Distance from river network classification in MBPNP



Map 25. Slope classification in MBPNP

2.3.1 Results-Rodopi National Park _- MaXent modelling

Predictive Ecological Niche Models-Brown bear (*Ursus arctos*) autumn conflict area model

The contribution of the variables studied in the MaxEnt model for autumn conflict area model, is presented in Table 17.

Table 17. Analysis of variable contributions

Variable	Percent contribution	Permutation importance
Distance from villages	23.9	16.4
Habitat types1	20.3	9.5
Distance from main roads	12.4	9
Cattle density	10.3	21.4
Distance from farms	7.5	0
precipitation	7.5	13
November ndvi	4.2	4
aspect	3.5	7.5
Distance from forest roads	3.1	3.2
slope	2.2	10.6
October ndvi	1.9	1
Distance from rivers	1.7	0
September ndvi	1.1	0.7
Human population density	0.3	3.3
Cultivations shannon index	0.1	0.3
matemp	0	0.3
sheepdensity	0	0
goatsdensity	0	0
alt	0	0

Table (17) gives estimates of relative contributions of the environmental variables to the Maxent model. To determine the first estimate, in each iteration of the training algorithm, the increase in regularized gain is added to the contribution of the corresponding variable or subtracted from it if the change to the absolute value of lambda is negative.

For the second estimate, for each environmental variable in turn, the values of that variable on training presence and background data are randomly permuted. The model is reevaluated on the permuted data, and the resulting drop in training AUC is shown in the table, normalized to percentages. From this table we can see that the environmental variable with highest gain when used in isolation is "***distance from villages"***, which therefore appears to have the most useful information on itself. The environmental variable that maximizes the gain decrease when it is omitted is "***distance from main roads"***, which therefore appears to infer the most information that is not contained in the other variables.(fig 24)

Figure 24. Jackknife of regularized training gain test

The above figure (Jackknife of regularized training gain test) shows the results of the jackknife test of variables importance in the prediction model. The environmental variable with highest gain when used in isolation is "***distance from villages***", which therefore appears to contain the most useful and influential information on itself. The environmental variable that decreases the gain the most when it is omitted is "***distance from main roads***", which therefore appears to have the most information that is not present in the other variables. Other significant variables in the tested set are: *"habitat types", "cattle density", and "distance from farms*".

The model fitness values are as follows: regularized training gain = 0.786, training AUC = 0.896, unregularized training gain = 1.318.

Regarding the response of the variable "distance from villages" (scored into two classes (0-1000) and >10 km from settlements) it was found to have a higher positive effect in the autumn CA model for the brown bear (*Ursus arctos*) in the study area. Moreover, regarding the response of the variable "cattle density" (scored at 20-30 cattle's /km$^{2)}$ was found to have a higher positive effect in the autumn CA model for the brown bear (*Ursus arctos*) in the study area.
Of the 44 classes of habitat types, the categories: a) Land principally occupied by agriculture, with significant areas of natural vegetation, b) mixed forest and c) Transitional woodland-shrub was found to have a higher positive effect on the autumn CA model for brown bear (Ursus arctos) in the study area. The results are presented in Figures 25-27 and map 26. The curves depict how the predicted probability of brown bear (Ursus arctos) changes as each class of habitat type variable varies.

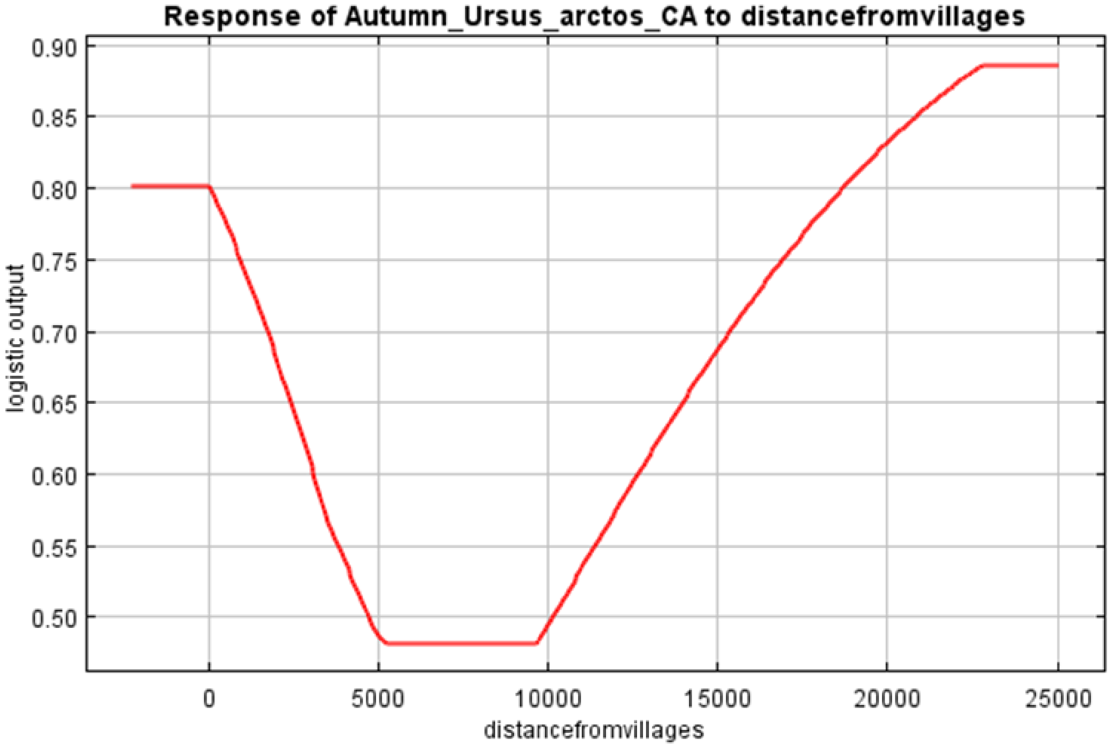


fig. 25, 26: Response of brown bear (Ursus arctos) CA autumn model in Rodopi NP to the variable “distance from village” and to the variable “cattle density”

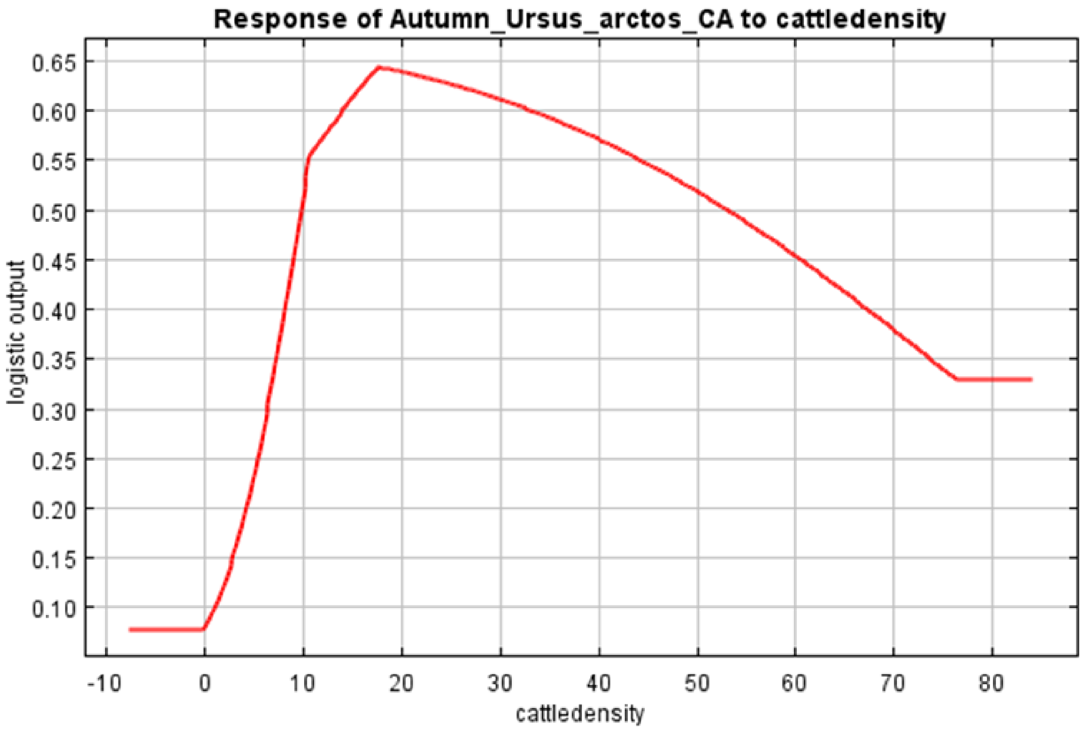
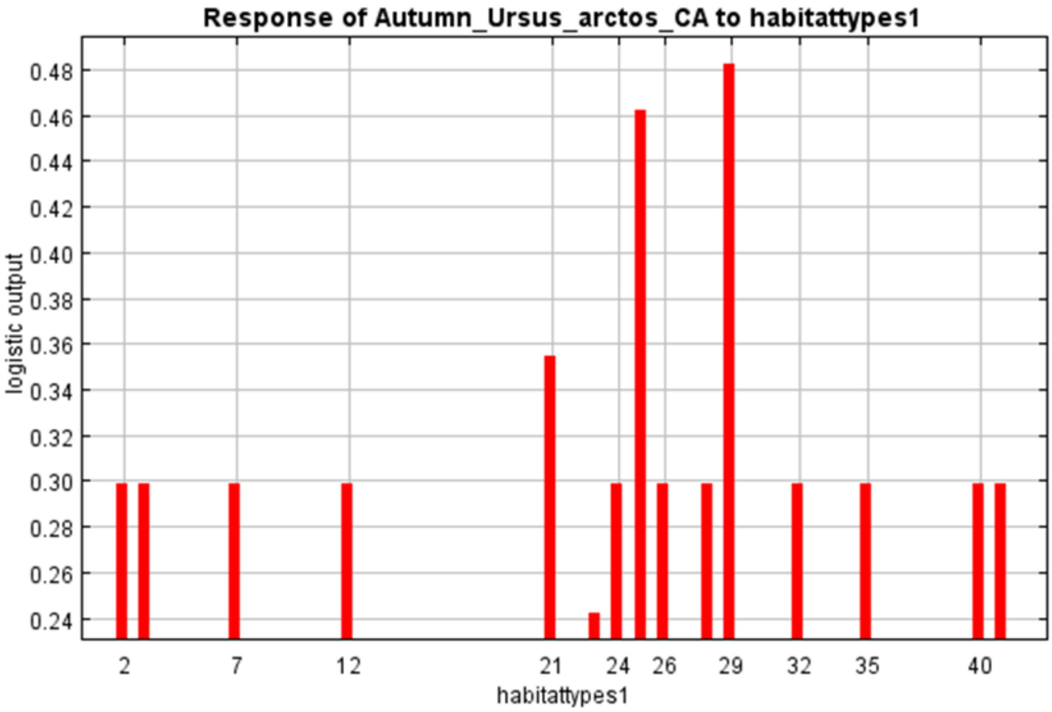
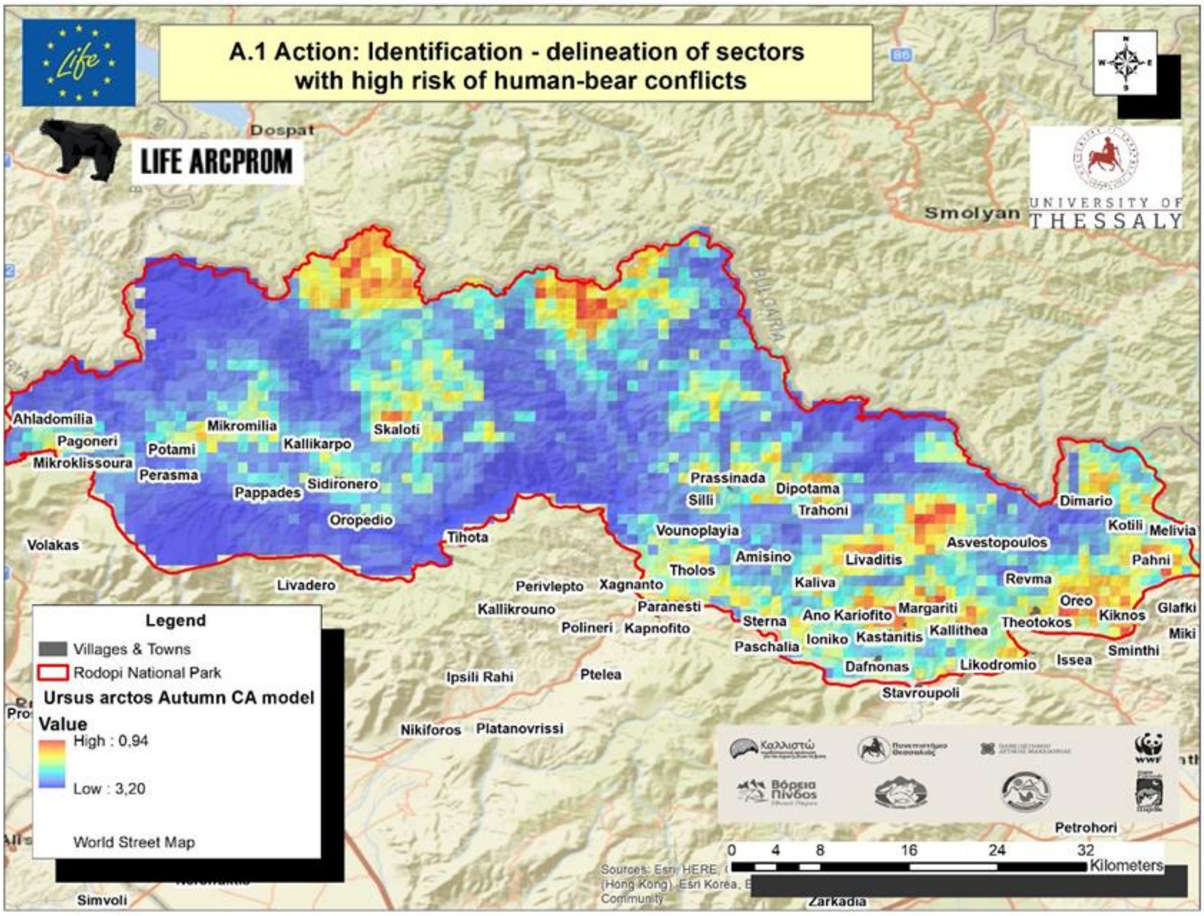


Figure 27. Response of brown bear (Ursus arctos) CA autumn model in Rodopi NP to the variable " habitat types".



Map 26: Brown bear (Ursus arctos) autumn CA model at Rodopi National Park



- **Predictive Ecological Niche Models-Brown bear (*Ursus arctos*) spring conflict area model**

The contribution of the variables studied in the MaxEnt model for spring CA model, is shown in Table 18.

Table 18. Analysis of variables contributions

Variable	Percent contribution	Permutation importance
Habitat types	47	4.8
Distance from villages	39.6	69
aspect	3	0
Distance from main roads	2.6	1.6
Distance from farms	1.9	19.5
April ndvi	1.6	1.5
slope	1.5	1.6
May ndvi	1.4	2
precipitation	1.4	0
alt	0	0
matemp	0	0
Distance from forest roads	0	0
Cattle density	0	0
Sheep density	0	0
Goats density	0	0
Human population density	0	0
Distance from rivers	0	0

Table 18, gives estimates of relative contributions of the environmental variables to the Maxent model. To determine the first estimate, in each iteration of the training algorithm, the increase in regularized gain is added to the contribution of the corresponding variable or subtracted from it if the change in the absolute value of lambda (λ) is negative. For the second estimate, for each environmental variable in turn, the values of that variable on training presence and background data are randomly permuted.
The model is reevaluated on the permuted data, and the resulting drop in training AUC is shown in the table, normalized to percentages. The environmental variable with highest gain when used in isolation is again “distance from villages” which therefore appears to have the most useful information on itself.
The environmental variable that decreases the gain the most when it is omitted is “habitat types”, which therefore appears to have the most information that is not present in the other variables.

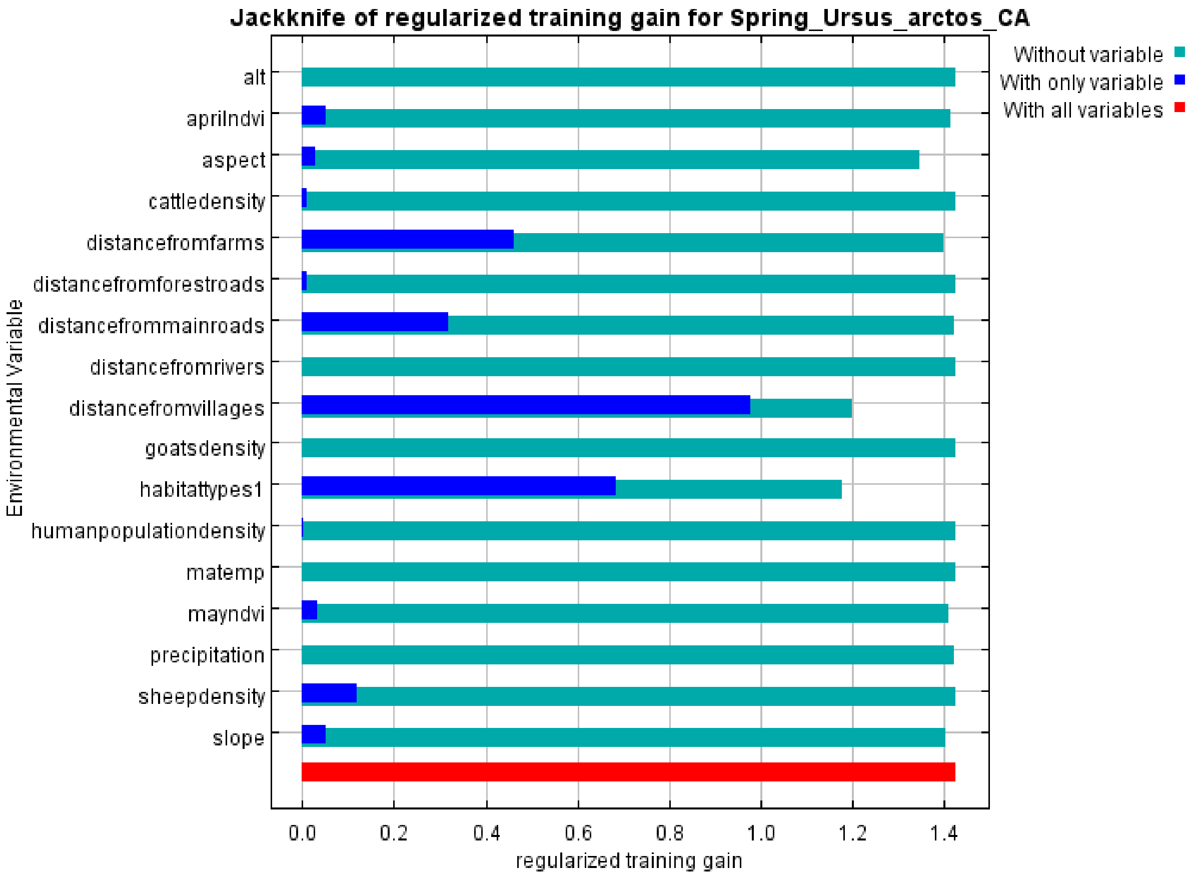
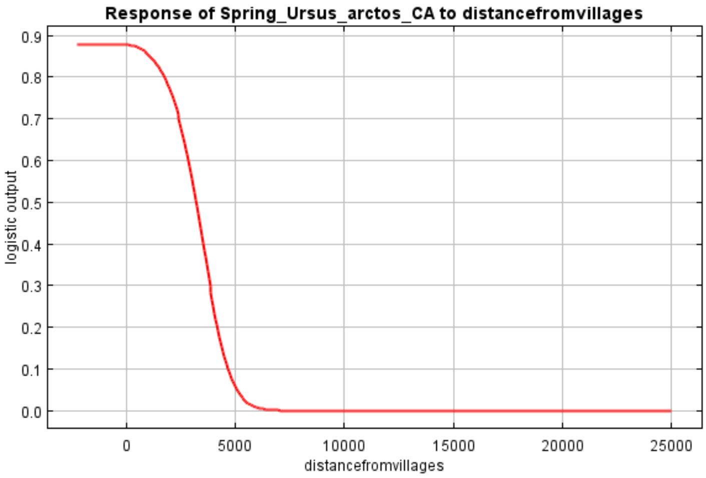


Figure 28. Jackknife of regularized training gain test

The above figure (Jackknife of regularized training gain test) shows the results of the jackknife test of variable importance. The environmental variable with highest gain when used in isolation is distance from villages which therefore appears to have the most useful information by itself.
The environmental variable that decreases the gain the most when it is omitted is habitat types1, which therefore appears to have the most information that isn't present in the other variables. Moreover, two variables (distance from farms and distance from main roads) of the GIS data base seem to play an important role in spring CA model.

The model fitness values are as follows:
Regularized training gain = 1.426, training AUC = 0.967, unregularized training gain = 2.258.

The results are presented in Figures 29 and 30 as well as on map 27. Fig. 29 and 30 depict how the predicted probability of brown bear (Ursus arctos) spring CA changed as each class of variable the most influential variables ("habitat types" and "distance from villages") has varied**.**
Of the 44 classes of Corine Land Cover (CLC) – land-use categories, the category of Land principally occupied by agriculture, with significant areas of natural vegetation (21 class) and Transitional woodland-shrub (29 class) was found to have a higher positive effect on the spring CA model in the study area



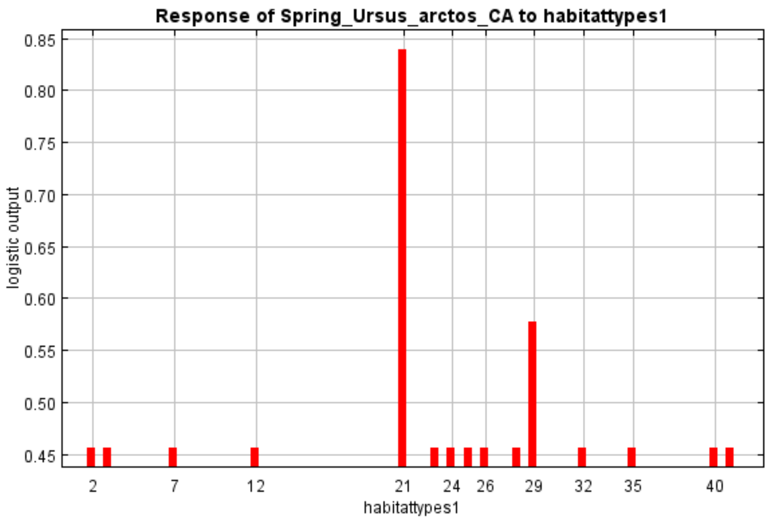
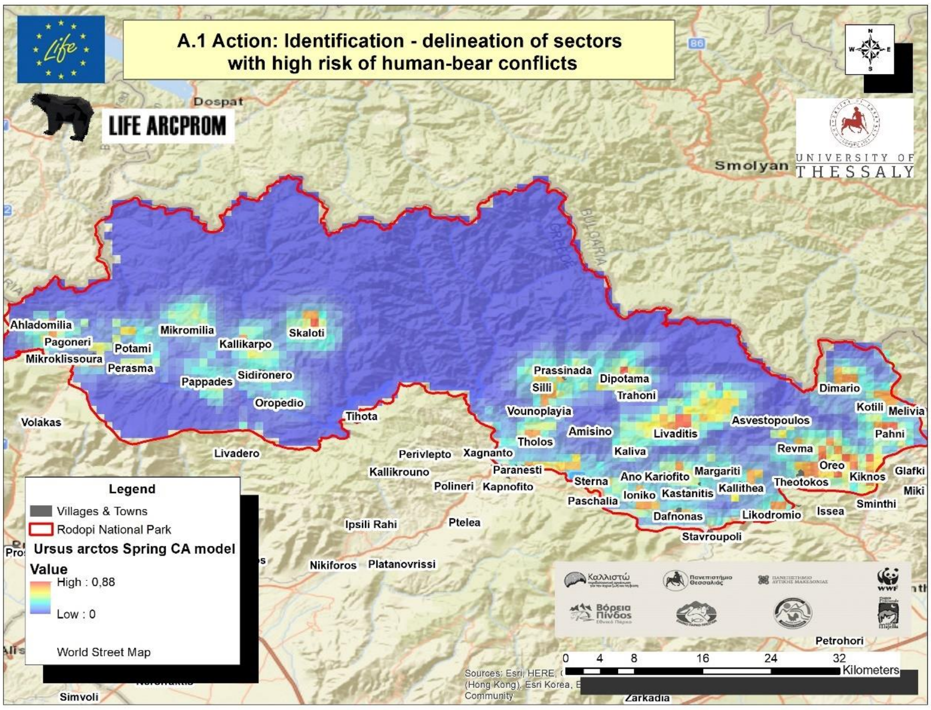


Figure 29. Response of brown bear (Ursus arctos) to the variable "distance from villages" in spring

Figure 30. Response of brown bear (Ursus arctos) to the variable "habitat types" in spring

Map 27: Brown bear (Ursus arctos) summer CA model at Rodopi National Park



Brown bears go through three biochemical and physiological stages in their active period from spring to autumn, starting from a low food intake in the spring (hypophagia), going to a state of normal food intake in the summer, and ending in a high food intake in autumn (hyperphagia). Green vegetation, such as grass, herbs and tree buds, are the preferred food items by bears in spring and early summer, when they still have not bloomed andare more nutritious in proteins. Land principally occupied by agriculture, with significant areas of natural vegetation supports bears during this period of their life cycle. Regarding the response of the variable "distance from villages", as the distance from settlements increases the probability decreases. High conflict zone detected from 0-1000 buffer zone from villages.

- **Predictive Ecological Niche Models-Brown bear (*Ursus arctos*) summer conflict area model**

The contribution of the variables studied in the MaxEnt model for summer CA model, is in Table 19.

Table 19. Analysis of variable contributions

Variable	Percent contribution	Permutation importance
habitattypes1	31.7	12.9
distancefromrivers	14	8.5
distancefromvillages	13.8	33.5
humanpopulationdensity	10.4	17.9
distancefrommainroads	8.1	12.6
distancefromforestroads	8	2.9
slope	6.7	5.8
cattledensity	3	0.5
goatsdensity	2.4	1.7
precipitation	1.6	2.8
julyndvi	0.2	0.7
aspect	0.1	0
junendvi	0	0.3
matemp	0	0
distancefromfarms	0	0
sheepdensity	0	0
augustndvi	0	0
alt	0	0

Table 19 gives estimates of relative contributions of the environmental variables to the Maxent model. To determine the first estimate, in each iteration of the training algorithm, the increase in regularized gain is added to the contribution of the corresponding variable or subtracted from it if the change to the absolute value of lambda is negative. For the second estimate, for each environmental variable in turn, the values of that variable on training presence and background data are randomly permuted.

The model is reevaluated on the permuted data, and the resulting drop in training AUC is shown in the table, normalized to percentages. The environmental variable with highest gain when used in isolation is “habitat types” which therefore appears to have the most useful information by itself.

The environmental variable that decreases the gain the most when it is omitted is “habitat types”, which therefore appears to have the most information that isn't present in the other variables. Moreover, it appears that two variables (distance from rivers and distance from forest roads) play an important role in summer CA model.

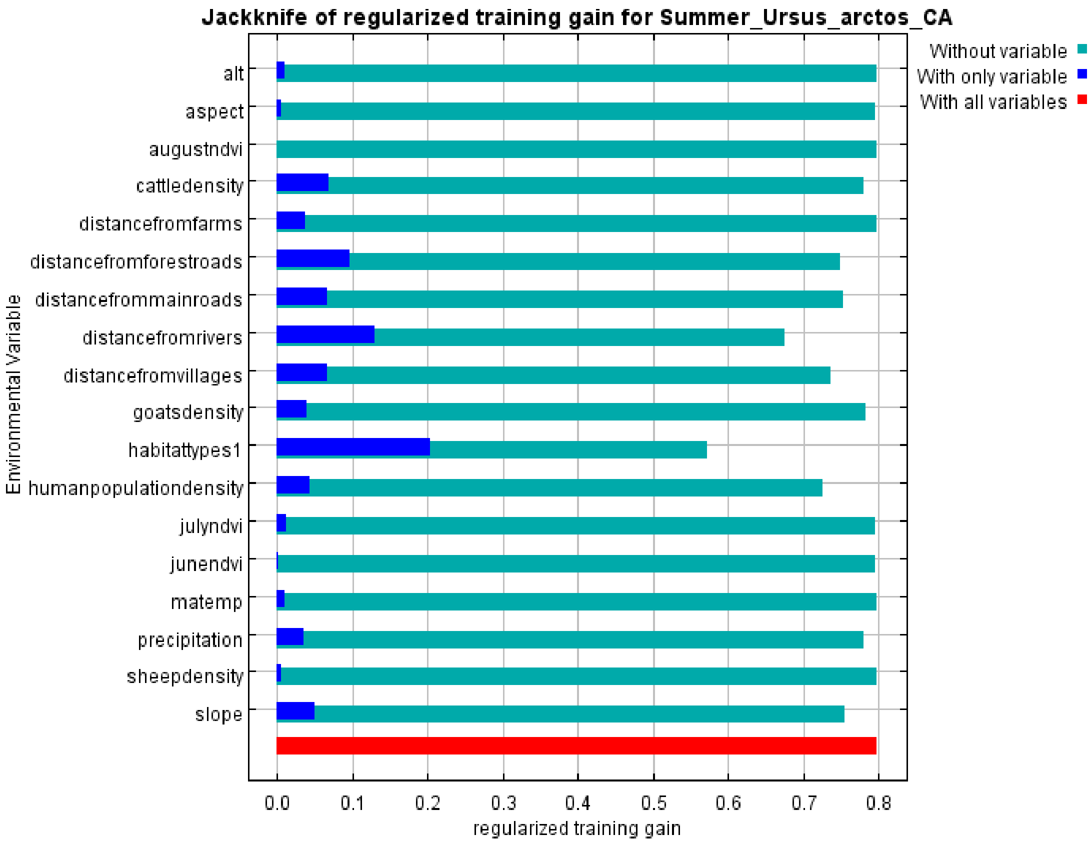


Figure 8. Jackknife of regularized training gain test

The above figure (Jackknife of regularized training gain test) shows the results of the jackknife test of variable importance. The environmental variable with highest gain when used in isolation is "habitat types" which therefore appears to have the most useful information by itself. The environmental variable that decreases the gain the most when it is omitted is "habitat types", which therefore appears to have the most information that isn't present in the other variables.
The model fitness values are as follows : Regularized training gain = 0.796, training AUC = 0.922, unregularized training gain = 1.759.

The results are presented in Figure 31 & 32 depicting how the CA summer model of brown bear (Ursus arctos) changed as each class of the most influential variables varies.
Of the 44 classes of Corine Land Cover (CLC) – land-use types, the following categories: a) Land principally occupied by agriculture, with significant areas of natural vegetation, b) Coniferous forest, Sclerophyllous vegetation and c) Transitional woodland-shrub were found to have a higher positive effect on the summer CA model of brown bear (Ursus arctos) in the Rodopi National Park.
Regarding the response of the variable distance from rivers (100-200m), as the distance from rivers increases the probability decreases. Finally map 28 illustrates the scoring classification of potential human-bear conflict zones in summer season.

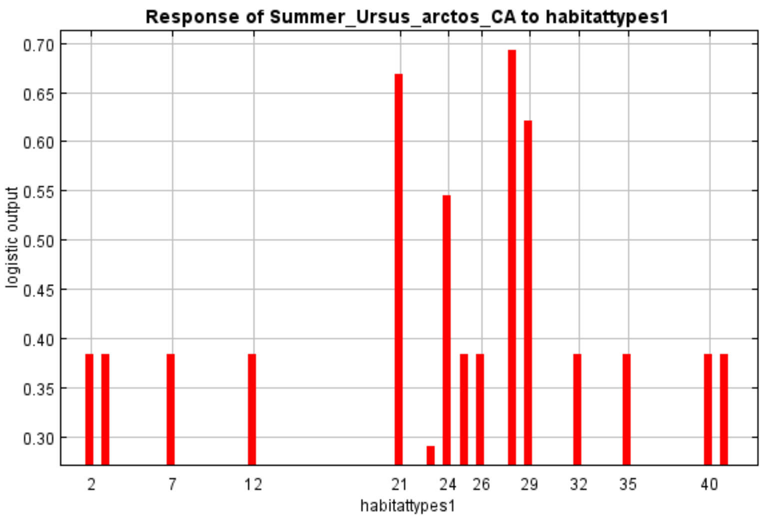


Figure 31. Response of brown bear (Ursus arctos) to habitat types1

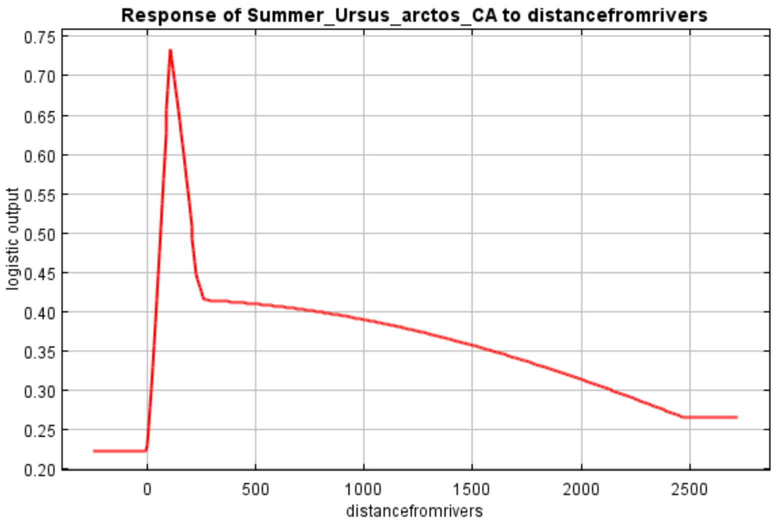
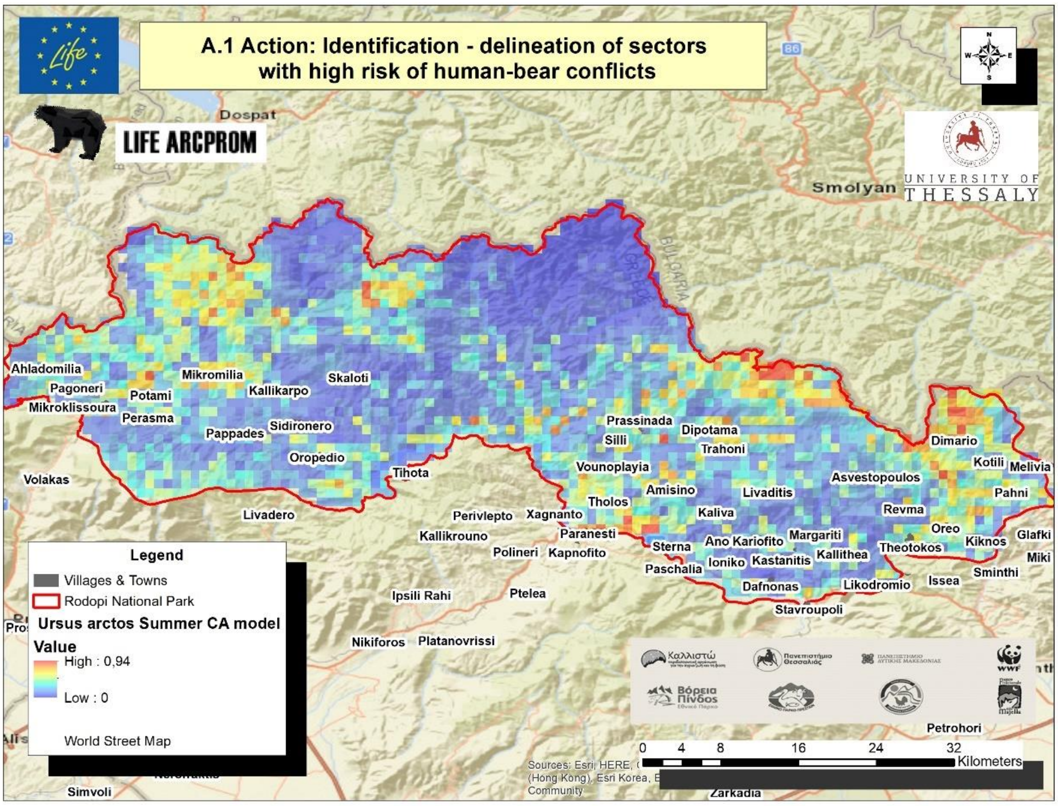


Figure 32. Response of brown bear (Ursus arctos) to distance from rivers



Map 28. Brown bear (Ursus arctos) summer CA model at Rodopi National Park

2.3.2 Results-Prespes National Park – MaXent modelling:

Predictive Ecological Niche Models-Brown bear (*Ursus arctos*) autumn conflict area model

The contribution of the variables studied in the MaxEnt model for autumn CA model, is in Table 20.

Table 20. Analysis of variable contributions

Variable	Percent contribution	Permutation importance
Habitat types1	41.5	9.3
Forest roads	39	72.1
alt	14.7	17.8
Goat den	2.2	0
Cattle den	1.2	0.3
Human population density	0.7	0.2
October ndvi	0.7	0.3
Villages distance	0	0
Habitat types_	0	0
Nove ndvi	0	0
Main roads dist	0	0
Septe ndvi	0	0
Distance from rivers	0	0
Distance from farms	0	0
Sheep den	0	0
matemp	0	0

Table 20 gives estimates of relative contributions of the environmental variables to the Maxent model. To determine the first estimate, in each iteration of the training algorithm, the increase in regularized gain is added to the contribution of the corresponding variable or subtracted from it if the change to the absolute value of lambda (λ) is negative. For the second estimate, for each environmental variable in turn, the values of that variable on training presence and background data are randomly permuted.
The model is reevaluated on the permuted data, and the resulting drop in training AUC is shown in the table, normalized to percentages. The environmental variable with highest gain when used in isolation is “distance from forest roads” (forestroads) which therefore appears to have the most useful information by itself.
The environmental variable that decreases the gain the most when it is omitted is “forest roads” (forestroads), which therefore appears to have the most information that isn't present in the other variables. Moreover, three variables (alt, habitattypes1 and mean temperature) seem to play an important role in autumn CA model.

Figure 33. Jackknife of regularized training gain test

The above figure (Jackknife of regularized training gain test) shows the results of the jackknife test of variable importance. The environmental variable with highest gain when used in isolation is “forest roads” (forestroads) which therefore appears to have the most useful information by itself. The environmental variable that decreases the gain the most when it is omitted is forest roads (forestroads), which therefore appears to have the most information that is not present in the other variables.
The model fitness values are as flows: Regularized training gain = 2.948, training AUC = 0.997, unregularized training gain = 4.255.

Regarding the response of the variable “altitude”: it is likely thar as long as altitude increases the probability of conflict decreases.

The results are presented in Figures 34 & 35 and depict how the CA autumn model of brown bear (*Ursus arctos*) changed as each influential variable class changes.

Of the 44 classes of Corine Land Cover (CLC) - land uses, the categories: Natural grasslands and Inland marshes was found to have a higher positive effect on the autumn CA model of brown bear (Ursus arctos) in the Prespes National Park. It is worth noting that these categories include riparian agricultural crops in the national park area.

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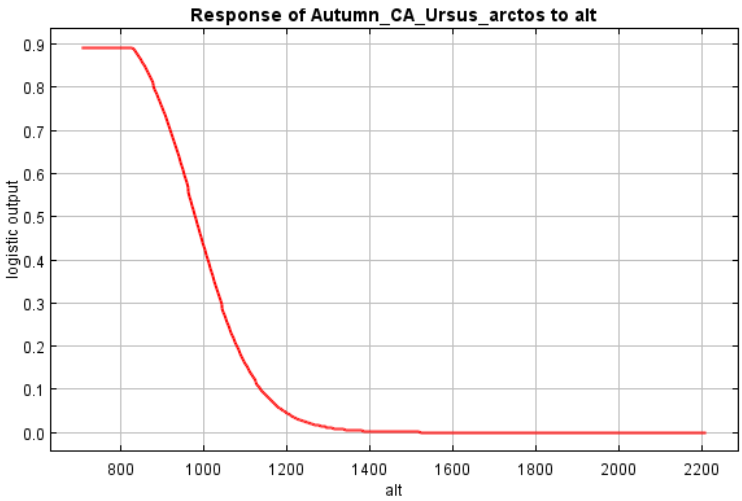


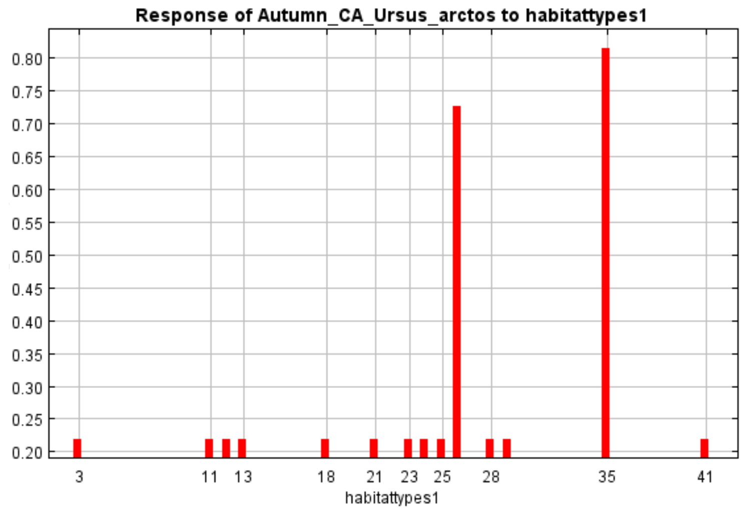
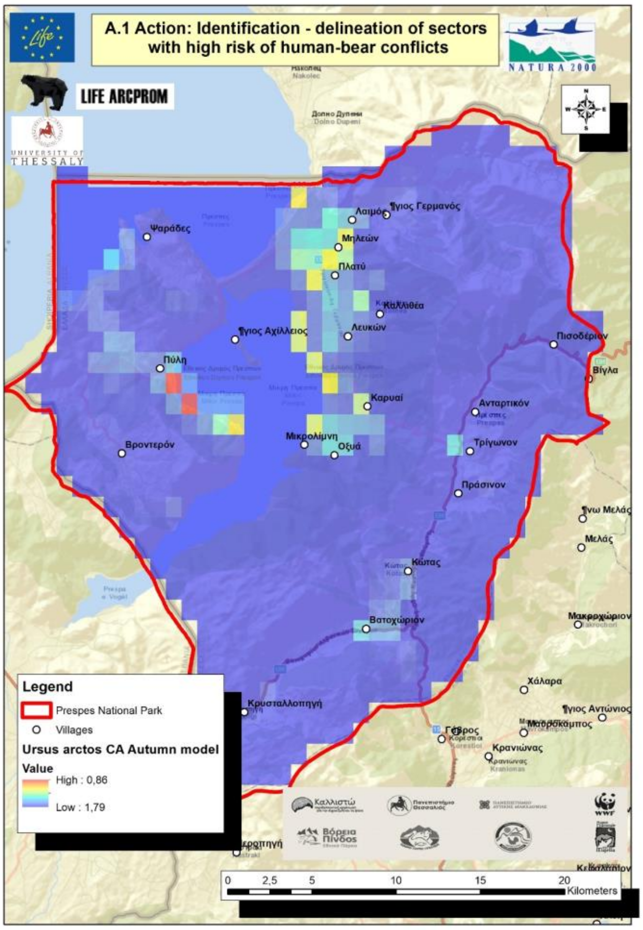


Figure 34. Response of brown bear (Ursus arctos) to altitude (alt)

Figure 35. Response of brown bear (Ursus arctos) to habitat types1



Map 29. Brown bear (Ursus arctos) autumn CA model at Prespes National Park

Predictive Ecological Niche Models-Brown bear (*Ursus arctos*) spring conflict area model

The contribution of the variables studied in the MaxEnt model for spring CA model, is in Table 8.

Table 21. Analysis of variable contributions

Variable	Percent contribution	Permutation importance
distancefromfarms	67.8	85.1
habitattypes_	18.2	4.5
habitattypes1	10.6	3.1
matemp	1.9	3.5
aprilndvi	1.6	3.8
goatden	0	0
forestroads	0	0
distancefromrivers	0	0
cattleden	0	0
villagesdistance	0	0
sheepden	0	0
mayndvi	0	0
mainroadsdist	0	0
humanpopulationdensity	0	0
alt	0	0

Table 21, gives estimates of relative contributions of the environmental variables to the Maxent model. To determine the first estimate, in each iteration of the training algorithm, the increase in regularized gain is added to the contribution of the corresponding variable or subtracted from it if the change to the absolute value of lambda (λ) is negative.

For the second estimate, for each environmental variable in turn, the values of that variable on training presence and background data are randomly permuted. The model is reevaluated on the permuted data, and the resulting drop in training AUC is shown in the table, normalized to percentages.

The environmental variable with highest gain when used in isolation is "distance from farms" which therefore appears to have the most useful information by itself. The environmental variable that decreases the gain the most when it is omitted is "distance from farms", which therefore appears to have the most information that isn't present in the other variables. Moreover, three variables (habitattypes1, habitattypes) play an important role in spring CA model.

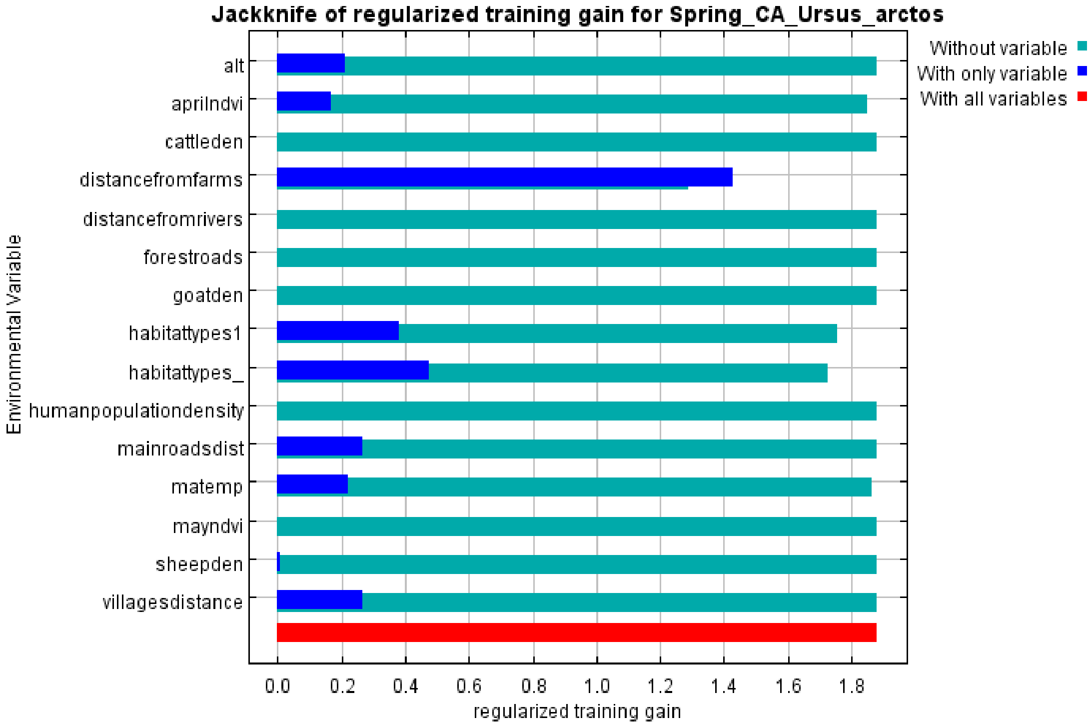


Figure 36. Jackknife of regularized training gain test

The above figure (Jackknife of regularised training gain test) shows the results of the jackknife test of variable importance. The environmental variable with highest gain when used in isolation is distance from farms which therefore appears to have the most useful information by itself. The environmental variable that decreases the gain the most when it is omitted is distance from farms, which therefore appears to have the most information that isn't present in the other variables. The model fitness values are as follows:
Regularized training gain =1.878, training AUC = 0.980, unregularized training gain = 3.125.

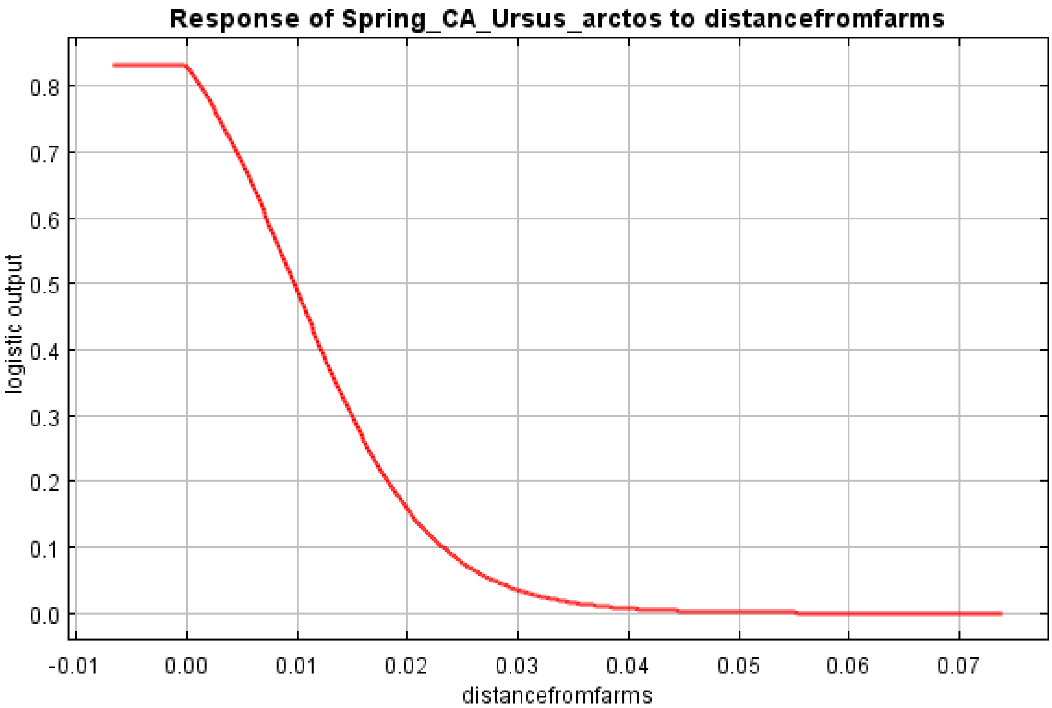
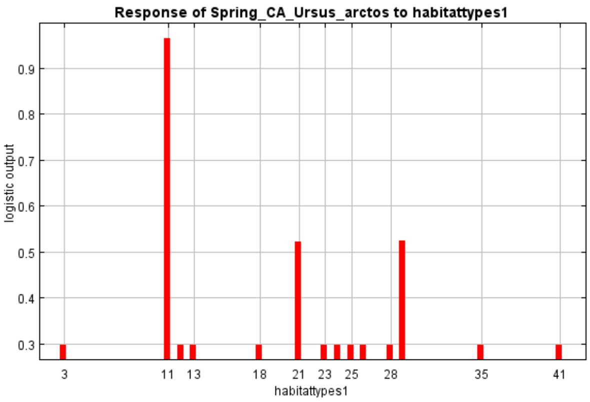
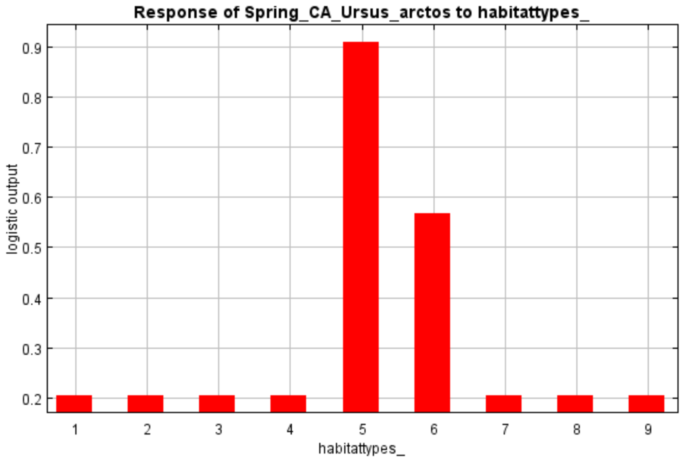


Figure 37. Response of brown bear (Ursus arctos) to distance from farms
Regarding the response of the variable (distance to farms), as the distance increases the probability of conflict decreases.





Figures 38-39. Response of brown bear (Ursus arctos) to habitat types

The results are presented in Figures 16,17 and map 30 depicting how the CA spring model of brown bear (Ursus arctos) changed as each class of land use variable was varied and illustrating the potential human-bear high risk conflict zones in spring season in MBPNP.

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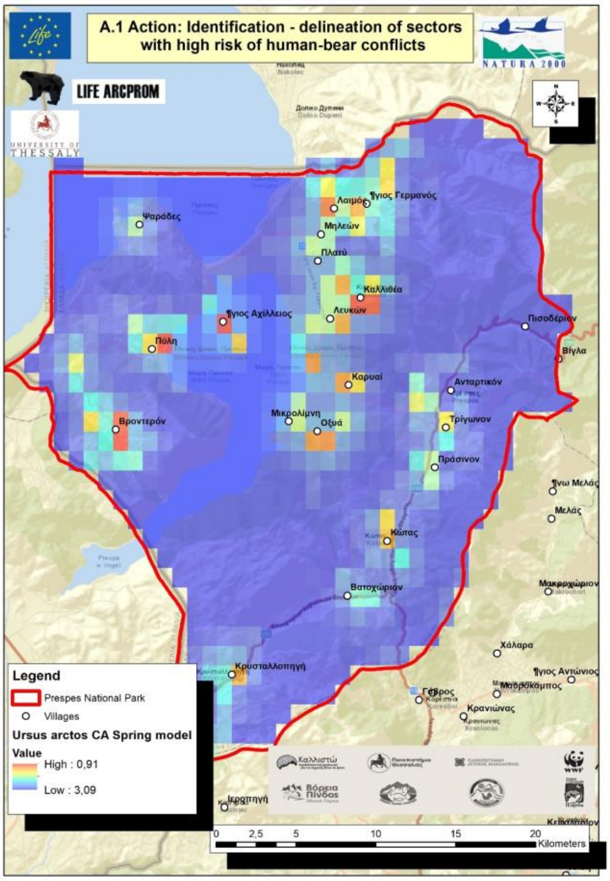


Of the 44 classes of Corine Land Cover (CLC) - the categories: a) areas near villages, b) Land principally occupied by agriculture, with significant areas of natural vegetation and c) Transitional woodland-shrub were found to have a higher positive effect on the spring CA model of brown bear (Ursus arctos) in the Prespes National Park.

Of the nine (9) classes of Prespes National Pak Habitat types mapping program- the categories: “areas near villages and meadows” was found to have a higher positive effect on the spring CA model of brown bear (Ursus arctos) in the Prespes National Park.

Map 30. Brown bear (Ursus arctos) spring CA model in Prespes National Park

- **Predictive Ecological Niche Models-Brown bear (*Ursus arctos*) summer conflict area model**

The contribution of the variables studied in the MaxEnt model for summer CA model, is in Table 22.

Table 22. Analysis of variable contributions

Variable	Percent contribution	Permutation importance
Distance from farms	50.2	20.2
Forest roads	23.7	47.9
Habitat types1	16.3	16.6
Habitat types_	5.2	6.5
Human population density	2.1	0.9
Distance from rivers	1.4	5
June ndvi	0.8	0
alt	0.2	2
August ndvi	0.1	0.1
Goat den	0	0
Main roads dist	0	0.5
Villages distance	0	0.2
matemp	0	0
Sheep den	0	0
Cattle den	0	0
July ndvi	0	0

Table 22, gives estimates of relative contributions of the environmental variables to the Maxent model. To determine the first estimate, in each iteration of the training algorithm, the increase in regularized gain is added to the contribution of the corresponding variable or subtracted from it if the change to the absolute value of lambda i(λ) s negative.

For the second estimate, for each environmental variable in turn, the values of that variable on training presence and background data are randomly permuted. The model is reevaluated on the permuted data, and the resulting drop in training AUC is shown in the table, normalized to percentages.

The environmental variable with highest gain when used in isolation is «distance from farms» which therefore appears to have the most useful information by itself. The environmental variable that decreases the gain the most when it is omitted is «distance from farms», which therefore appears to have the most information that isn't present in the other variables.

Moreover, three additional variables (<distance from forest roads>, <habitattypes1>, <habitattypes>) play an important role in summer CA model. (fig 40)

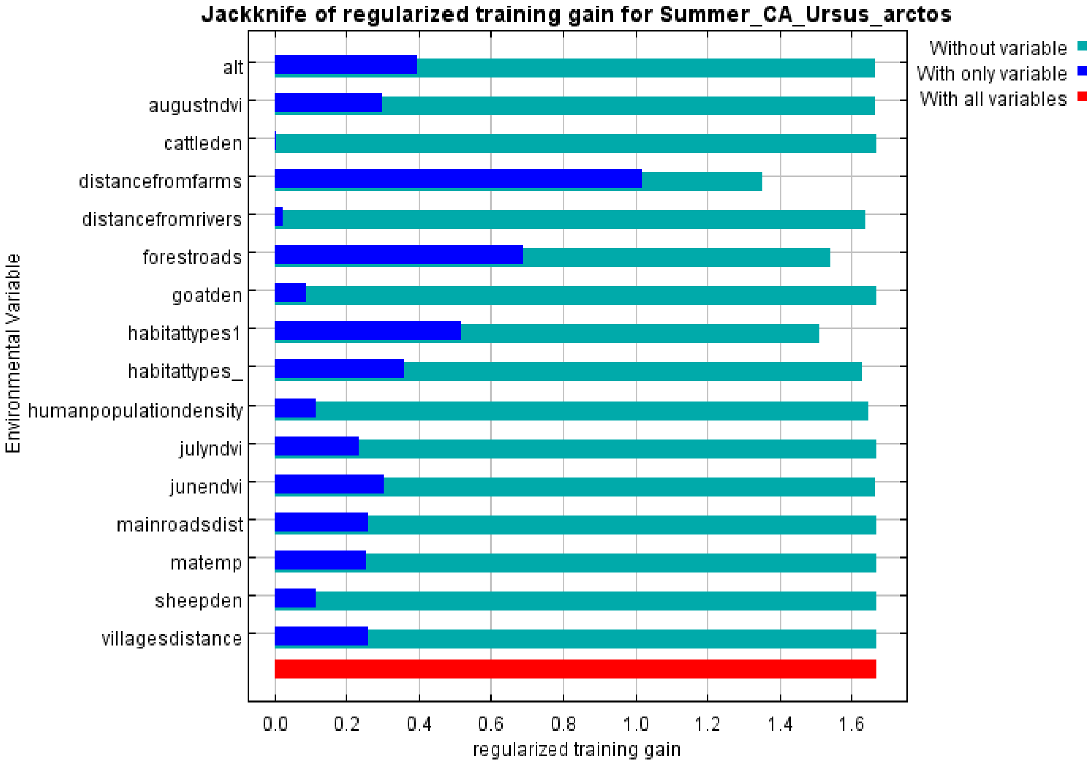
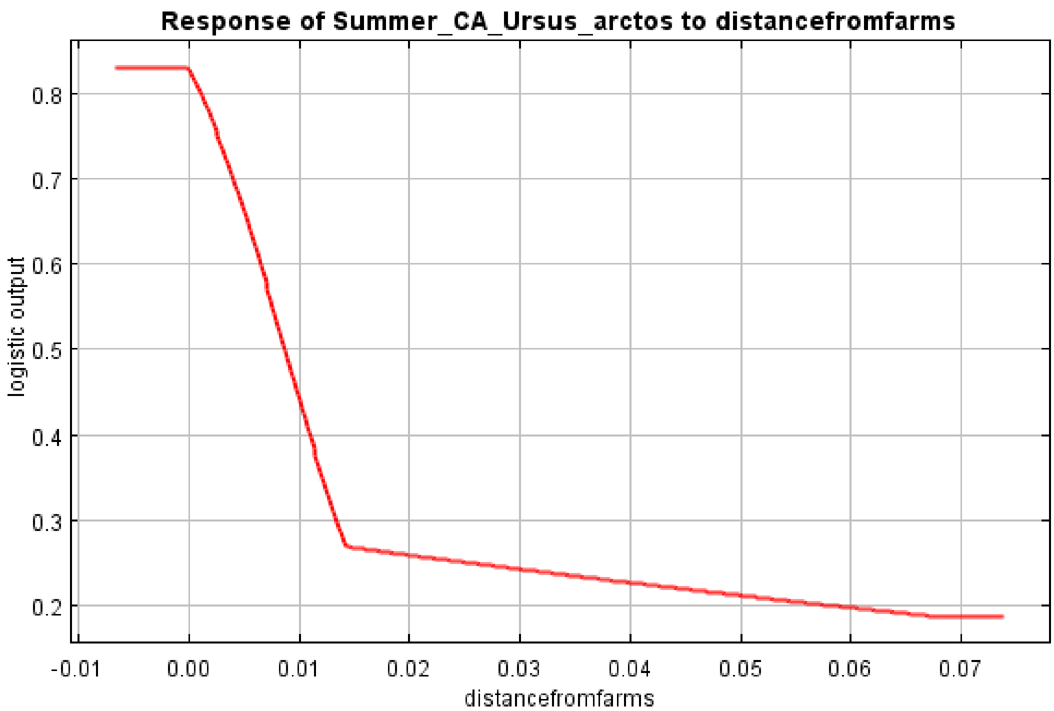


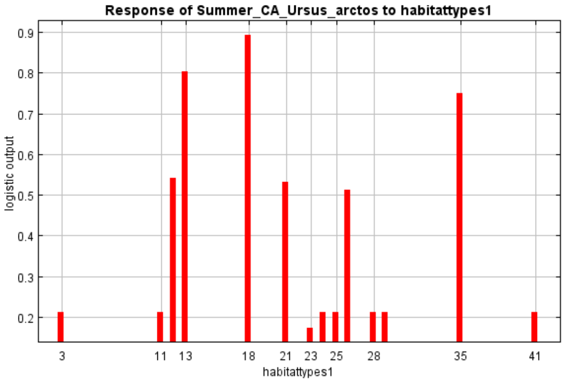
Figure 40. Jackknife of regularized training gain test

The above figure (Jackknife of regularized training gain test) shows the results of the jackknife test of variable importance. The environmental variable with highest gain when used in isolation is distance from farms which therefore appears to have the most useful information by itself. The environmental variable that decreases the gain the most when it is omitted is distance from farms, which therefore appears to have the most information that isn't present in the other variables. The model fitness values are as follows:
Regularized training gain = 1.667, training AUC = 0.955, unregularized training gain=2.060.

Figure 41. Response of brown bear (Ursus arctos) to distance from farms



Regarding the response of the variable (distance to farms), as the distance increases the probability of conflict decreases.



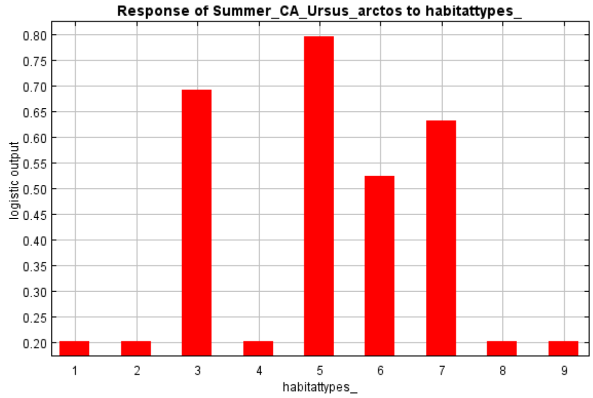
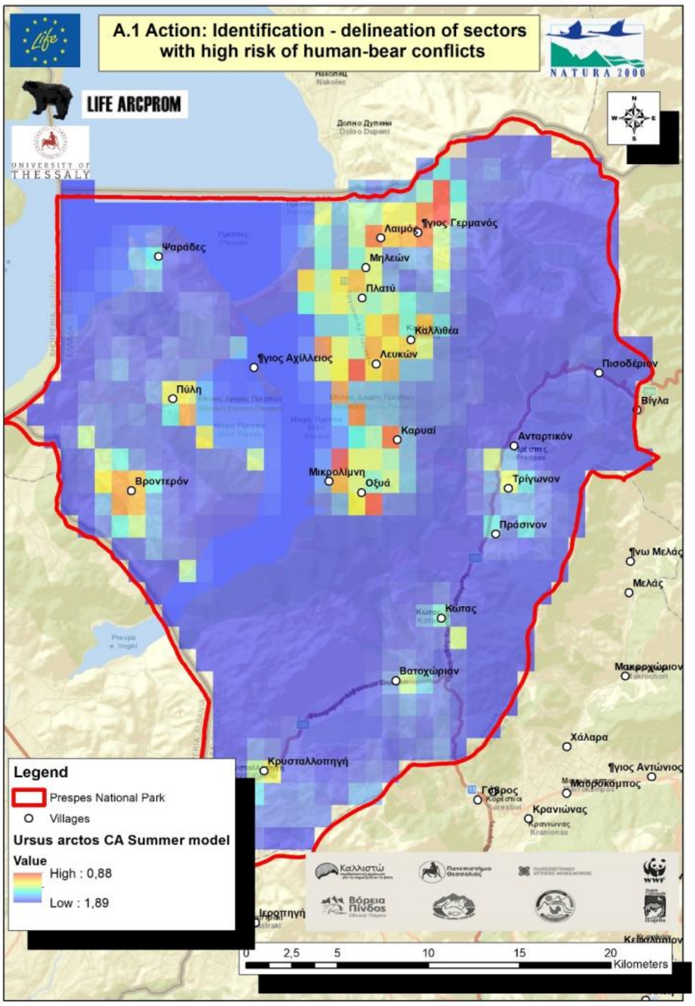


Figure 42-43. Response of brown bear (Ursus arctos) to habitat types



The results are presented in Figures 41-43 and map 31, depicting how the CA summer model of brown bear (Ursus arctos) changed as each influential variable class of land is changing.
Of the 44 classes of Corine Land Cover (CLC) - the categories: Permanently irrigated land, Pastures and Inland marshes was found to have a higher positive effect on the summer CA model of brown bear (Ursus arctos) in the Prespes National Park.

Of the 9 classes of Prespes National Pak Habitat types mapping program- the categories: agricultures (3) areas near villages (5) and shrubs (7) was found to have a higher positive effect on the summer CA model of brown bear (Ursus arctos) in the Prespes National Park.

Map 31. Brown bear (Ursus arctos) summer CA model at Prespes National Park

3. Discussion

In Europe, since the time when humans became farmers and livestock breeders, conflict with large carnivores has existed. People's property has been threatened by predators, like wolves and bears as landscapes changed. In Greece human-brown bear conflicts occur increasingly especially when rural people make anthropogenic foods (foods of human origin like domestic garbage, livestock, orchards or cultivations) available/accessible to bears.
Bears adapt their behavior to use these resources and during that process may damage property, attack on livestock animals, or cause public safety concerns. The challenge of managing human-bear conflicts can be attributed to a variety of factors.

The phenomenon is multifactorial, and knowledge may not provide all the necessary answers for managing conflict. Negative interactions between humans and wildlife species are a global problem since humans have encroached on wildlife habitats (Woodroffe et al. 2005a). Given that this situation can cause problems due to damages to property and livestock (Woodroffe et al. 2005b), the issue of human-wildlife conflict remains a global management priority for many wildlife species. Human-wildlife conflicts are often accumulated on a space-time scale and can cause large financial losses (Thirgood et al. 2005). However, for most species, little is known about space-time variability of the conflict phenomenon by category / type of conflict. Therefore, a better knowledge and understanding of the phenomenon will help in development the appropriate strategy for dealing with / compensating conflicts which will allow a more efficient allocation of resources through targeted management actions.
Livestock damages by large carnivores is a global problem on agricultural production. The extent of the phenomenon varies considerably accordingly by the way of breeding but also the breed of the domestic animal (Kaczensky 1999). The sheep and goats are more exposed, with bovine and equine depredation becoming also increasingly common especially when it comes to bear attacks. Most of the reasons are related to the possibility of easy food intake from anthropogenic food sources (e.g. waste) in relation to natural food availability.

More specifically, hardmast as well trees and fruits successful production undergo fluctuations over time. Another reason for close contact between bears (especially females with cubs) and humans nearby human settlements and residential areas is the avoidance of infanticide by adult males. Therefore, both behavioral and biological/seasonal factors and characteristics (Hypophagia/hyperphagia/denning) along the species annual cycle are the main drives of this phenomenon. During the hyperphagia period the bears caloric consumption can reach even 20,000 calories a day and aims to increase fat storage to enable them to survive during the following hibernation period.
Modelling the conflict sectors is an important issue in planning the conservation and management of large carnivores. Among the various ecological niche techniques currently available, MaxEnt is considered to use the best algorithm, thus providing the best predictive models (Elith et al., 2006, Zeimes et al., 2012). MaxEnt software has the advantage that it requires only presence data and small number of occurrences. The program can consider continuous and categorical predictor variables and includes a regularisation protocol to protect against overfitting; the methodology, in general, shows very good predictive performance. Bears use different habitat types inside their home ranges (Munro et al. 2006). Local extinction increased with decreasing forest cover for brown bear.

GIS modelling in both areas showed that habitat types, distance from road network (forest and paved roads), cattle density and distance from livestock farms are the main factors for human and brown bear conflict sectors. Bears prefer areas located on the boundaries of different habitat species, and especially in the gaps between the forest and open habitat areas (such as grassland and agricultural crops) (Mertzanis et al. 2006). In addition, they seem to avoid human settlements, but prefer areas which are at average distances and especially areas which serve as a source of food (e.g. fruit trees) (Mertzanis, 1992, Akriotis et al. 2006, Giannakopoulos et al. 2010). The bear's preference for forest habitat types in Rodopi National can be attributed to the availability and to seasonal (spring, summer, autumn) nutritional value associated with the presence of species found on the subfloor which are at the level of shrubs and greens (blueberries and grasses) of this habitat type (Kanellopoulos et al. 2006).

In Greece brown bears often found in mixed coniferous-broadleaf forests, but also in lower altitudes where oak forests with a solid structure or with gaps predominate (Mertzanis, 1992). Forest habitats are important, because forage is often high caloric and available in these areas especially before denning period. Findings indicated that brown bears use forest habitats, agricultural areas and open habitats. Brown bears prefer forest, agro- forestry and cultivated areas with high values of food availability in all seasons in many studies. Brown bears, adapted to low resource availability during winter and spring (Hellgren 1998), pregnant females did not feed for a long period of the year, thus breeding success depends critically on a pulse in energy availability for fat storage during the hyperphagia period in summer and fall (Mattson et al. 1991, Inman and Pelton 2002).

In the study area bears had access in food categories such as grass from meadows in spring, old hard mast and in summer fruits, berries, and in autumn such beechnuts, oak, nuts, chestnuts and grapes etc were critical for pregnant females that will hibernate during winter. Similar results for food preferences reported from Spain (Naves et al. 2006). However, bears showed strong variations in their habitat selection among individuals (Nielsen et al. 2002). Conflict areas could be correlated with the presence of human activities (orchards, farming, livestock grazing areas) in areas with refuge habitats and food availability. Brown bears show variation to many environmental parameters and habitat use differed among areas and individuals. In Croatia Kusak and Huber (1998), reported that food source is the main factor in bear distribution. ears are attracted to man-made food sources even from long distances due to the smell easily accessible, high calorific value food left exposed by humans.

In Greece, the phenomenon of bears approaching settlements and / or residential areas is observed more systematically in the last 10 years, mainly in Western Macedonia but also in other areas. This is since their population has begun to grow and expand their distribution (Mertzanis, 2012). Seasonal food availability (especially during the summer months) combined to fruit ripening in sectors adjacent to settlements but also the seasonal increase of inhabitants and thus domestic garbage production create the appropriate conditions for bears motivation to concentrated and easily accessible food resources (eg orchards, beehives, vegetables, crops cereals but also household waste in illegal landfills and bins) around or inside in the settlements).

The immediate vicinity of the settlement with the wider forest habitat which while deserted and their use is abandoned by the inhabitants the closer and it becomes more continuous. The reasons that push bears to approach human settlements have not yet fully clarified and are likely to differ from region to region or even between individuals. In general, it has been observed that the majority of approaches performed by juvenile males or females with neonates (Elfström et al, 2014). From all this we can conclude that the presence of lonely, adults close to settlements often indicates the presence of a rich, attractive habitat or lack of food in isolated areas, while the presence of young males and females with newborns in a lower quality environment (Elfström et al, 2014).

C. REPORT OF ACTIVITIES IN ITALY

Modelling area

The bear monitoring programme of the MNP and the LIFE project were extended beyond the MNP territory over five bordering areas (Figure 1). The MNP territory and the extensions are together known as the Bear Monitoring Area (BMA). The extensions are located (Figure 1) in thenorth (TC), the central east (LP-Pal), the southern fringe (AT), the south-western slopes of the MtRotella (Pe) and in the central west (Pac-CG). All but one of the extensions are located at lowerelevations (<1000 m a.s.l.) and consist largely of ploughland. Only the Mt Rotella extension is situated at mid-elevation and mainly forested. The Colledimacine municipality could not be included in the modelling due to late availability of its municipal boundary file.

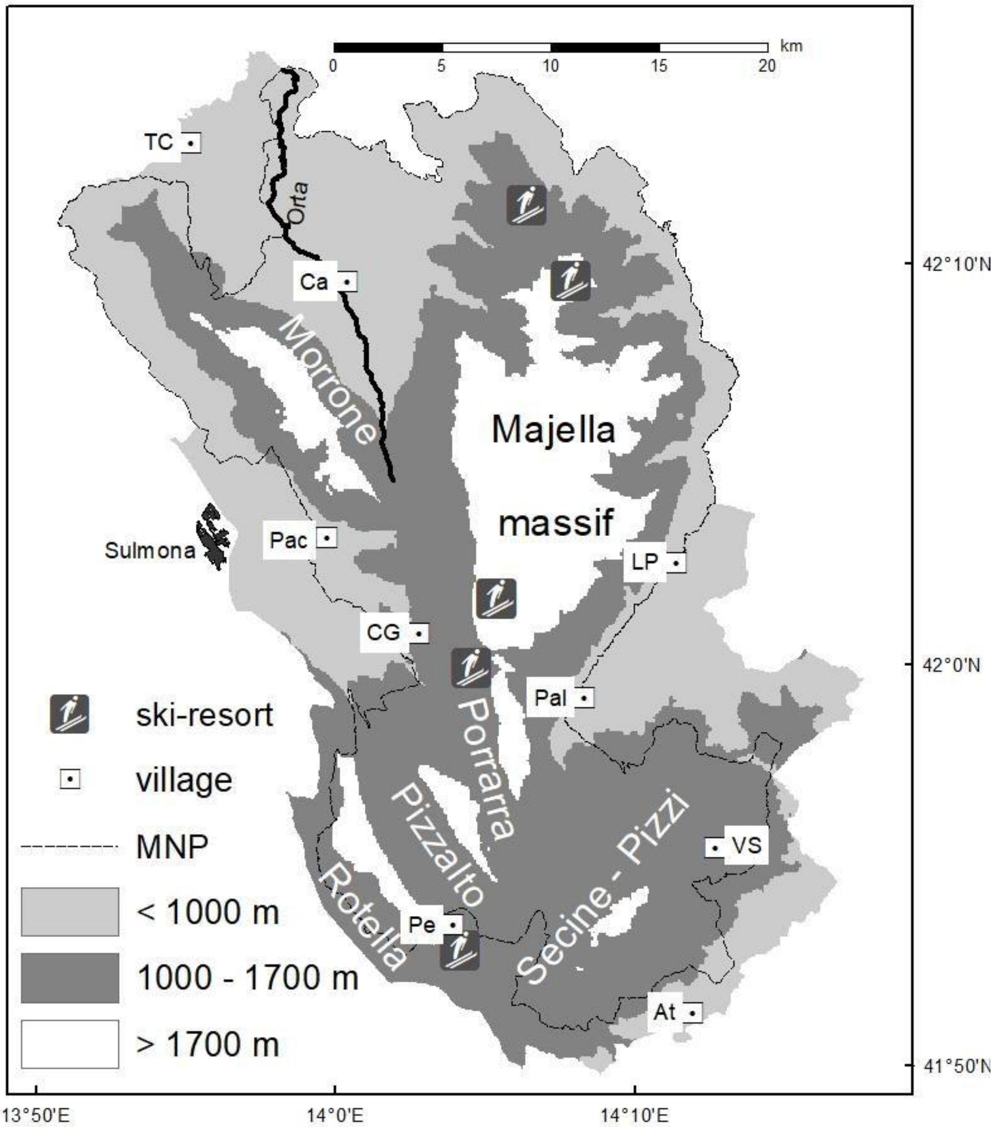


Figure 1. Location of the Bear Monitoring Area (BMA) and Maiella National Park (MNP). Names of ridges in white fonts. Village codes and their number of inhabitants in Table 3.

Over the past decade, bear presence and behaviour have changed in the MNP/BMA. Change is suggested by the presence of 2 female bears with cubs, the detection of hitherto unknown denning sites, the identification of two bears not genotyped previously in the Apennines (Di Domenico, Quattrociocchi & Antonucci 2018) and the widespread raiding of henhouses.

Maxent model

The maxent model was selected across the four national parks by the project to predict risks of human-bear coexistence. The maxent model generates spatial probabilities of presence. In this study, maxent is used to obtain probability of bear presence. High to medium probabilitiesrepresent bear ranges. The probability or risk of damage-by-bear is assessed by inputting damage cases in the maxent model. High to medium probabilities translate in risk zones.Risks for bears are likely to be associated with human infrastructure. To assess these risks, we entered a range of anthropogenic conditions (roads; human population; settlements; land use; ski-infrastructure) and biophysical conditions (water bodies; elevation; slope steepness; forest)into the maxent model. Similarly, the probability or risk maps for damage to henhouses and tobeehives were generated using the same human and biophysical conditions.

The modelling approach and terminology followed the published bear distribution modelsfor Maiella National Park (Gils et al. 2014). These models were based on point samples (n=129) of bear presence from 1996-2010. For the second decade of bear monitoring (2011-2019), a larger sample (n=ca. 600) and damage-by-bear records of henhouses, beehives and herded sheep and cattle were available. All samples were provided by the MNP. The presence samplesof the year 2020 arrived after completion of the modelling. However, the point sample data ofthe genotyped individual bears (2011-2020) could be used to assess the number of individual bears that occupied potential bear ranges over the entire second decade.

For spatial modelling, the same maximum entropy algorithm (maxent v. 3.4.1) was used for both decades. A set of prospective environmental predictor layers of bear occurrence were identified in preceding studies (Adjaye 2011; Gils et al. 2014). In the context of the project aim, we located a suitable human population presence layer (GEOSTAT 2011). All layers for thesecond decade models had to be prepared from scratch because the BMA is larger than the MNP, but poorer in spatially comprehensive environmental geodata (section 2.1). This fresh start with a set of environmental predictor layers allowed the use of a finer spatial resolution (90 m) than for the first decade (800 m). As in the previous study, we applied a point density analysis of bear presence as well as for locations of damage-by-bear cases.

Known bear environment

The MNP as bear environment has been described in Gils et al. (2014). In the current project across four NPs, a number of park features are highlighted for the full understanding of the specific management challenges for human-bear coexistence in the BMA/MNP compared withthe NPs in northern Greece. The MNP (ca. 700 km^2) is inhabited, unfenced and without visitor access control. It contains about 10 villages, 40 hamlets and three winter holiday resorts also frequented during summer. These settlements are connected through a dense public tarred road network with each other and the surrounding road network including the national road SS17 and the freeway A25. Further, a substantial part of the occupied bear range is situated on private farmland. Large stretches of these farmlands have been abandoned and are subject to bush encroachment (Tesfai 2010) and spontaneous reforestation (Gils et al. 2008). Further,inhabitants hold grazing and beech coppicing rights

in a number of locations. At elevations above the formerly and currently cultivated belt, state land prevails, consisting largely of beechforest as well as alpine grass- and shrublands. The historical pastoral summer grazing of alpinepastures has been totally abandoned. However, at mid-elevations limited livestock grazing continues, although at a historically low level. Several sheep and cattle herds are operated by hired shepherds using dogs for herd protection and control. The herd management includes overnight corralling with shepherd dogs to control depredation by wolf and bear. Free roaming flocks of horses and cattle without herders have also been encountered locally in the MNP, particularly at the Mt Morrone as well as in the Abruzzo-Lazio-Molise National Park (NPALM) (personal observation first author).
The BMA/MNP has functioned as sink for migrating male bears from source areas tothe southwest (NPALM) during in the first decade and probably for much of the past century. However, over the second decade female bears with and without cubs were sighted within theBMA/MNP (see section 3.4).

Risks in human-bear coexistence

The risks associated with human-bear coexistence in the BMA from the human perspective are, in order of frequency: henhouse raids, beehive raids, depredation of sheep & calves, pillaging of homestead gardens (fruits and vegetables) and bear-vehicle collisions on the national road SS17located between the BMA and the PNALM. Only, for the henhouse and beehive raids, we had enough case samples to attempt spatial modelling. Bear attacks on humans have never been recorded in the Apennines.
From the bear perspective, the main negative conditions within the MNP may be the disturbances generated by and from the major built infrastructure, especially ski-resorts (Gils et al. 2014). Such disturbances include light and sounds that may discourage a bear to use potential ranges. The nightlife associated with holiday resorts may amplify the impact of the disturbance thus counteracting nocturnality as escape strategy by bears. The national road SS17 at the periphery of the MNP presents a demographic risk for the relatively small bear population in the Central Apennines. Stretches of this unfenced road coincide with the migration corridor between the MNP and the PNALM. Issues and mitigation measures are dealt with comprehensively by the parallel LIFE Safe Crossing project. Poisoning, trapping and accidently shooting of bear in lieu of wild boar have been reported in the Apennines, but not from within the BMA/MNP.

1. Methods

1.1 Materials

The maxent algorithm requires two geodata inputs, namely point presence samples of objects(.csv comma delimited format) as dependent variable and environmental predictor layers (.asc format) as independent variables. The bear presence samples have been subdivided in four seasons based on the date of observation, namely spring, summer, autumn and winter. The raw presence data have been reformatted to fit software specifications. Incomplete and out-of-BMA presences have been removed. The environmental predictor layers are listed and specified in Table 1 (first column). The categories and number of bear samples have been presented in Table2 (first column).

Table 1. Environmental predictor layers, geodata sources and units. red=unpredictive; green=predictive; orange=predictive, but uninformative for potential bear ranges. D=Distance to.

PREDICTOR LAYER	GEODATA SOURCE	UNIT
DEM	SRTM 4.1	m
Slope	DEM/authors	%
Land Cover	http://opendata.regione.abruzzo.it /authors	18 classes
D-Settlement (D-Set)	http://opendata.regione.abruzzo.it	km
D-Ski Infrastructure (D-Ski)	Carta Turistica/authors	km
D-Roads & Paths	MNP	km
Nº Resident persons	GEOSTAT_grid_POP_1K_2011	km^2
D-Rivers	MNP	km
D-Streams	MNP	km
D-Rivers & Springs	MNP	km
D-Springs	MNP	km
D-Water Points & River	MNP	km
Forest & Land Use composite	http://opendata.regione.abruzzo.it/authors	16 classes
Land Use	http://opendata.regione.abruzzo.it/authors	15 classes

The environmental predicator layers have been pre-processed following standard ArcGIS operations including clip, recode, dissolve, union, select, eliminate, Euclidian distance, edit and polygon to raster. All predictor layers in raster format and raster outputs were geometrically matched with the DEM in the environment settings (extent, snap raster and cell size). Within each predictor layer in vector format, the polygons below the size of the smallest mappable unit (Westinga et al. 2020) at the 1: 25 000 scale (15 625 m^2) were eliminated by merging with neighbouring polygons.

Table 2. Predicted bear presence per season (upper part) and risk of damage-by-bear (lower part). Columns show the number of samples (2011-2019) (column 2), the goodness-of-fit of the model (AUC; column 3), the contribution (%) per predictive environmental layer (Table 1) to the model (column 4, 5, 6, 7 and 8), the number of predictive layers (column 9) and the number of Background Points (BP) (column10). The number of damaged henhouses = samples (2011-2019) plus 2018-2019 inventory of henhouses (Brotini, 2019).

BEAR PRESENCE	SAMPLES No	AUC	Cover %	DEM %	Slope %	D-Set %	D-Ski %	Predictor No	BP $.10^3$
Four seasons	590/1	0.79	45	33	22	-	-	3	20
Winter	40	0.87	56	17	-	-	27	3	2
Spring	130/1	0.81	28	29	20	24	-	4	10
Summer	216	0.84	44	38	-	-	18	3	10
Autumn	198	0.85	35	23	14	29	-	4	10
BEAR DAMAGE RISK four seasons									
Beehive	41	0.90	42	20	-	38	-	3	2
Henhouse	75	0.93	-	-	-	100	-	1	2
Livestock	*21*				*Insufficient data for modelling*				

We refrained from using WorldClim data as these showed to be grossly inaccurate for theMNP territory in previously published studies (Gils et al. 2014; Dai et al. 2017). An additional advantage is that we can use a finer spatial resolution (90 m) in modelling than the minimum resolution of WorldClim (800 m). By testing, the land use, vegetation and forest layers (Table 1) were found to be unsatisfactory as individual predictors. The bear models published for thefirst decade had shown that a large number of classes were counterproductive for a well-fitted model. Consequently, the land use map (Table 1) was recoded and generalised from 64 to 15 classes. The forest map (Table 1) was recoded and generalised from 27 to 8 classes. For the white patches without information in the forest layer, a generalised version (8 classes) of the land use map was inserted. This layer has been labelled Forest & Land Use composite (Table 1). The vegetation map of the MNP from 1999 had shown to be a good bear predictor for the first decade (Gils et al. 2014), but does not cover the BMA. Extrapolation of this vegetation mapover the BMA based on visual interpretation of satellite imagery was tested, but showed manyuncertainties that would require extensive ground sampling. An impossibility within the projecttimeline. Instead, the land use map (Table 1) was updated with 3 cover types: juniper, mountainpine and wetland. The juniper and mountain pine patches were copied from the vegetation map of 1999. The wetland mapping units were obtained by visual interpretation of satellite imagery and aerial photographs. We labelled this composite layer as Land Cover (Table 1).

Layers of the various drinking water sources have been prepared, because presenceof springs showed to be positively predictive for bear presence in the southern half of the MNP (Adjaye 2011). The classical human population census data were found unsuitable for the BMA. The census enumeration areas coincide with the municipalities. However, the BMA contains a number of rural upland portion of municipalities with urban portions outside the BMA that contain the majority of the inhabitants. In addition, municipality territories located entirely within the BMA showed rather low numbers of inhabitants, but often concentrated in nucleated villages or hamlets. Therefore, the census per municipality provide unhelpful numbers of inhabitant for our purpose. Instead, we used the GEOSTAT (2011) grid providing spatially disaggregated numbers of inhabitants. Disaggregation was achieved in GEOSTAT with the help of residential buildings as identified on satellite imagery. The boundaries of the built-up area of villages and hamlets was derived from the Land Use map (Table 1) and overlaid on the human population (GEOSTAT 2011).

The samples of bear presence and damage-by-bear cases have been provided by the MNP in excel sheets. The 2011-2019 version in December 2020 and the 2011-2020 version on17 May 2021. The following sample attributes were included in the excel sheets: observation type (sighting, hairs, footprints, camera trap and den), date, coordinates (XY), damage by bears (henhouses/chicken coops; beehives; orchards & homestead gardens; depredationsof livestock), number of individual bears, codes of genotyped individuals, bear type (male/ female, adult, cub), reliability ranking (1-3) of observations and observer (park staff/other). Further, an inventory of henhouses (2018-2019) including damage and presence of fencing in five municipalities was also supplied by MNP (Brotini 2019). Finally, a kml file of the GPS-collartrack of the female bear F1.99 from 17 November-25 December 2020 was made available. GPSreadings were recorded hourly from 17-24 November. From 25-30 November every half hour and in December every three hours. These kml data were used to illustrate bear mobility, but not in maxent modelling to avoid oversampling of this individual bear.

1.2 Methods

The use of the maxent model has been carried out following best practice as published in peer-reviewed, scientific literature (Gils et al. 2014; Duque-Lazo et al. 2016; Zeng et al. 2021). Optionalparameter settings of the maxent algorithm have been selected as follows. All five “Features” were used in tandem. In case of a relatively small number of samples (<60), “Auto features” have been applied. The “Response curve” and “Jackknife” options were used as standard assessmenttool of model output. The “Threshold feature” was disabled when a first run of the maxent model delivered an irregular response curve. The “Replicated run type” named “Bootstrap” was run with 20 replicates. The number of background points was selected in proportion to thenumber of samples (Table 2, last column).
All models were fed with the complete and seasonal sets of bear presence points and environmental layers (Table 1). Within the time frame of the project, we had to forgo to test and compare various filtering procedures of the bear presence point sets (see Discussion section 4.4). Next, we applied stepwise backward elimination of the least contributing layer. The elimination criteria were the lowest “Percent contribution” and/or lowest “Jackknife” valueper environmental predictor (“variable”) as provided in the maxent output. Layers resultingin an irregular response curve or a relatively large Standard Deviation were eliminated aswell. We aimed at a minimum number of predictor layers to reach a model with a goodness- of-fit indicated by an AUC ≥0.8. AUC values may vary between 0.50 and 0.99. An AUC ≥0.8is generally considered to be good. An AUC value of 0.5 means a random distribution, or in other words, none of the used environmental variables is a bear presence predictor. The pointdensity analysis of bear presence was carried out in ArcGIS/Spatial analyst with a 2 km circle radius. The output raster was converted from float to integer in ArcGIS/Spatial Analyst/Math and subsequent into polygons (Raster to Polygon). The point densities were reclassified in three classes for optimal visualisation. The probability and density maps were run three times throughthe neighbourhood filter for smoothing the map image.
Contiguous medium to high probability ranges >50 km^2 were considered to be a potentialbear range. The medium to high density patches as occupied bear range (Gils et al. 2014).

2. Results

2.1 Environmental prediction variables for bear presence

Good models (AUC ≥ 0.8) for bear ranges required 3 or 4 environmental predictors (Table 2), more than the 2-3 for the first decade. The explanation is probably that the best predictor layerof the first decade models, namely the terrain or topography (Gils et al. 2014) was neither available for the entire BMA in 2021, nor could such environmental predictor layer be developedfrom scratch within the project period.

The predictors of bear ranges across the seasons were land cover and elevation (DEM) (Table 2). Both the land use layer and the forest & land use composite resulted in a lower modelAUC than land cover. Slope was a predictor in spring and for year-round presence. Distance-to-settlement and distance-to-ski-infrastructure were mutually exclusive seasonal predictors. The predictive land cover categories were mosaics of agriculture & natural vegetation, permanent grassland/meadows, settlement and wetland. The absence of forest types, including beech forest as bear predictors is striking, because in sharp contrast to the findings for first decade inthe MNP, in the PNALM and Bulgaria (Gavrilov et al. 2016). The explanation is probably the finerspatial resolution of the current models. Further, many of the beech stands at lower elevationare abandoned coppice less suitable for the hyperphagia period in autumn, because of their relatively low mast yields. The difference with Bulgaria may be the legal bear hunt and a bear poaching history (Gavrilov et al. 2015) that causes bears to use forest cover as survival strategy.Elevation predicted higher bear presence at mid-elevation, i.e. between 700-1500 m a.s.l. The response curve of elevation shows a Gaussian, bell-shaped distribution peaking at around 1100m (Figure 2). This elevation peak is located substantially lower than in the first decade (1500 m).For slope steepness applies, the flatter, the better for bears (Figure 2). In the models of the first decade, slope was redundant as predicator, probably because of the coarser resolution of the environmental predictor layers. The distance-to-settlement predicts higher bear occupancies closer to settlements in spring and autumn. In contrast, the closer to ski-infrastructure within about 10 km, the lower the predicted bear presence in winter and summer (Figure 2). A negative impact of ski-infrastructure on bear occurrence was also identified for the first decade.The distance-to-roads and distance-to-settlements were redundant in the models of the first decade.

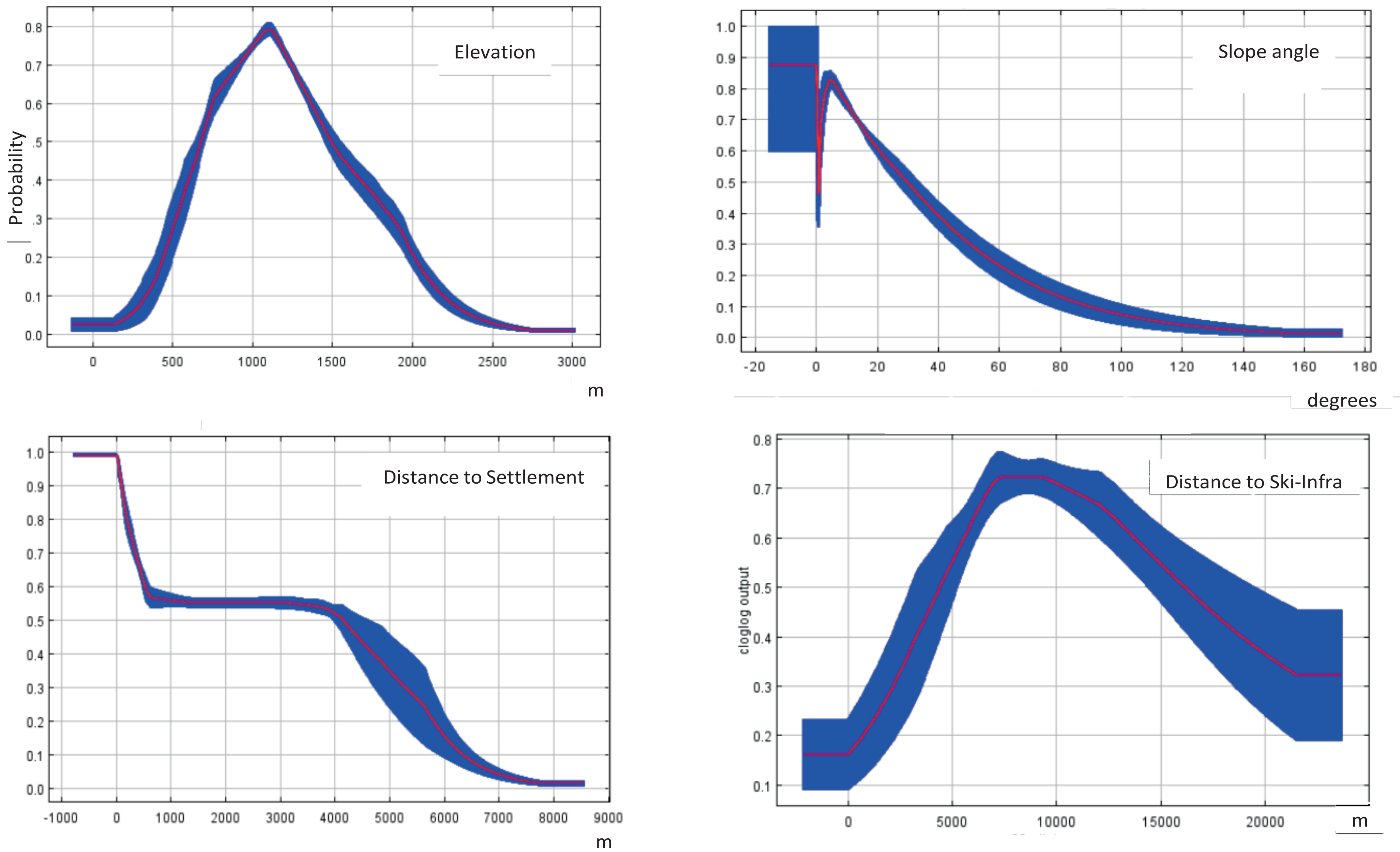


Figure 2. Four examples of response curves (red line) with standard deviati on (blue band). Elevati on (upper left), slope steepness (upper right) and distance to sett lement (lower left) as obtained for bear range predicti on for four seasons over the second decade (2011-2019). Distance to ski-infrastructure during winter (lower right).

Distance to settlement, land cover and elevation combined predicted the damage by bears to beehives (Table 2). The closer to settlements, the more damage cases, particularly in mosaics of agriculture & natural vegetation and grasslands at the lower side of mid-elevations(700-1100 m a.s.l.). Distance to settlement was the sole predictor for damage to henhouses by bears, irrespective of the wider environment (Table 2). Unsurprisingly, the closer to settlements,the more damage cases.
Distances to various water sources, the number of inhabitants per built-up km^2 polygon, the forest & land use composite layer and the land use layer were redundant for models ofthe second decade (Table 2). Distance-to-roads (paved + unpaved + paths) showed the highest contribution to most bear presence models. However, we refrained from using this road variablefor building our final models as it just reproduced the road network. As the roads were not predictive in the first decade and no new roads were constructed, we conclude that either thebear presence sampling strategy or the behaviour of the bear has changed. We discuss this finding below (section 4.1).
In summary, most of the human conditions (local roads, settlements, number of resident humans and land use) were unpredictive, i.e. do not present a risk, for bear presence. The significant exception was the ski-infrastructure that showed a negative impact on bear presenceup to 10 km distance. The presence of bears was generally well predicted by a combination ofbiophysical conditions. These were in order of importance: four land cover types, elevation andslope.

2.2 Potential and occupied bear ranges over the combined seasons

We identified (Figure 3a/3b) three occupied ranges (*green*), an unoccupied, potential range (*red*), a partially occupied, potential range (*dotted red*) and a formerly occupied but currently seemingly unoccupied range (*orange*). The potential bear range over the four seasons combinedinclude (Figure 3a *left*) from north to south, the northern slopes of the Majella massive, the slopes both sides of the Orta valley upstream of Caramanico (Ca), the surroundings of Campo di Giove (CG), the intermountain valleys with bordering forested slopes of the Porrara, Pizzaltoand Rotella ridges (Pe) and most of the south-eastern quarter (Secine-Pizzi) of the BMA roughlybetween Palena (Pal) and the surroundings of Ateleta (AT). The larger low probability areas of bear presence are the northern cultivated zone with dispersed settlement (Tocco da Casauria;TC), the altiplano of the Majella massive and the contiguous upper Porrara ridge, the eastern slopes of the Majella massif as well as the heights and western slopes of the Morrone ridge.

Table 3. Selected villages or hamlets and their codes in the fgures for topographic orientati on purposes. The human populati on (POP) within the compact built-up area was derived from the Land Use map (Table 1) overlaid on the human populati on (GEOSTAT 2011).

CODE	NAME	POP
AT	Ateleta	609
CG	Campo di Giove	805
Ca	Caramanico	1086
LP	Lama dei Peligni	1168
Pac	Pacentro	1168
Pal	Palena	1399
Pe	Pescocostanzo	1143
TC	Tocco da Casauria	2411
VS	Valle del Sole	131

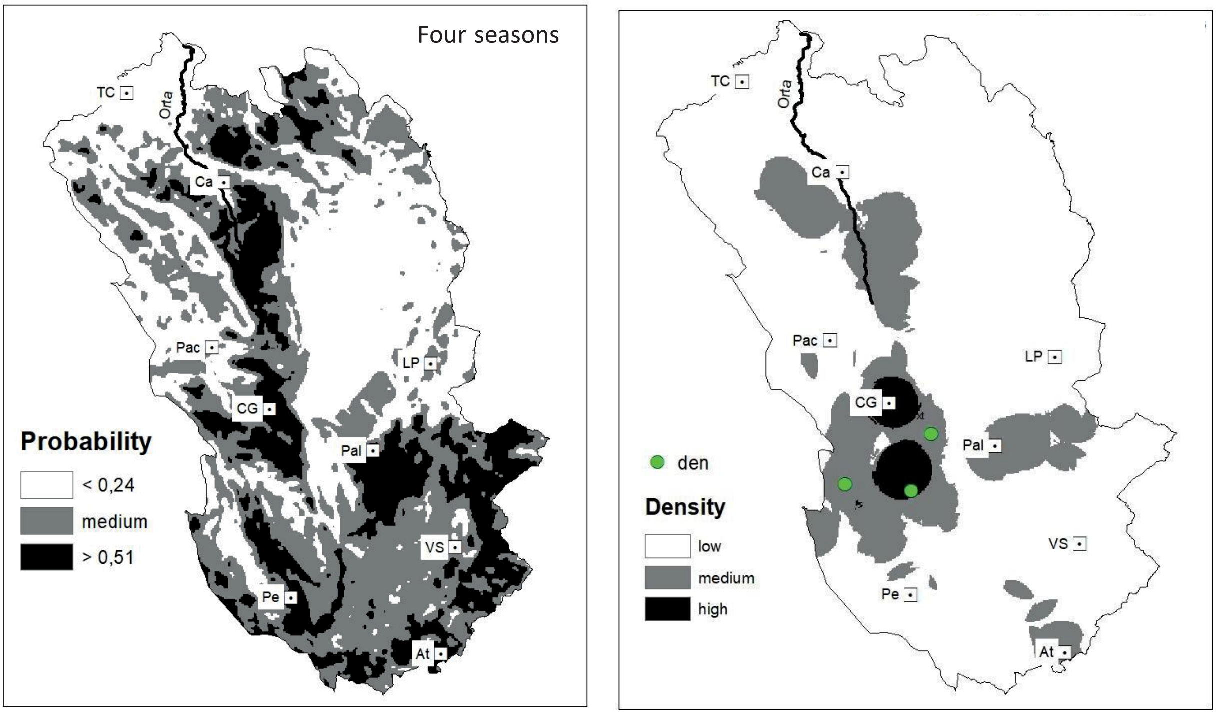
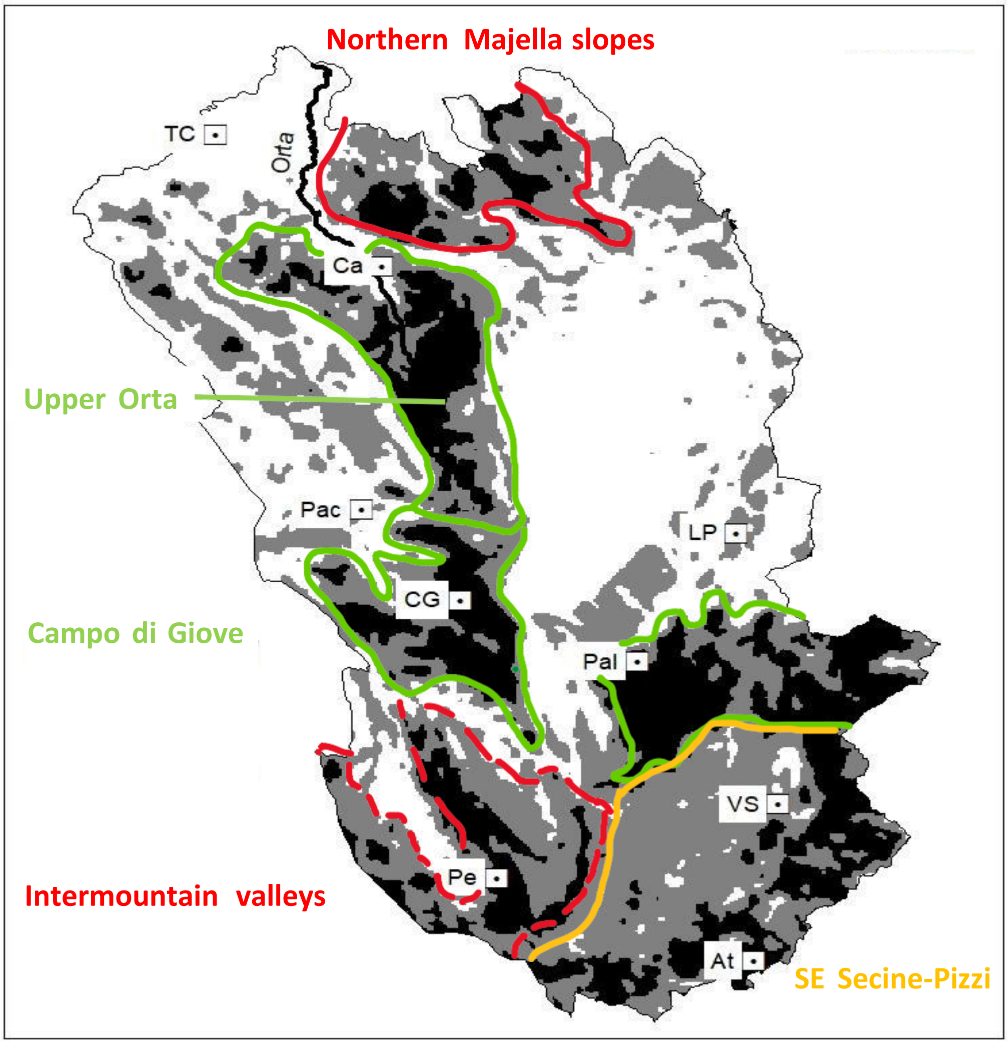


Figure 3a. The predicted probability of bear presence (left) and density of bear presence points for the four seasons combined (right). The conti guous medium-high probability patches indicate a potenti al bear range and the conti guous medium-high density patches an occupied range. The codes for villages and their number of inhabitants are provided in Table 3.

The two high density or occupied bear ranges of the four seasons combined were situatedclose together in the central west of the MNP (Figure 3a *right*). One of the ranges centres at Campo di Giove village (CG) and Le Piane (plain). The second lies to the south in the contact zoneof the Piano cerreto (enclosed or intermontane plain) and the contiguous wooded eastern slopeof the Mt Pizzalto (Carta turistica 2007). Both high bear density ranges consist of agricultural lands at a mid-elevation plain (ca. 1000 m a.s.l.) bordered by wooded mountain slopes (Carta turistica 2007). Cultivation has been largely abandoned in Le Piane, but in the Piano cerreto a portion of the land is still under the plough (first author field observation 2017). Together, these high density bear ranges and the surrounding medium density range are associated with threedens (Figure 3a *right*) of a female bear (F1.99). These occupied bear ranges correspond *grosso modo* with the occupied ranges identified in the first decade (Gils et al. 2014: Figure 8).

Two occupied bear ranges have been identified in the Upper Orta valley (Figure 3a *right*).At the eastern side of the river, the range centers on the agricultural lands (orange legend colour as in Figure 5) at ca. 1000 a.s.l. m and to the east of the San Eufemia village (Carta turistica 2007).West of the river, the lower gentle slopes of the Mt Morrone serve as bear range. The slopes area mosaic of agricultural lands, grassland and deciduous woodland with dispersed settlement (Carta turistica 2007). These two potential bear ranges may be interconnected, although the river Orta canyon is locally hard to cross. These two bear ranges were also identified for the firstdecade (Gils et al. 2014: Figure 8).

Figure 3b. An interpretation of Figure 3a. Three occupied, potential ranges (green), an unoccupied, potentialrange (red), a partially occupied, potential range (dotted red) and a formerly occupied but currently seemingly unoccupied range (orange).



An additional occupied range was identified around Palena village (Figure 3b). The terrainis slightly sloping at 800-1100 m a.s.l. and covered by a mosaic of agricultural lands, grassland and deciduous woodland. Because situated outside the MNP territory, this range was not identified in the first decade. Size wise, this Palena patch could represent a range for a single bear. A small medium density range, too small for a home range was indicated in the far south of the BMA, near the Ateleta village, just outside the MNP. This range was much larger in the first decade (Gils et al. 2014: Figure 8) and situated on slightly sloping, mid-elevation terrain covered with a mosaic of agricultural lands, grassland and deciduous woodland.
The six identified medium-high density or occupied ranges (Figure 3a *right*) coincided *grosso modo* with potential ranges (Figure 3a *left*). However not all potential ranges were occupied (Figure 3b). The unambiguously occupied ranges are the Upper Orta, Campo di Gioveand Palena (Figure 3b: *green*). The major unoccupied potential ranges were situated at the northern Majella slopes and the SE quarter (Secine-Pizzi). The northern Majella slopes were neither identified as potential bear range, nor occupied for the first decade (Figure 3b: *red*). Incontrast, the SE Secine-Pizzi range (Figure 3b: *orange*) was identified as a potential and a denselyoccupied bear range during the first decade (Adjaye 2011; Gils et al. 2014: Figure 8). What hashappened in the southeast to the bear(s) over the past decade? This question was addressed insection 3.3. The intermountain valley patch with Pescocostanzo presents an ambiguous picture(Figure 3b: *dotted red*). While the patch was clearly a potential range in the second decade,it was occupied year-round only in its northern portion. The unoccupied southwest may be related to the seasonal impact of the adjacent ski-infrastructure (see Discussion below).

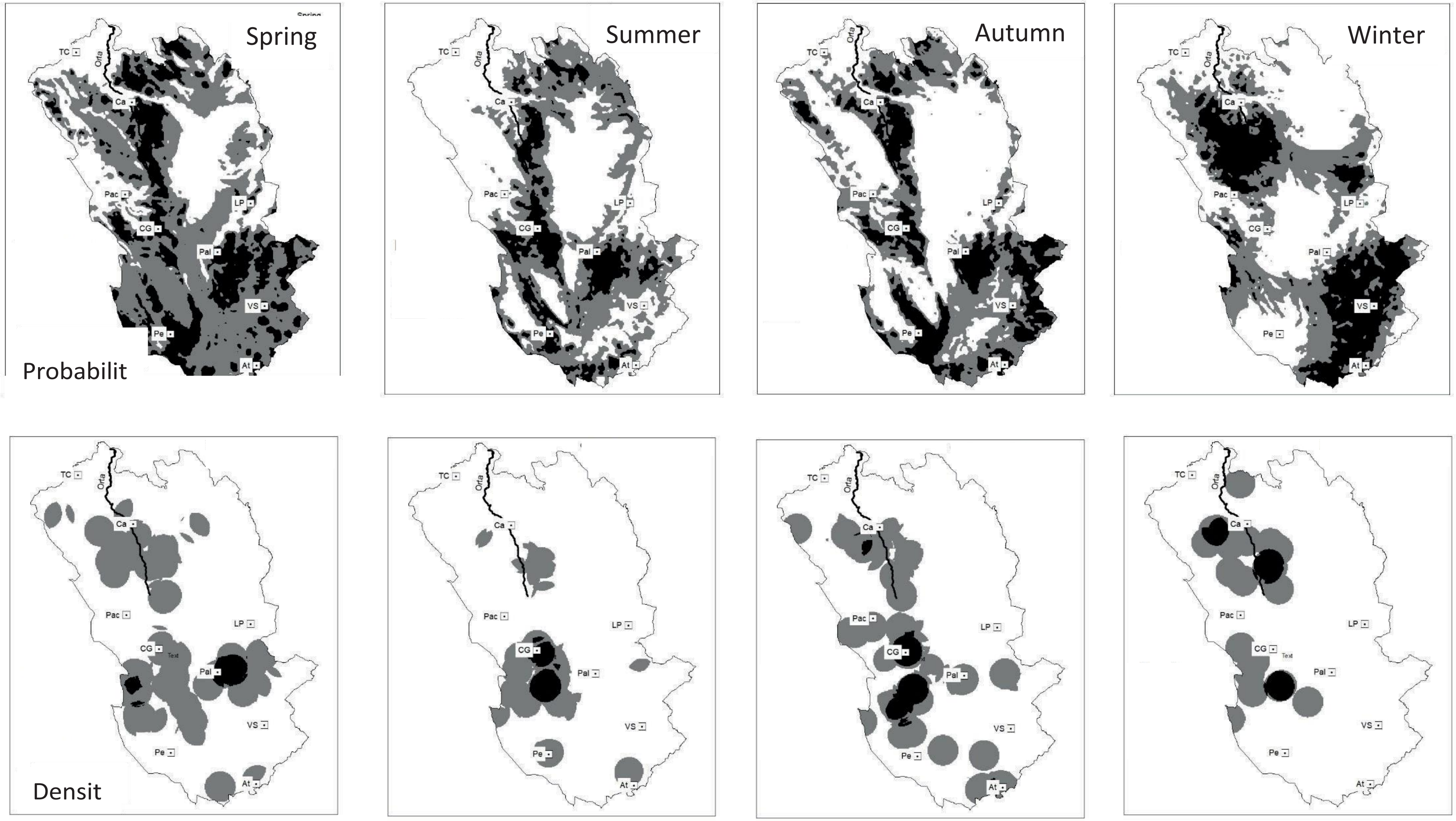


Figure 4. Predicted probability of bear presence per season (top) and observed density of bear samples per season (bott om). Both probabiliti es and densiti es are provided in three classes, low (white), medium (grey) and high (black). The conti guous medium-high probability patches indicate a potenti al seasonal range and the conti guous medium-high density patches an occupied seasonal range.

2.3 Seasonal potential and occupied bear ranges

The potential spring season range (Figure 4) of the bear was larger than those of the other seasons. Spring is the mating season when bears roam widely to trace mating partners. The predicted summer and autumn ranges were similar in both showing large white patches indicating low probability of bear presence. These low probability areas corresponded with the higher elevation of all mountains. For the winter, the high probability areas for bear were the Orta valley and the south-eastern quarter of the BMA. Noteworthy seemed the highly suitable,but isolated patch during winter at the eastern slope of the Majella massive and a possible bearmovement corridor to the upper valley of the Orta.

However, the number of winter samples was on the low side (Table 2) because of hibernation and therefore this prediction maybe lessreliable compared to those for the other seasons.
The medium-high bear density patches or occupied ranges per season have been depictedin figure 4 (*bottom*). A first observation is the apparent gap between the north and the south of the BMA roughly along a virtual line from west to east i.e. from Pacentro (Pa) to Lama dei Peligni (LP). Only in autumn, this gap disappeared.

This central gap was also observed in the firstdecade (Gils et al. 2014: Figure 8). To facilitate closing the gap, the development of a steppingstone corridor by purposive landscaping between the disjunctive northern and southern bear ranges was recommended. Secondly, the medium-high bear densities were more dispersed inspring and autumn but contracted in winter and summer. This could be the result of a winter and summer holiday seasons with a negative impact on the bear range. The contraction ofthe summer and autumn ranges on the western side of the Upper Orta bear range may be associated with a lack of drinking water sources on the Morrone slopes.

The bear(s) seemed to abandon the slope and move closer to the Orta river in the summer. Further, the high winter density in the Orta valley was striking and suggested hitherto unidentified denning sites. Finally,in comparison with the first decade (Gils et al. 2014: Figure 7), the south-eastern quarter of the BMA/MNP seemed remarkably underpopulated over the second decade across all seasons.Under-sampling of bear presence in the second decade could be an explanation. In conclusion,most of the identified occupied potential bear ranges could not support a bear across all four seasons. A considerable seasonal bear mobility within the BMA/MNP seems therefore required.

The only potential bear ranges that was unambiguously occupied during the past two decades as well as across the four seasons are those around Campo di Giove. Therefore, we labelled this the bear hotspot of the MNP/BMA (Figure 3a *right*; Figure 4 *bottom*), more soas it contained three dens of the female bear (F1.99) during the 2016/2017 winter. The bear hotspot contained a relativity small high density spring season range, several summer and autumn ranges and a winter range at close proximity (Figure 5). The background of the Carta turistica (2007) illustrates the mosaic of the ploughland plains, wooded slopes and grassland ofthe bear hotspot.

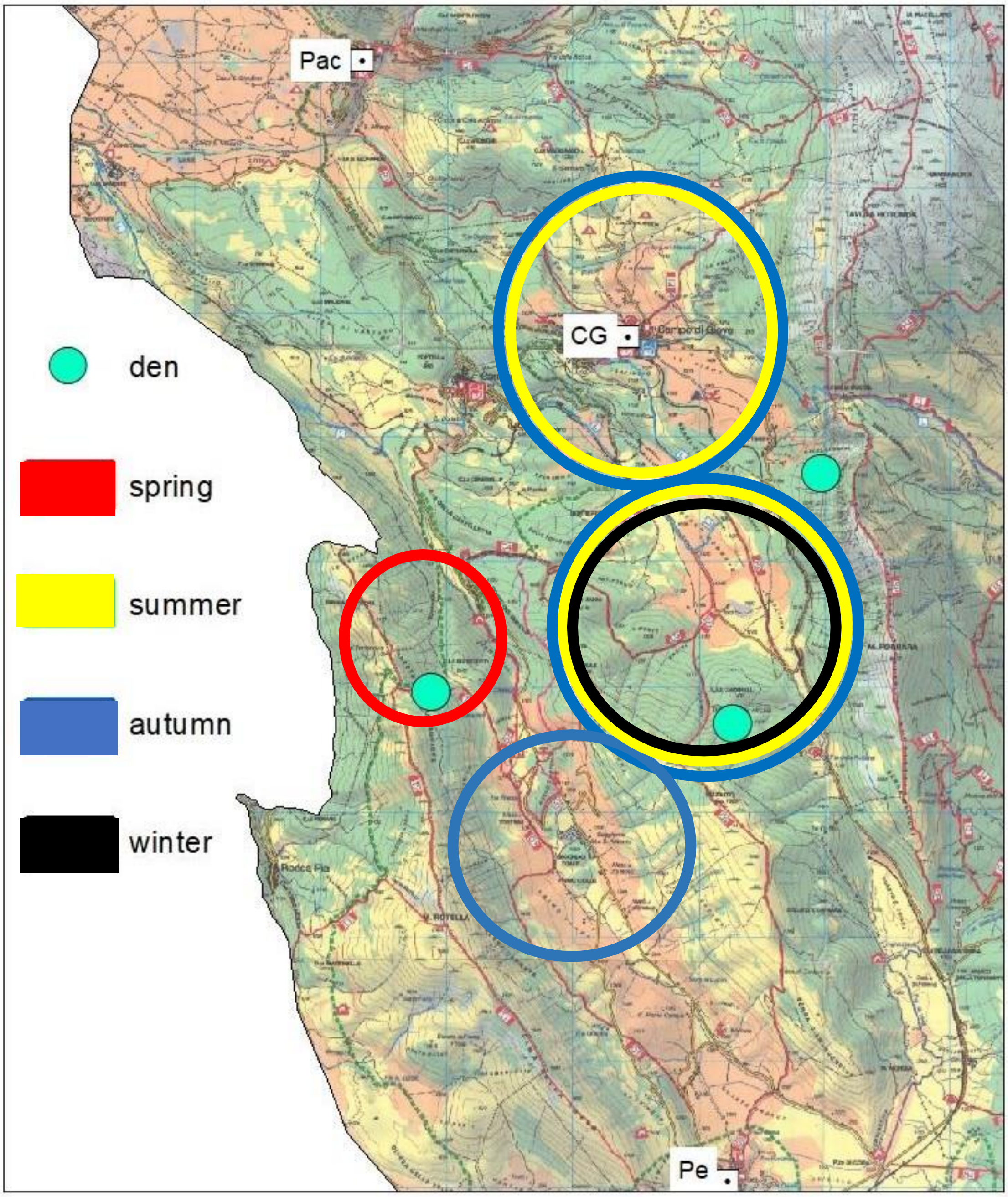


Figure 5. Bear hotspot. Seasonal high density or occupied bear ranges around and south of Campo di Giove. In the background the Carta turistica. The background colours are orange for ploughland, yellow for meadow & pasture and green for forest. The range boundaries have been generalized for visualisation purposes.

2.4 Individual bears and occupied ranges

From 2012-2020, thirteen (13) individual adult bears were genotyped. Per calendar year, the number varied between 1-5 (Table 4). These numbers represent the minimum numbers of individual bears. The number of bears per year corresponds with the estimate provided for thefirst decade (Gils et al. 2014). The female bear F1.99 was recorded every single year starting from 2013. The other female (F1.172) and the thirteen male bears were documented in a singleyear or a few consecutive years, maximally four (M1.93). The latter (M1.93) was roaming all occupied ranges over his four year stay (Figure 6). This large range size corresponds with a reported male bear range in the Balkan (Gavrilov et al. 2015).

Table 4. The genotyped bear individuals per year from 2012-2020.

YEAR	BEAR	No
2012	F1.99; M1.93	2
2013	F1.99; M1.93; M1.95; M1.72	4
2014	F1.99; M1.93; M1.95	3
2015	F1.99; M1.93; M1.104; M1.105; M1.106	5
2016	F1.99; M1.66; M1.101; M1.105	4
2017	F1.99; M1.66; M1.106	3
2018	F1.99; M1.127	2
2019	F1.99	1
2020	F1.99; F1.172; M1.120: M1.128; M1.171	5

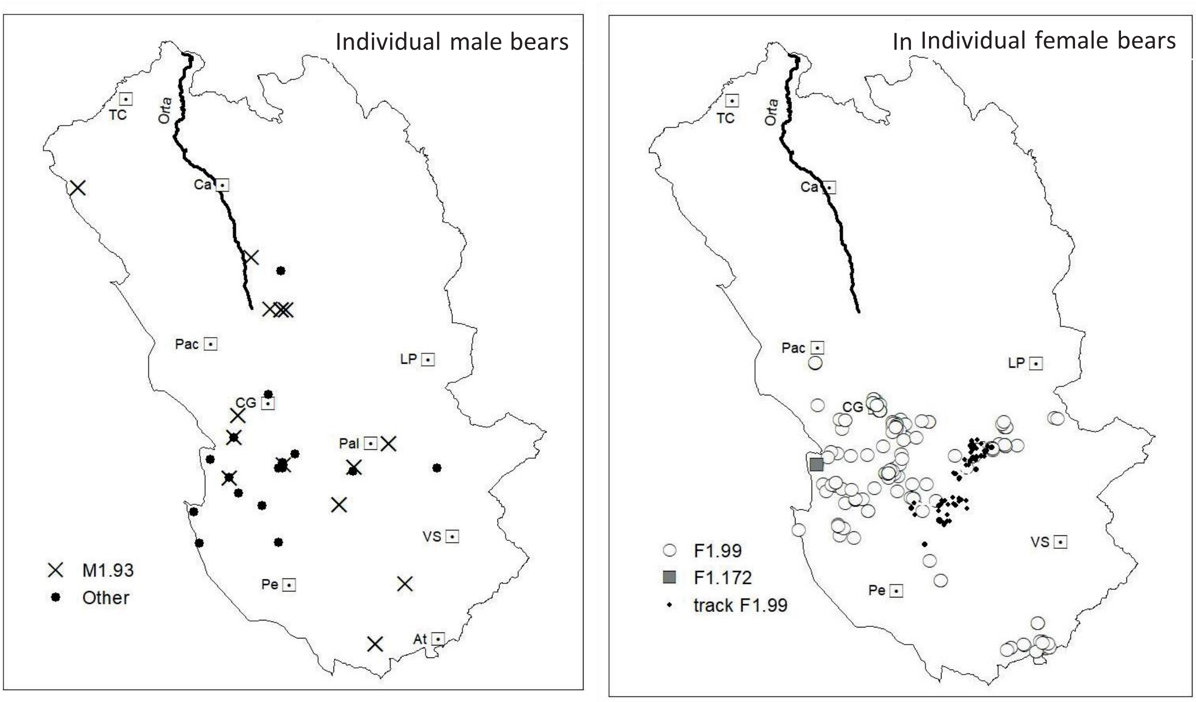


Figure 6. Presence points of individual male bears (left) and two individual female bears (right) that were genotyped during 2012-2020. Most males occurred within the range of the females in the triangle between Pacentro (Pac), Lama dei Peligni (LP) and Pescocostanzo (Pe). Only the male bear M1.93 showed a substantial range beyond this triangle and was therefore individually labelled.

The two genotyped adult female bears represent a novelty for the MNP/BMA (F1.99; F1.171). The first female bear (F1.99) started habitually raiding henhouses, orchards and vegetable gardens in 2015. Garbage bin (bear-proof?) contents were added twice to the menu in 2019. Eventually, this bear became known as "the problem bear" as well as "Peppina" (Salviamol'orso 2015-2017 in English; original in Rapporto Orso Marsanico 2015-2017). This femalebear is also remarkable as raiding has been most frequently attributed to migrant, adolescent male bears elsewhere (Molinari et al. 2014). However, five other female bears showed similar problematic behaviour over the years in the central Apennines (personal communication; Dr Giovanna di Domenico, MNP). The female F1.99 was spotted in the company of a single ortwo adult male bears in spring 2013. Again, male consorts were recorded during summer and autumn 2015 and in spring 2016. In May 2017, once more a male consort was observed. In June2018, the problem bear was sighted with a triplet. She took her triplet with her on henhouse raids until May 2019. Thereafter, she was spotted alone on her regular henhouse raids. The other genotyped female (F.171) appeared in 2020. In addition to the F1.99 female bear with a triplet (2018), an unidentified female bear with twin cubs was sighted (2014). The presence of at least two reproductive females overthe past decade in the MNP/BMA were remarkable because female philopatry was considered strong in the Apennine bear population (Ciucci et al. 2017).

The problem female bear was recorded only in the southern half of the BMA, that is to thesouth of the Orta river watershed at the Passo San Leonardo (1280 m a.s.l.). She moved aroundover the occupied ranges around Campo di Giove and Palena as well as the small patch around Ateleta (Figure 3a). This range is considerably larger than the 60 km^2 reported for female brownbears elsewhere (e.g. Gavrilov et al. 2015). The second female identified (F1.172) in 2020, wasspotted at the Campo di Giove range just within the BMA.

Most of the thirteen genotyped male bears were located in the same ranges as the female problem bear, that is within the southern half of the BMA. Two males (M1.93; M1.66) were sampled in the northern plus southern half during 2012-2015 and 2016-17 respectively (Figure 6). The male bear M1.93 was identified 25 times and associated with raiding a henhouse, a beehive and an orchard.

The location of the records of two females and all genotyped males within the BMA/MNP (Figure 6) suggested that most may have immigrated from a source area to the southwest. Thepotential source areas are the nearby Monte Genzana Alto Gizio Regional Reserve and the moredistant Abruzzo-Lazio-Molise NP (NPALM). Given the avoidance of steep terrain by bear (this study), the immigrant bears probably used the “Genzana” corridor also used by the National Road (SS17). However, this stretch of the SS17 presents a known risk for bear-vehicle collisions,notwithstanding underpasses and overpasses (Rapporto Orso 2015-2017; English: Salviamo l’orso 2015-2017).

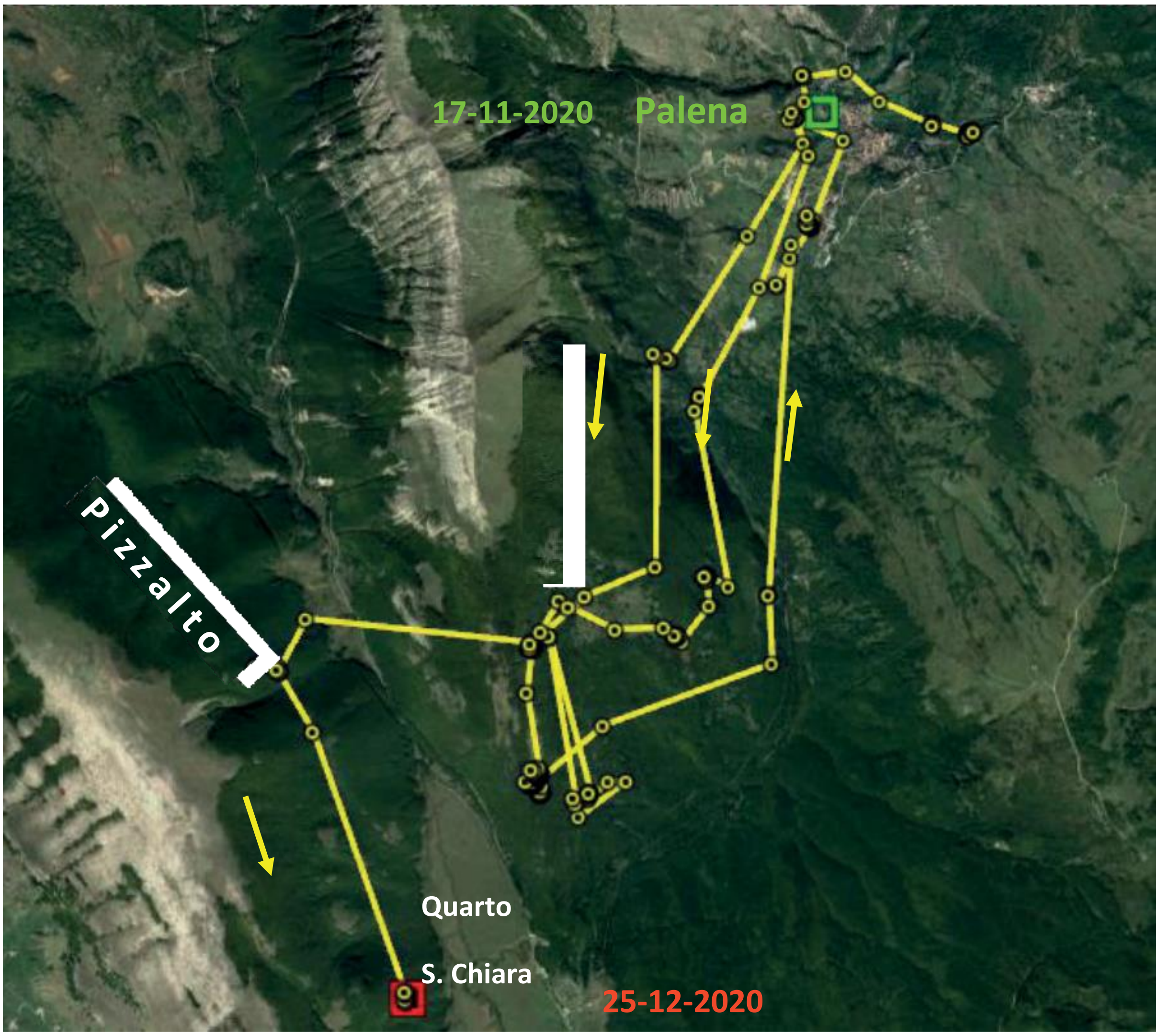


Figure 7. The track record (yellow line) of the GPS-collared female bear (F1.99) from November 17 to December 25 in 2020 between Palena village (green symbol) and surrounding farmland and the forested eastern slope of the Mt Pizzalto (red symbol). The arrows indicate the directi on of movement. See also Figure 6 right.

The female bear F1.99 was captured and GPS-collared at 17 November 2020 after raiding henhouses in Palena. After her release, she continued her habitual raiding. The GPS-track (Figure 7 *right*) showed that she moved between 17 November and 25 December 2020 about 8.4 km over 30 days as the crow flies from the Palena village fringe over the Mt Porrara to theMt Pizzalto (Figure 1; Figure 7). However, she did not follow a direct route towards Mt Pizzalto.She stayed and revisited small woodland patches in the village periphery, each for a few days, obviously using these as stepping stones for her henhouse raids. After leaving the village periphery twice for the extensive woods on the lower eastern slopes of the Mt Porrara above the village farmlands, she kept to the contour line within the woods while avoiding both the valley floor (Quarto S. Chiara) and the alpine heights with ski-infrastructure at the Mt Porrara. Within the woods, she stayed for days in three different locations, presumably suitable for pre- hibernation hyperphagia. From the woods, she returned once to the village periphery (Figure 7,*yellow arrow*). Relative large stretches (1-3 km) were covered at a speed of up to 1,8 km/hour between the stepping stones in the village periphery and the large woodland. At December 19,the female bear left the Mt Porrara slopes

and cruised into the wooded eastern slope of the Mt Pizzalto. A place where she had denned during the winter of 2016-17. On Christmas day (December 25), the GPS signal stopped.
The skewed female/male ratio (2/11) demonstrates that the BMA represents a sink for the Apennine bear population. However, the discovery of three female bears, two of them with cubs in the BMA during the past decade gives hope that a self-sustaining bear population maydevelop in the BMA/MNP.

2.5 Bear damage of beehives

The medium-high probability, or risk for damage-by-bears to beehives applies to practically all mid-elevation (700-1100 m a.s.l.) surroundings of settlements (Figure 8; *left*). The medium- high density of damage cases followed largely the same pattern with the exception of the northern and eastern rim of the Majella massif (Figure 6; *upper right*). The northern rim does contain buildings, but these are largely holiday residences and infrastructure, not smallholdings associated with beekeeping. Also arable land is relatively scarce here. The absence of medium-high density of damage cases in the eastern rim is due to the absence of occupied bear rangesin the second decade (Figure 3). Remarkable is the relatively large area of beehive damage in the occupied bear range of Palena (Figure 6; *centre right*).

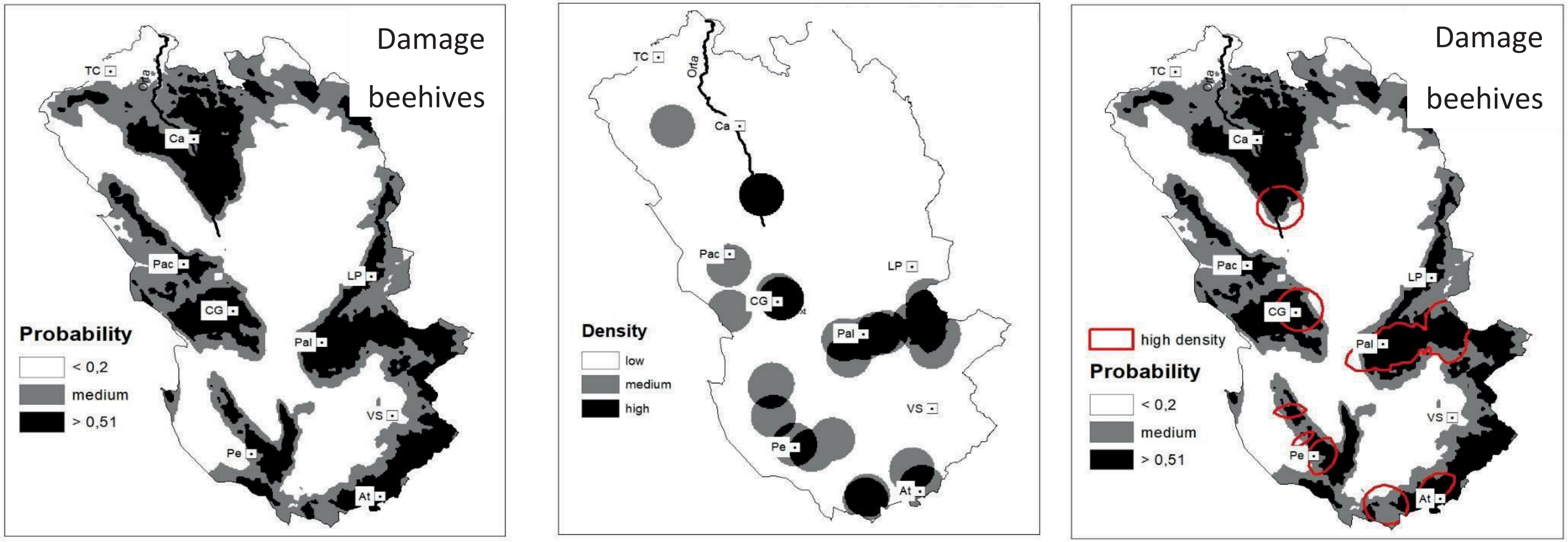


Figure 8. Beehive damage by bear. Probability or risk zones (left), medium to high density patches (centre) and high density patches over probability (right). Both probabiliti es and densiti es are provided in three classes, low (white), medium (grey) and high (black). The conti guous medium-high probability patches are a high risk zone. The densiti es represent the incidences of the past decade

2.6 Bear damage of henhouses

In the BMA, poultry is mostly kept in small backyard henhouses (synonym: chicken coops) by villagers and smallholders. The henhouses contain on average about 15 chicken and may be considered as kitchen garden poultry. A few producers keep over 100 chicken. Most, but not all chicken runs are equipped with iron mesh fences, also known as chicken wire of 1-2 m high. About 20% are protected with bear-proof electric fences (Brotini 2019).
The sole predictive variable for damage by bears to henhouses showed to be the distanceto settlement. Consequently, the model output reproduced the settlement map (Figure 9; *left*). In other words, all settlements show a high risk for henhouse damage by bears. The actual recorded damage density was high around Campo di Giove and Ateleta (Figure 9 *right*). The first is the bear hotspot of the BMA, the second shows an unusually dispersed rural settlement pattern. However, around Ateleta we identified an undersized medium density bear range (Figure 3a right). Nearly all damage to henhouses was caused by the "problem bear" (F1.99) denning in the Campo di Giove range. This problem bear with her cubs raided henhouses habitually throughout the southern half of the BMA, but not in the northern half. Only two male bear (M1. 93; M1.95) were found damaging henhouses occasionally, not habitually.

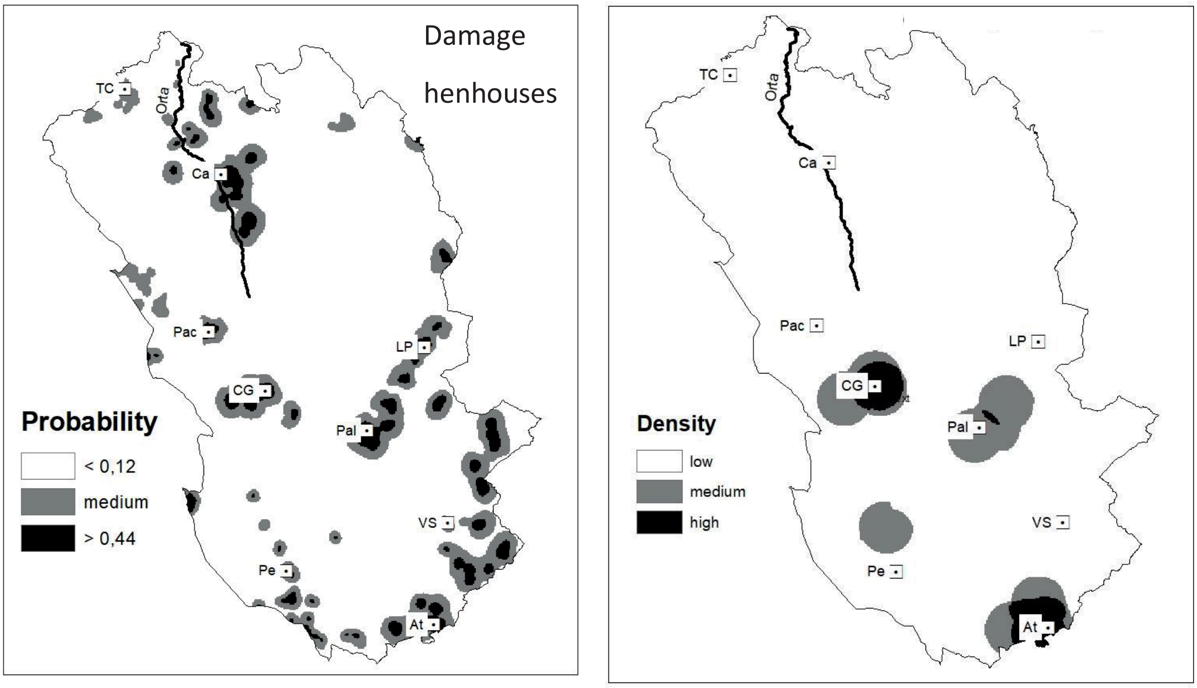


Figure 9. Henhouse damage by bears. Probability or risk zones (left) and density (right). Both probabiliti es and densiti es are provided in three classes, low (white), medium (grey) and high (black). The conti guous medium- high probability patches are a high risk zones. The densiti es represent the incidences of the past decade.

The large number (75) of henhouse damage cases (about 10/year) associated with a single bear (F1.99) is not only excessive for the MNP/BMA, but also in a regional context. Onlyin Carinthia, Austria, the number of damage cases per bear/year (6) came close. In Slovenia (about 1) and Croatia (0,02), the case numbers were substantially lower (Molinari et al. 2016).

3. Discussion

3.1 Bear predictors

The biophysical predictors, land cover and elevation (DEM), were not only the best predictors of bear ranges in the first and second decade, but also of endemic plants in MNP (Gils et al. 2012). Moreover, land cover and elevation contain similar spatial information as climate. This similarity should not be surprising as climate determines to a large extent land cover and elevation drives mountain climate (Gils et al. 2014). The advantage of using land cover and elevation over climate as predictor is twofold. For the first predictors, we have geodata at a fine spatial resolution (90 m) and empirical values for each grid cell. For climate, there are only extrapolated values for each grid cell and that at coarser resolutions (1 or 5 km). Moreover, these extrapolations are based on an extremely biased and a very small set of meteorologic stations far from the research area. Consequently, using land cover and elevation as predictors allows for models delivering spatially more detailed as well as more accurate predictions.

Mosaics of farmland and woodland were found to be an effective predictor of bear presence. That finding opens opportunities to intervene in on-going land cover dynamics. These opportunities include allowing or preventing bush encroachment, reforestation, land abandonment), landscaping by opening up large woodland patches and planting shrubs or trees to optimize the use of existing and potential bear ranges. In contrast to land cover, the other two main bear range predictors, elevation and slope steepness, are an immutable given. The finding that ski-infrastructure has a negative impact on bear presence in winter and summer, raises the issue of mitigation measures to minimize such impacts. Sound and light barriers consisting of evergreen trees & shrubs may be planted at sites selected in the sight lines (ArcGIS) between bear ranges and ski-infrastructure. Further, low-glare light fixtures may be installed or prescribed for the outdoors.

The mobility pattern of the habitually henhouse raiding bear (Figure 9) shows that small woodland patches in close proximity to villages act as stepping stone and base for the raids. Consequently, the removal of the woody cover, fencing the patch, the use of various repellents within and the removal of waste from the patch may be considered. A survey of actual and potential bases for raids may be undertaken.

Distance-to-roads, paved, unpaved and paths combined, was the best positive predictorfor bear presence in most preliminary models, or rather the best predictor of bear observations.In other words, the closer to the road, the higher the probability to observe a bear (sign). This in contrast to the published bear model for the first decade. We wondered whether this differencewas a modelling artefact, for example associated with a more detailed road network layer and/or the finer spatial resolution of the predictor layers of the second decade. However, runninga test model with the first decade bear presence samples and the current more detailed setof environmental predictors, roads disappeared as main predictor for bear presence. Instead, elevation, slope and/or distance to ski-infrastructure delivered a good model. Consequently, we conclude that the predictive power of roads during the second decade was not an artefact of the finer spatial resolution or the more detailed road data. Similarly, but to a lesser extent, distance-to-settlement or settlement was a positive predictor of bear presence in the second decade. In other words, close to settlements the probability of bear presence is relatively large. Again, in contrast to findings reported for the first decade. Also here, after testing with the bear presence points of the first decade and the environmental variables of the second, we found that the predictive power of proximity to settlements was not an artefact of a finer resolution or a more detailed road data. An additional insight was obtained by the comparison of the response curves of the bear distribution models in the first and second decade. The optimal bear presence in the second decade was situated at a much lower elevation in the second decade (ca. 1100 m a.s.l.)

than in the first decade (ca. 1500 m a.s.l.). The implication is that the bear came much closer to the settlements and associated farmlands at this lower elevation. In conclusion, the bear observations in the second decade are truly closer to roads and settlements.

How can we interpret these unexpected results on increased proximity of bears to anthropogenic infrastructure over the past decade? Firstly, observation bias comes to mind. Bears, or signs of bears were observed by people travelling by road and residing in settlements. However, why was there not such an observation bias in the preceding decade? A second hypothesis is that resident bears have lost their shyness for humans and associated infrastructure in the past decade and/or immigrant bears are less shy than the former resident bears. This undoubtedly applies to the problem bear (F1.99) damaging at least 75 henhouses in the BMA. A third explanation would be that the bear range and rural settlements (about 10 villages and 40 hamlets) with their interconnecting roads and farmland coincide spatially. In other words, bears and humans co-habit in the elevation belt between 700 and 1500 m elevation, particularly in open plains and slightly sloping terrain at around 1000 m a.s.l. within a mosaic of farmland and woods. Woods provide food for the hyperphagia in autumn (acorns; beech nut) and dens during winter. During summer, the woods provide daytime shelter for bears against heat and humans. The manmade pastures, meadows and abandoned croplands offer a great variety of seasonal food (e.g. wild oats, herbs, seeds, berries, fruits, rosehips, hazelnuts, bulbs). In sum, historical farming has created a more varied and therefore suitable environment for bear by opening up the forests. In this scenario, roads and settlements were a proxy or predictor for the bear range. Finally, attractive food of human origin was located at recreational sites, in unprotected garbage bins, organic waste disposal sites and landfills, roadside litter, henhouses, beehives and orchards along roads and around settlements. Regular visits to such sites of free lunches may result in habituation and would lead to overrepresentation of bear observations near roads. The latter applies certainly to the problem bear (F1.99).

3.2 Bear ranges across two decades

The bear range in first and second decade of the millennium showed continuity as well as change. The Upper Orta valley as well as the intermountain farmed valley floors and wooded slopes of the Mt Pizzalto and Mt Rotella ridges seemingly each supported occupied bear ranges in both decades. However, the large bear range around the Secine-Pizzi hills suitable for two occupied ranges in the first decade, seemed to have shrunk in extent considerably in the second decade, particularly in summer (Fig 4 *right*). An additional potential and occupied bear range was identified outside the MNP, but inside the BMA from Palena eastwards.

We estimated that the Upper Orta range (Figure 3b) may be occupied at any one time by1-2 bears, the Campo Giove range by 2 bears and the Palena range by 1 bear. The SE quarter with the Secine-Pizzi could host potentially at least two bears and the Intermountain valleys ranges in its current conditions 1 bear. These intermountain range could probably supportan additional bear in the absence of ski-infrastructure, or mitigation of its impact. Similarly,the Northern Majella slopes may host 1-2 bears depending on the future impact of the ski-infrastructure.

3.3 Data quality

Our model tests raised concerns on bear presence sampling being biased by oversampling along or near roads. We assessed the sample data, but could not exclude the possibility of such sampling bias (section 4.1). In order to minimize the possible impacts of sampling bias, we refrained from using the road layers (Table 1) for the generation of our final models.

Recommendations for testing corrections for potential road bias within the model input have been provided. Further, we suggested to rethink the sampling approach for the current decade.
A related concern on the bear presence data was the relatively high number of bear presence points related to the problem bear (F1.99). This bear was the main raider of henhousesand a substantial beehive raider as well. As F1.99 stayed in the vicinity of raided henhouses forthe following days and nights (Figure 7), she was also often sampled in the days after a raid. Just wholesale removal of F1.99 presence points from modelling to limit potential oversampling does not make sense. Similar problematic behaviour of bears has been observed in the Central Apennines (section 3.4). In other words, the high risk will not disappear with the dead or departure of this individual. An assessment of the sensitivity of the model output for a potential overrepresentation of this raiding and highly mobile individual bear, was beyond the time span of this study. A recommendation for a sensitivity test has been provided.
A third concern was the use of bear presence points for spatial modelling irrespectiveof their reliability ranking. The ranking itself is beyond doubt. However, exclusion of the least reliable (class 3) observations would potentially amplify a road and raider sample bias. The twoclasses (1-2) would seem to have required professional attention and consequently correctly earned a high reliability assessment. However, incidental observations by citizen scientist mayhave been less professional, but possibly covered different geographic areas and bears. In otherwords, these citizen scientist observations may have been spatially more diverse. Data filteringbased on the reliability ranking would therefore need some testing for which we provided recommendations. Nevertheless, the number of class 3 samples is rather low and therefore unlikely to have a substantial impacted on the model output on its own. In summary, presence data filtering for road proximity, the raider bear, for equal numbers of samples/season and the reliability ranking may be considered for a follow-up study.

3.4 Deepening and detailing the modelling approach

The bear monitoring data set of the MNP 1996-2020 is a priceless source for further modeling of the enfolding human-bear coexistence. The current data set allows to develop a variety of additional models with relevance for park management. A number of options for deepening and detailing the research is suggested in the next paragraphs.
In terms of environmental predictors, a refined land cover map, a terrain/relief map anda forest/farmland edge map could improve the predictive power of additional models. For the cover map, we suggest to use the Carta turistica of the MNP (2007) as the base, particularly for the cropland, anthropogenic grassland (meadows; abandoned; pasture) and their mosaics.For field verification, the inventory of shrubs with nuts or fruits suitable as bear food would be helpful. The hazelnut, juniper, rosehip (Tesfai 2010) and buckthorn are each locally common and represent a specific seasonal food source for bear. A predictive terrain map for bear ranges may be generated by TPI (Terrain Position Index) in GIS software (ArcMap; QGIS) based on the DEM. Hillshade imagery based on the DEM may also be tested for the purpose. A forest/farmland edge map has already shown predictive value, but only in the southern MNP (Adjaye, 2011) and could be generated based on the Carta turistica, satellite imagery or a combination.
The BMA may be subdivided in 2-6 segments for separate modelling. In some segments, seasonal drinking water availability could show predictive power (e.g. positive in the south; negative at the Morrone). Figure 3b can be taken as a guide for subdivision.

Given additional time, the bear presence point data may be filtered in various ways. For example, use only points outside a road and/or settlement buffer of a few km wide. Further, we could remove or reduce the high number of samples of the “problematic female bear” (F1.99) from the data set. Her appearance and the number of samples resulting from her raiding behaviour may be considered a black swan event that is unsuitable for statistical modelling. Also, the reverse is advised, that is to model the distribution of the problem bear separately. Other variations on bear presence data filtering are thinning, removal of less reliable observations, random removal of samples in numerically overrepresented seasons (summer and autumn; Table 2) to create parity in number of samples across seasons (Gils et al. 2014). Finally, the subdivision of the bear presence data by calendar date into four seasons may be refined by accounting for the weather conditions over the years.

For future bear distribution monitoring, we suggest to rely less on incidental samples.In addition, a systematic sampling strategy may be designed. Sampling pre-set transects for bear scat, hairs, footprints by teams of well-instructed and equipped citizen scientists may be considered. The modelling output of the current study could help in selection of transects.

D. CONCLUSIONS AND CONTINUATION OF THE ACTIVITIES

GREECE

Regarding the questionnaires approach: outcome maybe highlighted as follows: a) bear damage on livestock and apiculture is a clear factor of conflict, b) this problem is more prominent when it comes to cattle and transhumant flocks, c) husbandry methods (surveillance vs unattendance) are of capital importance in losses management/control, d) use of preventive measures (although not as much as expected) is also of capital importance to minimize damage and subsequent conflict, e) the LGDs is among the most traditional and fairly effective preventive measure, f) LGDs losses from poisoned baits is an underlying problem which triggers bear damage and subsequent conflict g) a general dissatisfaction is perceived in regards to the national compensation system mostly in relation to the indemnification criteria and procedure

Regarding the modelling approach: the Conflict areas appear to be correlated with the presence of human activities (orchards, farming, livestock grazing areas) in areas with refuge habitats and natural or human related food availability. Brown bears show adaptive variability in their behaviour to many environmental parameters whereas habitat use differs among areas and individuals. In the investigated sub project areas, a clear seasonality appears in the identified sectors of human-bear conflict (potential or effective) risk. This seasonality spatially differentiates potential or effective bear-human conflict sectors and therefore needs special attention regarding the spatial orientation, intensity and timing of the concrete conservations measures to be implemented by the project.

Summer and autumn seasons appear to exhibit the highest risk of conflict in terms of number of identified sectors in each sub project area.

ITALY

Risks: conclusions and recommendations

The main risks for human-bear coexistence from the perspective of the bear population are associated with the ski-infrastructure including holiday home complexes. This association was already predicted by the models of the preceding study covering the first decade. The bear ranges at high risk from the holiday and ski-resorts are marked in a red colour in Figure 3b. The local roads and permanently inhabited villages and hamlets within the MNP/BMA do not present a direct risk for bears.

The main risk for the bear population in MNP/BMA is located along stretches of the national road SS17. Issues and mitigation measures are dealt with comprehensively by the parallel LIFE Safe Crossing project.

The main risk for the resident human population consist of damage by bears to beehives, henhouses, vegetable gardens and orchards. The risk zones for beehives and henhouses are depicted in black (high risk) and grey (medium risk) in Figure 8 and Figure 9 respectively. The high-medium risks apply to nearly all rural settlements and their environs. For henhouses the predicted high-medium risk zones apply to the built up area (Figure 9). The high-medium risk zones for beehives cover the wider surroundings (Figure 8) as well.

Mitigation measures for the impact of the holiday home and ski-infrastructure on bears and of bears on rural settlement have been suggested. The next project phases will deal with mitigation.

For a good understanding of the identified issues in human-bear coexistence the reader may consider that humans and bears co-habit in the MNP/BMA in a belt between 700-1500 m.This shared elevation belt is a mosaic of cultivated and grazed land on plains and contiguous foot slopes bordered by steeper slopes with forest patches. Above the belt (>1500 m), neither humans nor bears live permanently. Lower down (<700 m), humans use the landscape with such high intensity as to preclude the establishment of a permanent bear population.

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ANNEX : Questionnaires templates:

a) Livestock raisers

Καλλιστώ
περιβαλλοντική οργάνωση
για την άγρια ζωή και τη φύση

QUESTIONNAIRE - Bear damage on livestock - LIFE "ARCPROM"- LIFE18NAT/GR/00782
Initial design: Petridou M., Psaralexi M., Iliopoulos Y, Giannakopoulos Al., Mertzanis Y.

I. GENERAL INFORMATION						
1. Interview basic information - location						
1. Code	2. Date	3. Interviewers name	4. Municipality	5. Village	Stable location	
					6.1. X	
					6.1. Y	

2. Interviewee's information			
1. First Name		5. Regime	6. Telephone number
2.Last Name		A) Permanent	
3.Father's Name		B) Transhumant	
4. Age		Γ) seasonal	

3. Grazing areas - grazing periods (months/ year)							
3.1	start	End	municipality	village	location	X	
						Y	
3.2	start	End	municipality	village	location	X	
						Y	
3.3	start	End	municipality	village	location	X	
						Y	

4. Flock composition							
1. # goats		2.# sheep		3. cattle		4. # calves	
1.1 breed:		2.1 breed:		3.1 Breed:			

5. Flock surveillance			
1.Persons total	2. Owner	3. assistant (1)	4. assistant (2)
	1. flock attendance at stable	1. flock attendance at stable	1. flock attendance at stable
	2. occasional attendance at grazing	2.occasional attendance at grazing	2. occasional attendance at grazing
	3. Continuous attendance at grazing	3. Continuous attendance at grazing	3. . Continuous attendance at grazing

6. Flock overnight: type of infrastructure - surveillance					
A. Summer period			B. Winter period		
1. Infrastructure	2. fencing	3. shepherd overnight	1. Infrastructure	2. Fencing	3. shepherd overnight
1. none	1. provisional	1. Yes	1. none	1. provisional	1. Yes
2. provisional	2. stone/concrete	2. No	2. provisional	2. concrete/stone	2. No
3.building	3. mesh <1.5m	3. occasionally	3. building	3. mesh <1.5m	3. Occasionally
4. fence	4. mesh>1.5m	4. other	4. fence	4. mesh >1.5μ	4. Other

[1]

QUESTIONNAIRE - Bear damage on livestock - LIFE "ARCPROM"- LIFE18NAT/GR/00782
Initial design: Petridou M., Psaralexi M., Iliopoulos Y, Giannakopoulos Al., Mertzanis Y.

7. Unattended livestock overnight? (especially calves)	
1.Yes 2. No 3. Other:	1. Yes 2. No 3. Other:

8. Dead livestock management
1. combustion
2. burial
3. left in the grazing spot
4. left out of stable
5. consumed by LGD's
6. fed to LGD's
7. buried according official protocol
8. Other

II. PREVENTIVE MEASURES

9. LGD's:				
1. Matures:		**2. LGD's origin**	**3. Foreign breeds?**	**4.networking with other livestock breeders**
a. ♀:	**b.** ♂:	1. local:	1. No	1. no
		2. From Other area	2. Breed/number:	2. locally
c. pups:				3. regionally:

10. LGD's training			
1. Pups training	**2. Contacts with humans?**	**3. Attacks to humans;**	**3. Other comments**
1. Nothing specific 2. training by other adult LGD's 3. in enclosure with young livestock 5. commands	1. No (impossible to catch) 2.only with owner & shepherd 3. Family 4. Visitors	1. No 2. Rarely 3. Often	

11. LGD's behavior - efficiency				
1. Follow flock?	**2. Stay overnight nearby flock?**	**3. attacks to hunting dogs?**	**4. reaction to bear presence**	**5. Other comments**
1. yes, all 2. yes, most of them 3. few of them 4. No	1. yes, all 2. yes, most of them 3. few of them 4. No	1. No 2. Occasionally 3. Yes, always 4. killing behavior	1. no perception 2. only barking 3. attack without physical contact 4. physical contact/clash 5. bears injured/killed	
6. guard without attendance	**7. LGD's seen during interview?**			
1. Yes 2. No	1. Yes, all 2. Yes, a few 3. No			

12. LGD’s loss from poisoned baits			
1. Frequency	**2. Incentives**	3. Quantitative data	
1. Rarely 2. regularly 3. on a yearly basis	1. fox eradication 2. bears/wolves eradication 3. competition with hunters 4. stray dogs 5. randomly-garbage 6. local conflicts 7. Other:	**3.1 Period**	**3.4 Season**
		3.2 # Total number of lost dogs	**3.5 Last incident**
		3.3 # number of incidents	**3.6 # number of lost dogs**
4. Types of p. baits	1. parafine capsules 2. **pieces of meat** 3. minced meat 4. sausage	5. anti-rat poison 6. fish 7. internal organs 8. dead livestock	7. other

13. Livestock loss from natural causes	
1. yearly average :	
2. Main causes (diseases, accidents etc..):	

14. Other preventive measures?	
1. Lights 2. El. Fences 3. Other	1. Lights 2. El. Fences 3. Other

b) Beekeepers

Καλλιστώ
περιβαλλοντική οργάνωση για την άγρια ζωή και τη φύση

Questionnaire on bear damage on beekeeping production - project LIFE "ARCPROM"

Design: Petridou M., Iliopoulos Y., Psaralexi M., Mertzanis Y.

I. Info on interview location						
1. Code	2. Date	3. Interviewer	4. Municipality	5. village	6. location	
					6.1. X	
					6.1. Y	

II. Info on interviewee			
1. First name		5. Regime	6. telephone No
2. Last name		A) permanent	
4. Age		B) transhumant	
		Γ) other	

III. Size of exploitation			
1. No beehives		2. Insurance	1. Yes 2. No 3. Other:
3. Association affiliation	1. Yes 2. No	4. Association Name:	
5. Status:	1. Professional 2. Amateur 3. Main profession:___________________________		

IV. Locations of beehive unit				
	5.1 Location 1	5.2 Location 2	5.2 Location 3	5.2. Location 4
1.Municipality				
2. Village				
3. Locality				
4. X				
5. Y				
6. Starting period				
7. ending period				
9. land Ownership	publ. comm. prv.	publ. comm. prv.	publ. comm. prv.	publ. comm. prv
10. Fencing	◻ mesh ◻ wooden ◻ E/F ◻ NO ◻ Other	◻ mesh ◻ wooden ◻ E/F ◻ NO ◻ Other	◻ mesh ◻ wooden ◻ E/F ◻ NO ◻ Other	◻ mesh ◻ wooden ◻ E/F ◻ NO ◻ Other
11. Fence height	<1.5 >1.5	<1.5 >1.5	<1.5 >1.5	<1.5 >1.5
13. domestic power	YES NO	YES NO	YES NO	YES NO
14. Other deterrents	◻ lights ◻ propane canon ◻ stripes ◻ other	◻ lights ◻ propane canon ◻ stripes ◻ other	◻ lights ◻ propane canon ◻ stripes ◻ other	◻ lights ◻ propane canon ◻ stripes ◻ other

[1]

Questionnaire on bear damage on beekeeping production – project LIFE "ARCPROM"

Design: Petridou M., Iliopoulos Y., Psaralexi M., Mertzanis Y.

V. E/F Description			
1. Brand/Company			
2. Type	☐ mesh/net ☐ wire strands		
3. poles height:		**4.number of lines**	
5. height of upper stand:		**6. height of lower strand:**	
7. distance between wires:		**8. distance between poles:**	
9. Power:	Mixed: ☐120V ☐220V	Battery: ☐9 V ☐12 V	
10. Solar panel	☐ Yes ☐ No	**Power:**	____________Watt
11. Energizer:	_____ to ______V __________to _________A		
12. exploitation surface:	___________m^2 / _____ m x ________m		
13. Maintenance	☐ regular ☐ sporadicly ☐ rarely		
14. acquisition	☐ purchase ☐ subsidy ☐other _______________		
15. When;			
16. Period of the year of operation	from _________ to ____________		
17. when started using E/F;			
19. Usefulness;	☐ Yes ☐ No ☐ N/A		
20. Decrease of damage?	☐ Yes ☐ No ☐ N/A		

VI. Losses from bear damage						
	2019		**2018**		**2017**	
	location:	**location:**	**location:**	**location:**	**Location:**	**Location:**
1. Municipality						
2. Location						
3. season/period						
4. No of beehives						
5. No of attacks						
6. with of without E/F	Y N	Y N	Y N	Y N	Y N	Y N
7. Damage frequency	Often ☐		occasionally ☐		rarely \☐	
8. No of damaged beehives						
9. No of declared damage						
10. Compensation						
11satisfied by compensation:	**A. High B. Average C. poorly D. At all** **reasons:**					

Καλλιστώ

Questionnaire on bear damage on beekeeping production - project LIFE “ARCPROM”

Design: Petridou M., Iliopoulos Y., Psaralexi M., Mertzanis Y.

VII. Bear presence

	Latest observation	FWCOY/ FWY	Tracks/scats	Den/ denning site	Day bed	Dead ind.	other
Village/location							
X							
Y							
date							
Adult(s)							
Young/ yearlings							
Type of info	D. Ind.	D. Ind.	D. Ind.	D. Ind.	D. Ind.	D. Ind.	D. Ind.

** Possible cause of death	Hunting	Drive hunt	poison	Damage/retaliating kill	Traffic fatality	other:

*** autopsy made?	No:	Yes:	Who:

Bear population trends (last years)	increase	decrease	Stable	**Bear presence in the area**	
				permanent	Sporadic

c) Farmers (cultivators)

Καλλιστώ
περιβαλλοντική οργάνωση για την άγρια ζωή και τη φύση

QUESTIONNAIRE - Bear damage on farm production (cultivations) - LIFE "ARCPROM"

Initial design: Petridou M., Psaralexi M., Iliopoulos Y. Mertzanis Y.

I. Interview basic information - location				
1. Code	2. Date	3. Interviewers name	4. Municipality	5. Village

6. Location		6.1 X		6.1 Y	

II. Interviewee's information			
1. First Name		5. Main Profession	6. Telephone No
2. Last Name			
4. Age			

III. Bear presence							
	Latest observation	FWCOY/ FWY	Tracks/scats	Den/ denning site	Day bed	Dead ind.	other
Village/location							
X							
Y							
date							
Adult(s)							
Young/ yearlings							
Type of info	D. Ind.	D. Ind.	D. Ind.	D. Ind.	D. Ind.	D. Ind.	D. Ind.

** Possible cause of death	Hunting	Drive hunt	poison	Damage/retaliating kill	Traffic fatality	other:
*** autopsy made?		No:	Yes:	Who:		

9. Bear population trends (last years)	increase	decrease	Stable	10. Bear presence in the area	
				permanent	Sporadic

IV. Losses due to bear damage				
	Cultivation plot 1	**Cultivation plot 2**	**Cultivation plot 3**	**Cultivation plot 4**
1. village				
2. location				
3. X				
4. Y				
5. type of cultivation				
6. surface (ha)				
7. total No of trees				
8. damage extent				
9. No of damaged trees				
10. year				
11. Season				
12. Frequency				
13. Fencing	◻ mesh ◻ wooden ◻ E/F ◻ no ◻ other	◻ mesh ◻ wooden ◻ E/F ◻ no ◻ other	◻ mesh ◻ wooden ◻ E/F ◻ no ◻ other	◻ mesh ◻ wooden ◻ E/F ◻ no ◻ other
14. fence height	<1.5 >1.5	<1.5 >1.5	<1.5 >1.5	<1.5 >1.5
15. Effectiveness	YES NO	YES NO	YES NO	YES NO
15. Other deterrents	◻ lights ◻ propane canon ◻ stripes ◻ other	◻ lights ◻ propane canon ◻ stripes ◻ other	◻ lights ◻ propane canon ◻ stripes ◻ other	◻ lights ◻ propane canon ◻ stripes ◻ other
16. Device Effectiveness				
16. Damage declared	YES NO	YES NO	YES NO	YES NO
17. Compensation	YES NO PEND.	YES NO PEND.	YES NO PEND.	YES NO PEND.
18. Satisfied/compensation system?	A. high B. average Γ. low Δ. Not at all Reasons:			

[2]