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Cartarea habitatelor și determinarea capacității de suport pentru principalele sisteme hidrografice din Muntenia, în contextul refacerii arealului istoric al speciei *Castor fiber* în România

Habitat mapping and determining the carrying capacity for the main hydrographic systems from Muntenia, in the context of restoring the distribution range of the Eurasian beaver in Romania

REZUMAT/ABSTRACT

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Vă mulțumim.

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INTRODUCTION

The species Castor fiber, commonly known as the European beaver or simply beaver, was among the group of species that disappeared during the modern era. The last documented presence of this species in Romania dates back to the year 1824 when a Transylvanian pharmacist mentioned having sent several beaver specimens to Budapest for naturalization purposes (Nania, 1991).

Across its entire range, the species experienced a significant decline starting from the 15th century, with the lowest point in population recorded during the 19th century. It is estimated that around 1200 individuals persisted in eight distinct nuclei located in France, Germany, Poland, Ukraine, Norway, Belarus, Russia, and Mongolia. (D. Halley et al., 2012a; D. J. Halley et al., 2021; D. Halley & Rosell, 2003).

Thus, the species disappeared from the majority of European countries, with the primary cause being excessive hunting and trapping for fur and "castoreum," a substance secreted by the anal glands (Graham et al., 2022; Iso-Touru et al., 2020; Smeraldo et al., 2017a; Žbogar et al., 2022). There are also sources that mention other contributing factors to the extinction, such as the degradation of specific wetland habitats, which, in some European states, were converted into agricultural lands or integrated into residential areas (Bajomi, 2011; Nania, 1991; Remm et al., 2018).

The reintroduction of the beaver in Romania took place between 1998 and 2003 as part of a European effort to restore the species' range, achieved through the import of individuals from Bavaria (Germany). The reintroduction nucleus consisted of a total of 182 individuals grouped in families and solitary individuals. As hydrographic systems for the reintroduction, the rivers Olt, Ialomița, and Mureș were chosen from a larger number of watercourses, and all necessary preparatory actions were undertaken (Ionescu et al., 2010).

The population growth of the species has led to an expansion of its range, encompassing both the main course of rivers subject to reintroduction efforts and numerous tributaries. It was during this period that the number and scale of conflicts escalated rapidly. Along the tributaries, beavers constructed dams to improve their living conditions, resulting in the flooding of lands, access routes, and the felling of trees along the riverbanks. In favorable areas, the increasing beaver population led to a proliferation of burrows and galleries, occasionally causing damage to protective dikes and other hydro-technical structures essential for safeguarding the population against floods.

Consequently, the present study serves as a continuation of past endeavors, contributing to the organization and implementation of a comprehensive mechanism, namely the management of a protected species, encompassing all obstacles and challenges inherent to this task.

Chapter 1. PURPOSE AND RESEARCH OBJECTIVES

The purpose of this research is to assess the carrying capacity of the environment for the main hydrographic systems in the Muntenia region, with the aim of restoring the historical range and maintaining a favorable conservation status of the Castor fiber species at the national level.

Objectives:

Obj.1. Critical review of relevant literature;

Obj.2. Determination of habitat suitability for beavers to facilitate the restoration of the species' historical range in the historical region of Muntenia;

Obj.3. Calculation of carrying capacity for the main hydrographic systems in the historical region of Muntenia;

Chapter 2. CRITICAL REVIEW OF LITERATURE

2.1. Population Size and Distribution of the *Castor fiber* species in Eurasia

Although the species was on the brink of extinction at the beginning of the 20th century, the remaining eight refuge nuclei in Eurasia served as a starting point for the restoration of distribution and population size.

Through the implementation of conservation measures, coupled with concerted repopulation efforts in numerous European states, the population size experienced a rapid increase. From a historical low of approximately 1200 individuals, the species' population expanded to around 1.5 million specimens within a century (D. J. Halley et al., 2021).

The presence of the Castor fiber species on Romanian territory is substantiated by numerous pieces of evidence. On one hand, there are fossil remains, and on the other hand, the native terms for the species, such as "breb" (Romanian), "hod" (Magyar), or "biber" (German), and their derivatives like "brebenă," "brebină," "breboaie," "hodișă," "hodoșă," "brebeneț," "brebenel," "brebișor," "hodișel." These have formed the basis for toponyms, hydronyms, or family names (Filipașcu, 1969; Ionescu, 2006; Nania, 1991).

Tab. 1 Situația actualizată a populației castorului eurasiatic în principalele statele din Europa și Asia (Bouroș et al., 2022; Czabán et al., 2018; D. J. Halley et al., 2021; Kodzhabashev et al., 2023; Pucci et al., 2021)

The updated status of the Eurasian beaver population in the main states of Europe and Asia

State	Extinction year	Population size year/individuals
England	18th century	2019/150
Austria	1869	1990/7600
Belgium	1848	2019/2200
Belarus	Relict population	2018/51100
Bosnia	No data	140
Bulgaria	1850	450-600
Czech Republic	1876	2016/6000
Croatia	1857	2016/600
Denmark	11th century	2018/252
Switzerland	1820	2016/2800
Estonia	1841	2018/18000
Finland	1868	2019/4500
France	Relict population	2018/14000
Germany	Relict population	2018/35000

State	Extinction year	Population size year/individuals
Italy	1541	2021/>2
Latvia	1870	2016/150000
Lithuania	1938	2019/121000
Luxembourg	No data	2018/75
Moldova	No data	2021/>2
Mongolia	Relict population	2018/800
Norway	Relict population	2020/80000
Holland	1826	2019/3800
Poland	Relict population	2018/124622
Portugal	1450	0/2018
Russia	Relict population	2019/622000
Scotland	16th century	2018/547
Serbia	1903	2017/240
Slovenia	1750	2017/400
Slovakia	1858	2016/9600
Spain	17th century	2017/650
Sweden	1871	2016/130000
Wales	16th century	2019/15
Ucraine	Relict population	2013/46000
Hungary	1865	2018/>4000

2.2. Historical Range of the Castor fiber species in Romania

2.2.1. Toponymic Evidence

Toponymic sources in Romania provide evidence of the coexistence of the Castor fiber species with humans and highlight its significance for the local population. These sources are numerous and extensively documented in works published in the 20th century (Filipașcu, 1969; Nania, 1991).

In Muntenia, there are place names such as "hotarul brebonei," "podul brebului," or "hotarul hodobenilor," which originate from the root "hod." In the 16th century, settlements like Hodopeni and Brebine are mentioned in writings, but one of the most renowned localities in Muntenia is Brebu in Prahova County, which is referenced in numerous historical texts. Legal documents from the same period mention individuals like Mănea from Brebina, Stanciu from Brebin, Albul from Brebina, along with Oprea from Brebi. In Teleorman County, on the banks of the Vedea River, there is still a locality called Brebina, attesting to the presence of beavers in the past. Additionally, "vâlceaua Brebenu" is mentioned. In the Dâmbovița Valley, the mountain Brebul is referenced as one of the few names that recall the presence of beavers in the mountainous area. In the same county, the stream Brebina is mentioned, and in the vicinity of the Crângurile commune, there is a tributary of the Argeș River

named Valea Brebina, as well as local names like "Rosătura Brebina" and "Zăvoiul Brebina." On the left bank of the Prahova River, north of Sinaia, "Poiana Brebenilor" is mentioned, while in Argeș County, near the locality of Bogați, one can find the hill and valley of Brebeneț (Filipașcu, 1969; Nania, 1991).

2.2.2. Hydronyms

Out of approximately 9600 names of water bodies, only a small percentage (0.25%) can be traced back to the popular names of the studied species, including variations in Romanian, Hungarian, and German (Apele României - GIS vector database).

Among these, the majority (66.7%) originate from the popular Hungarian name (e.g., "Hódos pataka" - Stream with beavers, Hodoșa - tributary of the Niraj River), while only 33.3% stem from the Romanian popular name "breb" (Table 2).

From a hydrographic perspective, a significant proportion consists of small-sized watercourses (order 7) - 34.8%, followed by streams of orders 2, 3, and 4, which together represent 60.8% (Figure 2). In terms of length, the majority of watercourses are small tributaries with lengths ranging from 2.3 to 10 km (Fig.1).

It is highly probable that some of the watercourse names originating from the root of "brebu" in its various forms might have undergone changes over time, making it challenging to quantify them as evidence of the species' presence in the present day. Modern cadastral systems no longer utilize toponymic indices, and it is possible that these names may gradually disappear, especially given the increased population mobility in recent years, which further contributes to the loss/modification of some toponyms.

2.2.3. Family Names

The first documented family name is "Hodor" (15th century), who was a scribe at the princely court. Subsequently, other family names like Hodă, Hodea, Hode emerged, and in the early 17th century, "Brebul" and "Brebor" were also recorded.

The online electronic platform nume.ottomotor.ro is an initiative aiming to index family names in Romania. It currently contains 2,700,000 names of individuals from 3,800 localities and 130,000 distinct family names. For instance, the name "Breban" has the highest number of records: 125, while others are much rarer, such as Brebu-22, Brebenel-25, Hodișan-35, Hodor-26, and Hodoș-19. (https://nume.ottomotor.ro/).

2.2.4. Archaeozoological Evidence

When referring to archaeological evidence, it is preferable to limit the scope to the Holocene period (Bejenaru et al., 2015a), even though there are older archaeological traces (Bejenaru et al., 2011, 2015b; S. M. Stanc et al., 2022).

Among the numerous collections of bones analyzed in recent studies, some mention the presence of beavers, but their proportion remains relatively low compared to the total of animal remains. This can be attributed to the presence of other species with higher hunting value.

In the existing collections, the occurrence of beavers is relatively rare in comparison to other wild species (deer, wild boar, carnivores, hare, and wild ox), being classified under the group "other species" (Bălășescu, 2020). Similarly, other studies have also reported low percentages of beaver presence (Bejenaru et al., 2011, 2015b; Bejenaru & Tarcan, 2019; Bem et al., 2021; M. S. Stanc & Bejenaru, 2014; S. M. Stanc et al., 2022).

Taking into account the percentage of beaver fossil remains within the total animal bones, it can be concluded that the Castor fiber species is among the poorly represented species, having been identified in five archaeological sites along the Danube's floodplain and two in Moldova (Bejenaru et al., 2011).

2.3 Reintroduction and Population Evolution of the Castor fiber species in Romania

2.3.1 Reintroduction of the Species

The first initiatives related to the reintroduction of the species were mentioned in 1939 (Botezat, 1934) when the beaver's range in Europe had drastically decreased. However, this attempt did not materialize, and it was later remembered as an important action in the 1960s and 1970s (Nania, 1991).

Fortunately, the context became more favorable towards the end of the 20th century when reintroduction efforts took place on three rivers: Olt, Mureș, and Ialomița. A total of 182 beaver specimens were released, forming the reintroduction nucleus, which became the basis for the population's recovery (Ionescu, 2006; Ionescu et al., 2010; Ionescu & Troidl, 1997).

The actual reintroduction action in Romania occurred after obtaining all legal approvals and conducting a sociological study on the possible reintroduction of the species, along with habitat analyses of several river sections, including Olt, Mureș, Ialomița, Crișul Negru, Târnava Mare, Târnava Mică, Danube, and the Danube Delta (Ionescu, 2006). Despite the controversies surrounding the reintroduction's negative impact in recent times (Vișan et al., 2015), the remarkable role of beavers in diversifying niches and trophic chains cannot be neglected (Saveljev et al., 2015).

2.3.2 Population Evolution after Reintroduction

2.3.2.1 Population Evolution in the Olt, Mureș, and Ialomița Hydrographic Basins

The current range of the species is significantly expanded compared to the period of reintroduction (1998-2003), which initially covered a significant portion of the upper and middle course of the Olt River, the lower course of the Mureș River, and the lower and middle sectors of the Ialomița River (Ionescu, 2006; Pașca et al., 2022).

The last comprehensive population assessment at the national level took place between 2012 and 2014 through the POS Mediu CLMAN project, estimating a population of approximately 1850 individuals based on the inventory of shelters (ICAS BRASOV, 2013).

Subsequently, population estimates were further conducted using the sample area method to fulfill reporting obligations regarding the species' conservation status at the European level, as required by Article 17 of the Habitats Directive (C. Pașca, 2020). The estimated population in 2018, after updating existing data with new observations, was around 2200 beavers (C. Pașca et al., 2018).

In some areas, the population has stabilized; for example, in the Râul Negru Basin, the latest study showed only a 10% increase in 5 years (Gridan, 2021) compared to the previous assessment (Vișan et al., 2015). For this area, the author (Gridan, 2021) points out that some previously populated areas have been abandoned, either due to food depletion or as a result of anthropogenic habitat degradation.

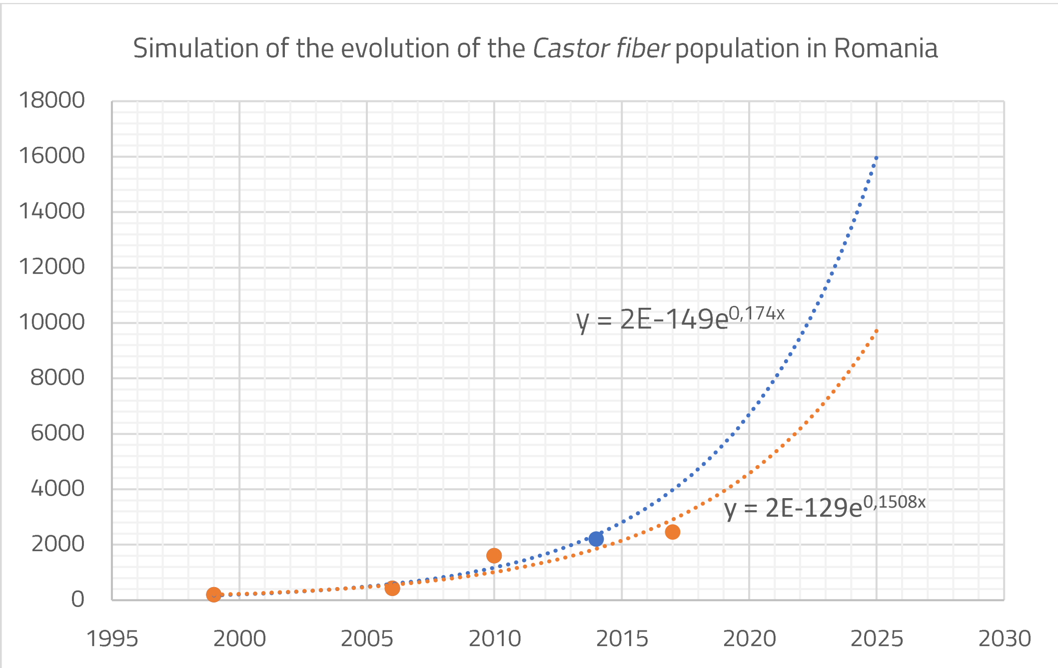


Fig. 3. Simularea dinamicii populației la nivel național, pe baza datelor existente în literatură
Simulation of population evolution at the national level, based on literature data

A scenario of the population dynamics based on existing data, starting from the reintroduction moment (following an exponential trend), suggests that in the short term (by the year 2025), the total number of beavers could fall within the range of 10,000 to 16,000 individuals (Fig. 3).

2.3.2.2. **Recolonization through Natural Dispersal in New Hydrographic Basins**

Apart from the three hydrographic systems that were repopulated with beavers, signs of their presence have been observed in new areas outside the reintroduction range.

The rivers in the north-western part of Romania were the first areas outside the reintroduction range where the species was detected (ICAS BRASOV, 2013; Vișan et al., 2015). Shortly thereafter, the first information about the presence of the species on the Someș River was also published (Fülöp & Márk-Nagy, 2012).

Through natural dispersal from the reintroduction nuclei, the species has spread to the Danube Delta and the Parcheș complex, located near the entrance to the delta (Kiss et al., 2012, 2013), and recently to the hydrographic basins of the Siret and Prut rivers (Bouroș et al., 2022).

Even more remarkable is the colonization of the Buzău, Trotuș, and Bistrița rivers, which, excluding the possibility of unofficial human actions, occurred through the movement of individuals from one hydrographic basin to another, specifically from the upper sections of some Olt River tributaries to the mountainous areas of the Uzului and Buzău valleys. Both examples are similar in that the populated sectors are located upstream of insurmountable anthropogenic barriers for mammals that move with difficulty on land. The Uzului Valley dam is one of the tallest hydro-technical dams in Romania. Supporting this hypothesis is the fact that no signs of presence have been identified downstream of these two dams.

2.3.2.3. **Initiatives for Artificial Recolonization in Historical Range Zones**

For the Danube Delta, the National Research and Development Institute for Forestry "Marin Drăcea" conducted a feasibility study (C. Pașca et al., 2013) regarding the supplementation of the existing population with individuals and a sociological study to assess the species acceptance (Panait, 2012). However, this initiative was not accepted by the authorities and researchers from the National Institute of Research and Development for the Danube Delta due to the lack of historical evidence of the species' past presence and concerns about "multiple, unforeseen ecological and economic repercussions" (Kiss et al., 2013).

In Dâmbovița County, a "LIFE" project is underway, which includes beaver repopulation activities using individuals from high-density areas on the Olt River. The plan is to capture and release 70 beavers in the upper sections of the Dâmbovița, Râul Târgului, and Argeșel rivers (Conservation Carpathia Foundation, 2020). The chosen areas for these activities are not the most suitable, mostly located in the mountainous region, which is not typical habitat for beavers, but they can contribute to reestablishing the species' range south of the Southern Carpathians by dispersing towards more favorable zones.

2.5. Analysis of Literature on Determining Carrying Capacity of the Environment

2.5.1. Theoretical Aspects

Carpenter et al. (2000) introduced the concept of social carrying capacity, which refers to the society's tolerance level for the impact on wildlife in various situations. This concept has motivated research and management actions aimed at restoring populations with low abundance, reducing overabundant populations to a healthier state, and exploiting species that hold social or economic importance.

A more realistic approach seems to be one where the species' population dynamics attempt to reach a balance around the line that defines the maximum level of carrying capacity (Mysterud, 2006). The latter does not appear to be an absolute value and can undergo modifications due to the criteria that define it. For instance, overgrazing or exceeding the optimal numbers of certain herbivore species can lead to a temporary decrease in carrying capacity due to habitat degradation. The habitat degradation may be either permanent or temporary, and in each case, it is followed by a reduction in the population of the affected species, which can recover if the degradation was temporary (Mysterud, 2006). In natural environments, the situation is much more complex, depending on the number of species in the community and particularly on how trophic niches overlap and how competing species adapt to changes.

In summary, the concept of carrying capacity is subject to multiple factors and interactions in natural ecosystems, and its assessment involves considering various ecological aspects and species dynamics within the community.

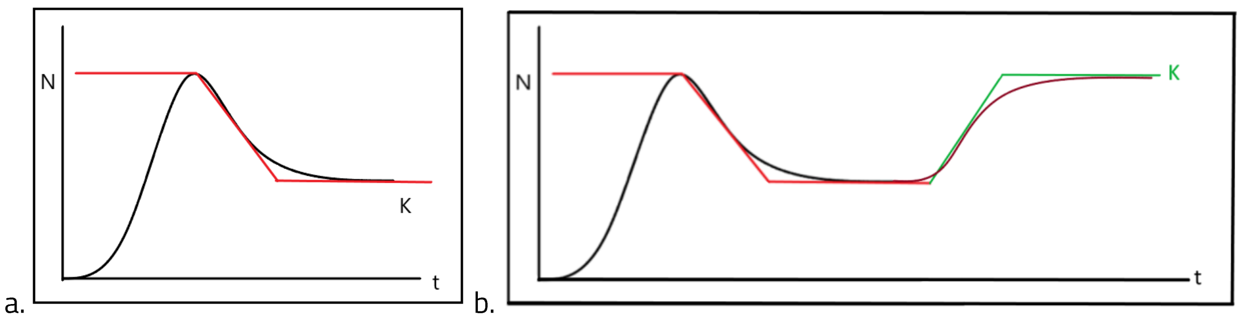


Fig. 6. (a.) Scăderea capacității de suport cauzată de factori antropici. (b.) Refacerea nivelului capacității de suport a mediului prin restabilirea condițiilor de viață (prelucrare după Mysterud, 2006).
(a.) Decrease in carrying capacity caused by anthropogenic factors. (b.) Restoring the level of carrying capacity of the environment by restoring living conditions (edited after Mysterud, 2006)

In Figure 6, the curve depicting the population's evolution (in black) represents the general trendline that averages the annual and seasonal variations and serves a didactic purpose.

2.5.2. Applied Aspects of Determining Environmental Carrying Capacity

The first study aimed at identifying the relationship between habitat quality and beaver density was conducted on the main course of the Olt River. Initially, a habitat diagnosis was conducted using the updated Heidecke method (Pașca et al., 2015). Subsequently, GIS layers containing river sections classified into habitat categories were overlaid with information regarding beaver distribution, including estimated numbers of individuals/families. Thus, beaver density per kilometer of river was determined for each of the three habitat categories: optimal, satisfactory, and unfavorable. This analysis yielded an average density of 2.28 individuals per kilometer for optimal habitats and 2.19 individuals per kilometer for satisfactory habitats. Interestingly, even habitats evaluated as unfavorable were found to be inhabited by beavers, though at a significantly lower density of 0.58 individuals per kilometer (C. Pașca et al., 2015).

2.6. Criterias and Methodologies for Analyzing Habitat Suitability

2.6.1. Adaptation and Evolution of the Methodology Used in Assessing the Suitability of Habitats for the Castor fiber Species in Romania

The methodology for evaluating riparian habitats used by beavers has undergone several phases of evolution. The initial concerns related to the method of analyzing habitats, classifying them into suitability classes, were recorded before the reintroduction of beavers in Romania. At that time, the Heidecke methodology was chosen, considering it to be the most suitable method for the country's conditions, particularly because, compared to North American methods, it also took into account the anthropic factor—an important aspect that influences the degradation of habitat quality and, consequently, its favorability for beavers. (Heidecke, 1989; Ionescu, 2006).

This method is based on field analysis by describing four main factors: **topography, hydrology, vegetation, and human influence (anthropogenic)**. Each of these factors includes specific sub-factors.

As the range of the Castor fiber species expands, the need for developing a faster and less costly method for assessing suitable beaver habitats becomes increasingly evident. The aim is to quickly identify areas that are optimal and satisfactory for colonization with beavers relocated from conflict zones. This approach focuses on prioritizing the identification of new optimal and satisfactory zones for population establishment.

2.6.2. The main criteria used in the analysis of the suitability of habitats for the Castor fiber species are as follows:

Hydrological requirements:

As the beaver is a semi-aquatic species, a primary limiting factor for its distribution and dispersion is the hydrological aspect, specifically the presence of water. Research and monitoring conducted after the reintroduction have demonstrated that the beaver is a eurytopic species, successfully populating aquatic bodies both in the lowland areas (e.g., Ialomița) and in hilly and mountainous regions.

All studies evaluating the suitability of a habitat for beavers consider the presence and constancy of water as the primary criterion (Howard & Larson 1985, Barela & Frey 2016, Zwolicki et al 2018). When considering the construction of dams or shelters, depth and width of the watercourse play a significant role.

Trophic requirements:

This is another aspect in which the beaver demonstrates a wide amplitude. As a general principle, due to its year-round activity, the beaver requires woody vegetation to meet its trophic needs during the cold season when herbaceous food is either unavailable or insufficient (Ionescu G. et al., 2010).

Regarding the species composition of available woody vegetation, beavers prefer softwood species such as willow, poplar, and alder, but in the absence of these, they consume other species, including conifers (Dvořák, 2013; Janiszewski et al., 2017; VIȘAN et al., 2015).

An important aspect that requires a separate study is the anthropogenic degradation of riparian vegetation. It presents two nuances: **quantitative** degradation and **qualitative** depreciation, both of which have an impact on the suitability of habitats available to beavers.

Configuration and structure of riverbanks:

Beavers construct their shelters, known as lodges, either underground, dug into the riverbanks, or above ground, where they build a conical structure using branches, mud, stones, vegetation, etc., with one or more chambers. Mixed shelters can also be found, which are dug into the bank and reinforced on the upper part with branches, mud, or other materials deposited above the main chamber. The mixed type is perhaps the most common and can be determined by the collapse of the ceiling of a lodge dug into the bank in an area with unstable sandy soil, or out of necessity when the bank's height is insufficient to allow the creation of shelter chambers, and the beavers attempt to break through the gallery's ceiling and emerge to the surface (Ionescu G. et al., 2010).

Methods of habitat evaluation:

In the meantime, alongside ecological criteria affecting the suitability and carrying capacity of the habitat, social criteria have been added, meaning the direct impact of human activity on the habitat or the species (Carpenter et al., 2000).

Habitat evaluation methods have evolved over time and space, moving from direct observations of potential habitat characteristics and quality to automated classification using software and satellite images. The evaluation criteria can also vary depending on the study.

Increasingly, recent studies utilize automated habitat evaluation programs and the analysis of satellite images to quantify habitat suitability since beaver habitat preferences are largely based on physical characteristics that can be easily mapped (Anderson & Bonner, 2013).

Chapter 3. METHODOLOGY USED AND RESEARCH LOCATIONS

3.1. Methodologies Used

3.1.1. Methodology for Assessing Habitat Suitability

Since the study aimed to cover a considerable area in the southern and southeastern regions of Romania, which includes a rich hydrographic network totaling over 4480 km of watercourses with various hydrographic characteristics, and considering the adaptability of the species, it was deemed that the use of the expedited evaluation method described by the author of this paper in 2021 (Paşca et al., 2021) provides sufficient precision to create a database on habitat suitability, which will serve as the basis for calculating optimal populations per hydrographic basin.

As the previously mentioned method relied heavily on the expertise of the researcher, leading to significant interpretation errors of the images, a data collection sheet was created, adding additional evaluation criteria to reduce assessment errors.

However, it is essential to mention that this method is recommended to be applied by personnel with expertise and experience in evaluating aquatic habitats used by beavers, so that the expert can recognize the main types of riparian habitats and make a more realistic estimation of the environmental conditions, anthropogenic impact, and potential risk level.

For approximately 9% of the analyzed sectors, field data were collected. These sectors include the Ialomița River, from its confluence with the Danube to the Dridu area, and two sectors of the Buzău

River: from its confluence with the Siret River downstream of Buzău municipality and from Vama Buzăului to Cașoca (Siriu Dam).

The main criteria considered for the analysis of habitat suitability are as follows: the hydrological criterion, the trophic criterion, the condition of the riverbanks, the anthropogenic factor, the presence of hydrotechnical constructions, and the potential risk generated in the conditions of beaver population in the area. Each of these factors was given a score from 1 to 3, where 1 represents unfavorable conditions, 2 represents satisfactory conditions, and 3 represents optimal conditions. For the last three fields in the table, the score represents the quantification of impact: 1-low, 2-moderate, 3-major.

The evaluation of habitat suitability was conducted by composing the scores given for the factors included in the evaluation sheet in two stages. The first stage includes the three essential environmental factors for the species: hydrological, trophic, and riverbank characteristics. The second stage involves downgrading the suitability class in case anthropogenic factors and risk for the local population are considered to impose such a downgrade.

Based on the recorded scores, the analyzed sectors were classified into one of the three suitability classes: **Unfavorable, Satisfactory**, or **Optimal**. In the evaluation sheet, the column "Suitability" was filled with one of the initials **N, S, O** representing the respective class.

The methodology used in calculating the carrying capacity of the environment involves the use of population density indices specific to each suitability category.

Since data regarding beaver density in different environmental conditions are highly heterogeneous at the European level, this study used previously calculated values for habitats along the Olt River (Pașca et al., 2015). Accordingly, the calculated average density for optimal habitats is 2.29 beavers/km, and for satisfactory habitats, it is 2.19 individuals/km.

For the unfavorable sectors, classified in the third suitability category (mainly due to the poor quality of riparian vegetation), the density of 1.03 individuals/km (Pașca et al., 2015) was used, based on the consideration that the restoration of woody vegetation would allow the colonization of such unfavorable areas.

Fig. 9. Exemplu de habitat optim pe râul Teleajen
Serii de imagini satelitare din perioada 2010-2021 (Google Earth)
Example of optimum habitat on the Teleajen River
Series of satellite images from 2010-2021 (Google Earth)

The use of the concepts of **biophysical** or **natural carrying capacity** and **social carrying capacity**, which also takes into account society's tolerance level towards the impact of wildlife, is becoming increasingly important in the face of the growing polarization of social groups concerning environmental issues. We believe that this approach opens new horizons towards harmonizing the ecological and socio-economic interests of society.

3.2. Research Area

The study area comprises the main hydrographic systems of Muntenia, a historical region in southern Romania, which was once part of Wallachia. Its boundaries are as follows: to the **north**, the Carpathian mountain ranges (which separate it from Transylvania); to the **west**, the Olt River (which separates it from Oltenia); to the south and east, the Danube River (which delimits it from Bulgaria and Dobruja); and to the northeast, the Milcov, Putna, and Siret Rivers (beyond which lies Moldavia).

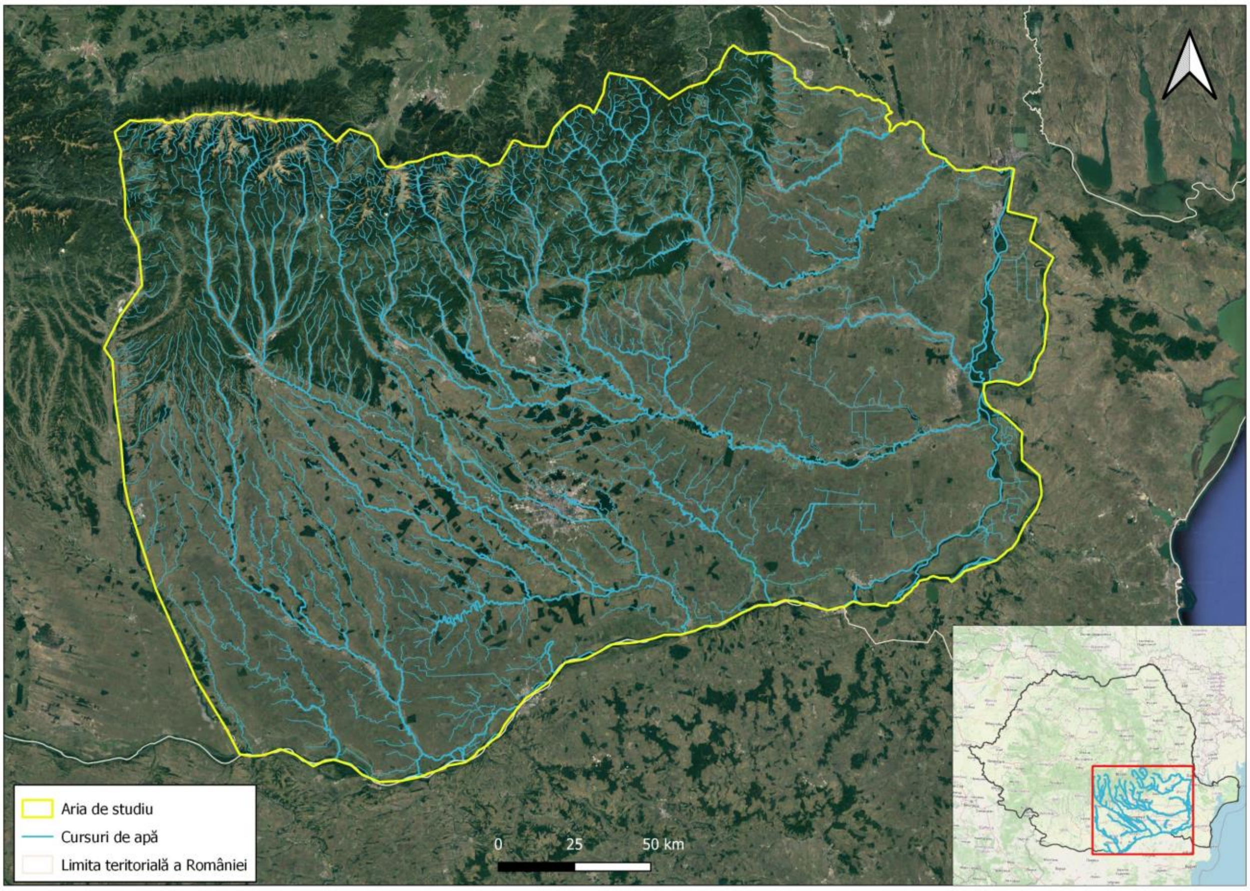


Fig.11. Aria de studiu - Harta principalelor sisteme hidrografice din Muntenia
Study area - Map of the main hydrographic systems from Muntenia

The study included the analysis of riparian habitats along 29 watercourses from **8 hydrographic systems** in the Muntenia region. These hydrographic systems, listed from east to west, are Călmățui (Teleorman), Vedea, Argeș, Mostiștea, Ialomița, Călmățui (Buzău), Buzău, and Râmnicu Sărat.

By centralizing the available information, the present study classified a total of **4,030 km of river courses** into different bonity classes, resulting in a total of **486 sectors**. For each sector, the corresponding beaver populations were allocated based on their habitat quality.

Chapter 3. RESULTS OBTAINED

4.1. Bonitate of Aquatic Habitats in Muntenia

4.1.1. The Călmățui Hydrographic System (Teleorman County)

General Description

The Călmățui River is one of the major watercourses located in the eastern part of the historical region of Muntenia, with its hydrographic basin spanning across Teleorman and Olt counties. It is a first-order tributary of the Danube River, and it discharges into the Danube through Lake Suhaia. This hydrographic system is one of the smallest, covering an area of approximately 1380 km2, with predominant development to the east of the main axis.

Among the few notable tributaries are Călmățuiul Sec, Urluiul, and Sohodolul. Due to the small size of the hydrographic basins and vegetation characteristics, the discharge is non-permanent in these tributaries (Ujvari, 1972), except for Urluiul, which has been subjected to hydrotechnical developments resulting in the creation of permanent water reservoirs that supply water for irrigation of agricultural areas in the region.

The longitudinal profile of the river is highly sinuous, influenced by the gentle slope of the terrain. Upstream of Lisa locality and downstream of Tudor Vladimirescu commune, the main course is embanked to protect localities and agricultural lands during periods of flooding. Flooding events are accentuated in the absence of arboreal vegetation, which would delay water runoff on the gently inclined slopes. Thus, during periods of heavy rainfall, typical in spring and autumn, the river's discharge increases suddenly and can pose a threat to the safety of the traversed localities.

Only 7 sectors, totaling just over 42 km of river course, can be classified as satisfactory habitats. These represent 18% of the total length of aquatic habitats. The average length of satisfactory habitats is 6.07 km, while for unfavorable habitats, it is 8.8 km.

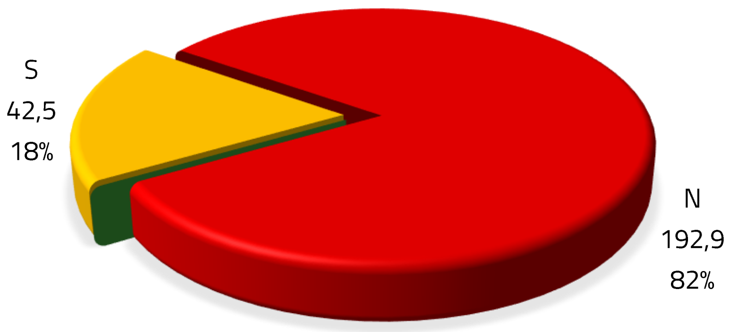


Fig. 12. Bazinul hidrografic Călmățui - Ponderea habitatelor pe categorii de bonitate
Calmățui hydrographic basin - Share of habitats by categories of creditworthiness

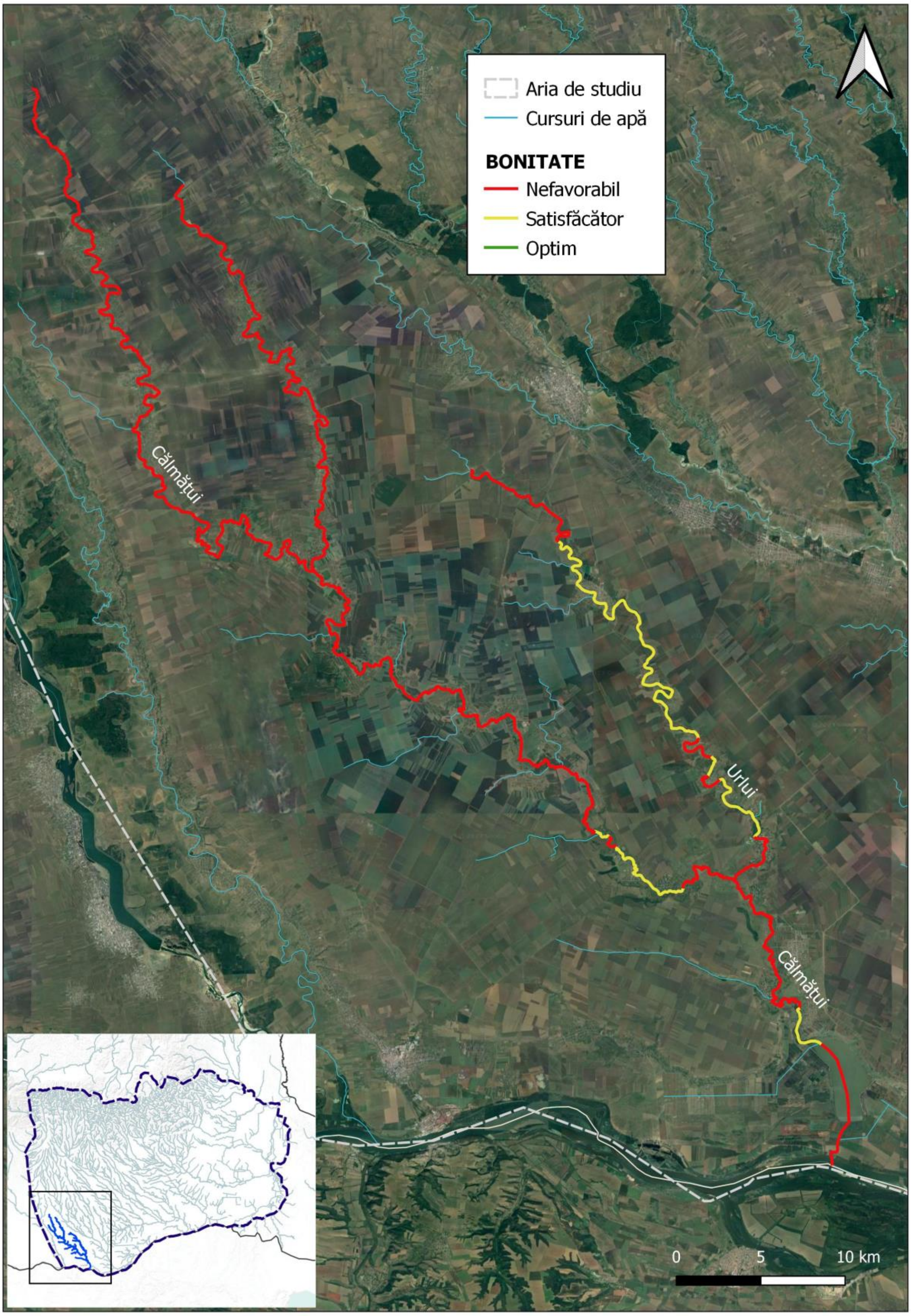


Fig. 13. Bazinul hidrografic Călmățui - Cartarea habitatelor pe categorii de bonitate

Călmățui hydrographic basin - Mapping of habitats by creditworthiness categories

The synthetic analysis of the habitats resulted in the delineation of 28 sectors, with 19 located along the main river course and 9 along the Urlui, the only tributary that can offer favorable conditions for the species. Among these, a significant majority of the sectors (21) are considered unfavorable for beaver population.

4.1.2. Vedea Hydrographic System

From the entire hydrographic basin, a total of **861 km** of river courses were analyzed, resulting in a total of 93 sectors with an average length of 8.8 km. The data clearly indicates a dominance of unfavorable habitats, accounting for 62% (534 km), while the favorable habitats from the optimal and satisfactory categories sum up to 327 km, approximately 38%.

The distribution of optimal habitats along the watercourses is highly uneven, with their proportion varying from 0 to 45%. Similarly, for satisfactory habitats, the coverage percentage ranges from 0 to 33%.

Fig. 18. Bazinul hidrografic Vedea - Ponderea habitatelor pe categorii de bonitate

Vedea hydrographic basin - Share of habitats by categories of creditworthiness

The Vedea River

Habitat Analysis

From the perspective of habitat quality, the Vedea River does not offer favorable conditions for beavers, as only 8.7% of the total habitats fall into the optimal class, along with an additional 22% classified as moderate-quality habitats. The vast majority of unfavorable sectors are completely devoid of woody vegetation. In the upper portion of the hydrographic basin, the minor riverbed is very wide and changes its course frequently, making the riverbanks unsuitable for building lodges.

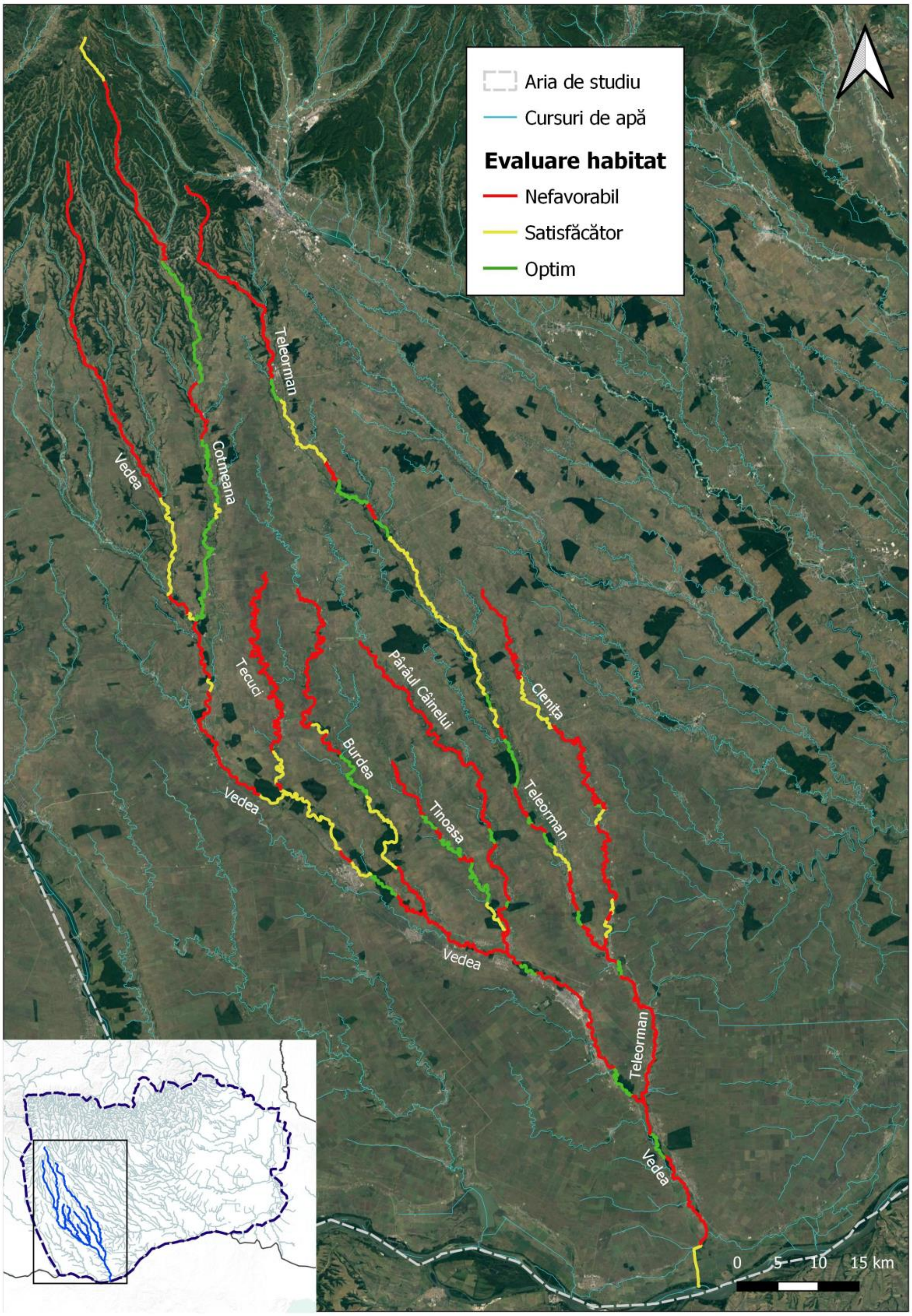


Fig. 25. Bazinul hidrografic Vedea - Cartarea habitatelor pe categorii de bonitate

The Vedea hydrographic basin - Mapping of habitats by creditworthiness categories

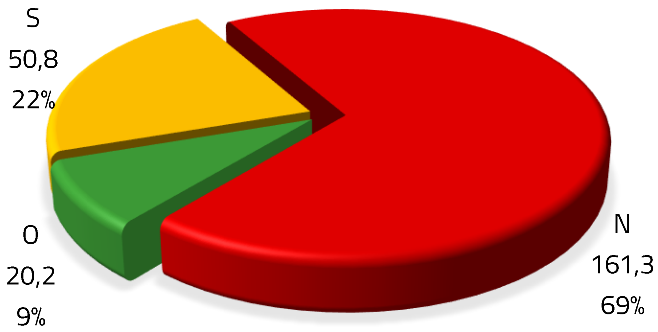


Fig. 19. Vedea - Ponderea habitatelor pe categorii de bonitate

Vedea river - Share of habitats by categories of creditworthiness

The first 60 km (from the source to downstream of the town of Bădești) are characterized by significant hydrological fluctuations, with periods of floods followed by others with very low water levels, which categorizes them as unfavorable habitats.

Next is a stretch of about 80 km (up to the municipality of Roșiorii de Vede) with alternating habitats of unfavorable and satisfactory conditions. On this section, the Vedea River passes through several forested areas that provide trophic support during the winter season.

Downstream of Roșiorii de Vede, 66 km out of the total 92 km are unfavorable habitats, lacking woody vegetation.

The Teleorman River

It is the most important tributary of the Vedea River, originating from the Cotmeana plateau at an altitude of only 339m (Ujvari, 1972).

Fig. 26. Râul Teleorman - Ponderea habitatelor pe categorii de bonitate

Teleorman river - Share of habitats by categories of creditworthiness

An analysis of the suitability of secondary tributaries' habitats was also conducted. For each tributary, the habitat was identified and evaluated along a total length of 105.6 km of river course. Out of this total, 38.9 km were classified as unfavorable habitats, while 66.7 km were deemed satisfactory habitats. Secondary tributaries that present more favorable conditions for beaver colonization are primarily those that traverse areas with abundant woody vegetation and stable water levels.

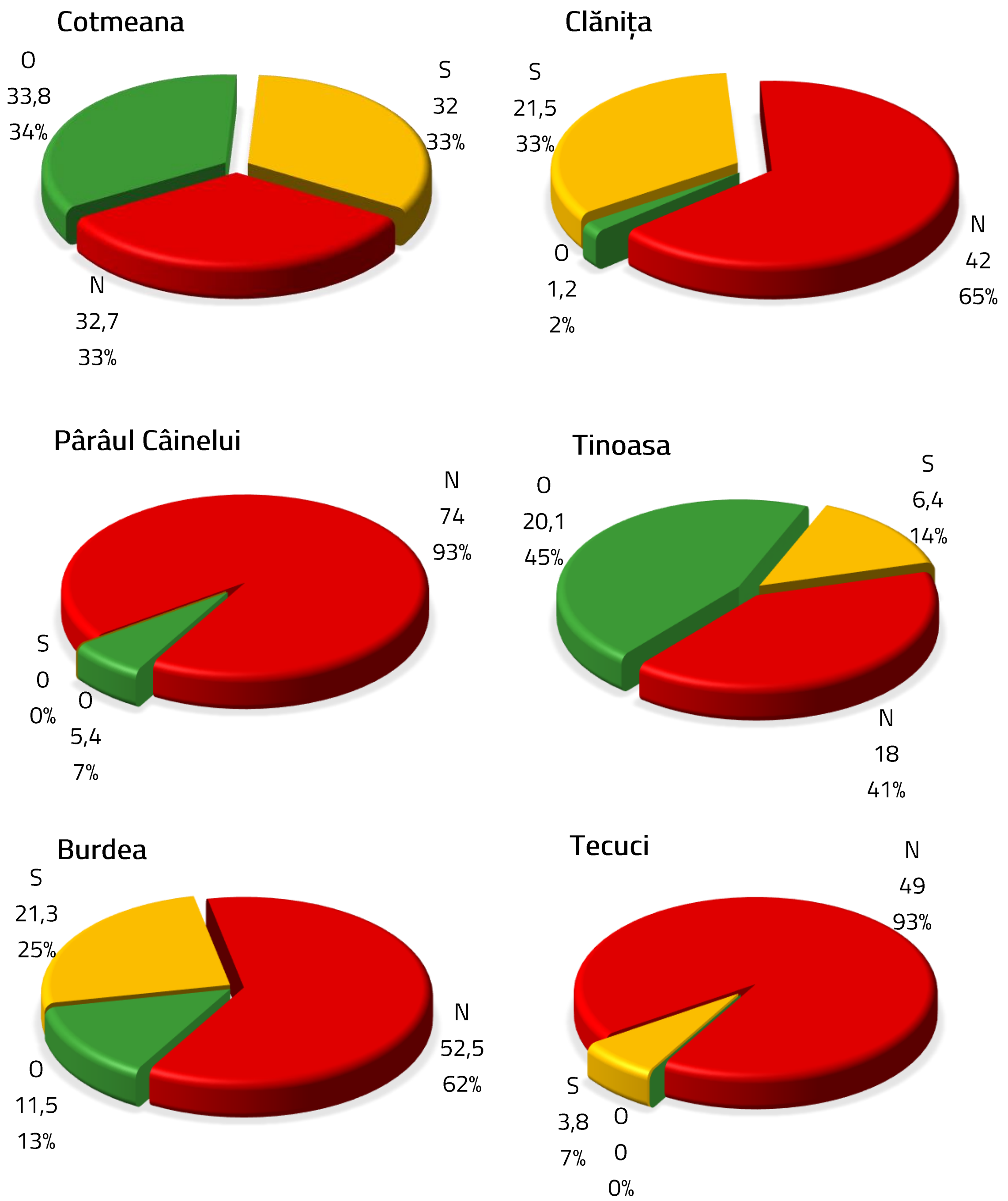


Fig. 28. Afluenții secundari ai râului Vedea - Ponderea habitatelor pe categorii de bonitate
Main afluents of Vedea River - Share of habitats by categories of creditworthiness

The results of the analysis indicate a dominance of unfavorable habitats along the Teleorman River, with a significant percentage in comparison to optimal and satisfactory habitats. This situation is mainly due to extensive hydrological fluctuations and the lack of woody vegetation in certain sectors. However, there are opportunities to improve the habitat conditions through the conservation and restoration of woody vegetation in specific areas, which could enhance attractiveness for beaver colonization and contribute to increased local biodiversity.

4.1.3. Argeș River Hydrographic System

General Description

The Argeș River basin is the largest aquatic system in Muntenia, covering an area of approximately 12,500 km². It has a dendritic shape, with a strong right-hand asymmetry downstream, where it collects a significant number of tributaries from the Romanian plain. The length of the basin is 242 km. The altitudinal range of the basin is very large, considering that the sources of the Argeș and Dâmbovița rivers, the two major components of the Argeș system, are found at altitudes above 1500 and 1200m, respectively (Ujvari, 1972).

In the upstream mountainous area, the slopes are much steeper, ranging from 45-60 m/km, but the slope decreases significantly in the lower section, reaching around 1 m/km near the point of discharge (Ujvari, 1972).

The most important tributaries are Dâmbovița, along with other relevant tributaries for the present study, such as Neajlov, Sabar, Câlniștea, Glavacioc, Dâmbovnic, Doamnei, and Târgului.

On the analyzed sectors, the number of freezing days ranges from 30-60, but despite this, ice cover forms rarely, with one major influence being the Vidraru Dam, which contributes warmer waters to this phenomenon (Ujvari, 1972).

The entire Argeș River basin has been analyzed, encompassing 1354.8 km of river courses, resulting in a total of 186 sectors with an average length of 7.2 km. The data indicates a clear dominance of unfavorable habitats, accounting for 47.5% (643.3 km), while favorable habitats from the optimal and satisfactory categories amount to 394.5 km (29.1%) and 317 km (23.4%), respectively.

The distribution of optimal habitats along the river courses is highly uneven, with their proportion ranging from 5.5% on the Târgului River to 42% on the Câlniștea River. The same pattern is observed for satisfactory habitats, with coverage percentages ranging from 9.8% (Târgului River) to 50.2% (Neajlov River).

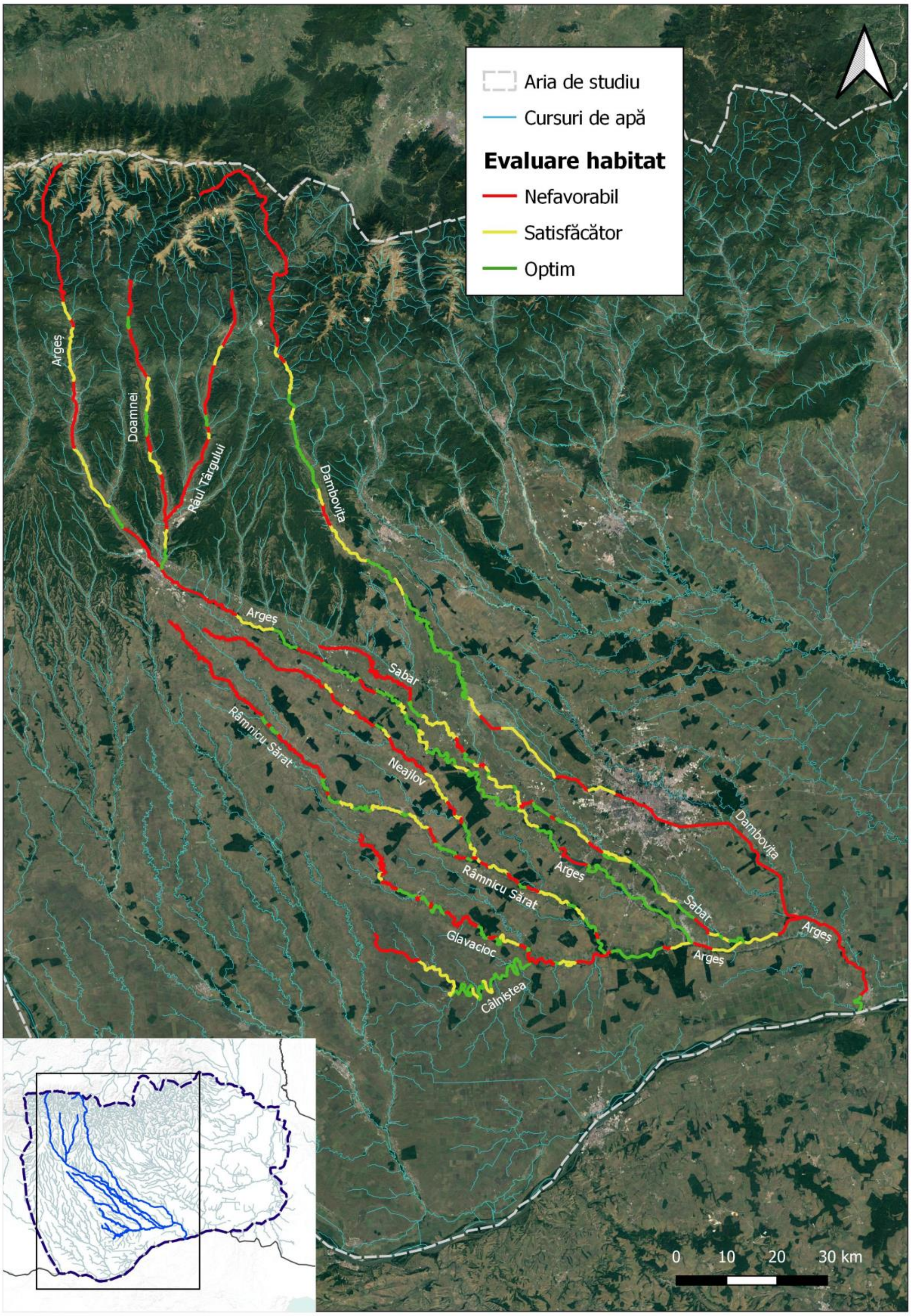


Fig. 31. Bazinul hidrografic Argeș - Cartarea habitatelor pe categorii de bonitate

Argeș River hydrographic basin - Mapping of habitats by creditworthiness categories

Fig. 29. Bazinul hidrografic Argeș - Ponderea habitatelor pe categorii de bonitate
Argeș River basin- Share of habitats by categories of creditworthiness

Argeș River

Habitat Analysis

Argeș River is one of the most significant rivers in Muntenia, originating from the southern slope of the Făgăraș Mountains (Ujvari, 1972).

On the main course, which stretches for about 340 km, a total of 324.8 km has been evaluated, and 39 sectors have been delineated. Among these sectors, 134.6 km (41.4%) are classified as unfavorable habitats, 76 km (23.4%) as satisfactory zones, and 114.1 km (33.1%) as optimal zones (Figure 30).

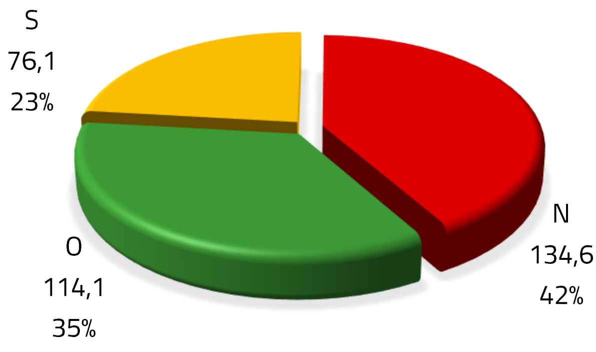


Fig. 30. Râul Argeș - Ponderea habitatelor pe categorii de bonitate
Argeș River - Share of habitats by categories of creditworthiness

Dâmbovița River

Habitat Analysis

With a surface area of over 2750 km² and a length of approximately 260 km, the Dâmbovița River is the most significant tributary of the Argeș River, both in terms of water flow and other hydrological characteristics. On the main course, which stretches for about 265 km, a total of 262.5 km has been evaluated, and 21 sectors have been delineated. Among these sectors, 128.9 km (48.7%) are classified as unfavorable habitats, 60.8 km (23.2%) as satisfactory zones, and 73.8 km (28.1%) as optimal zones (Figure 33).

Fig. 33. Râul Dâmbovița - Ponderea habitatelor pe categorii de bonitate
Dâmbovița River - Share of habitats by categories of creditworthiness

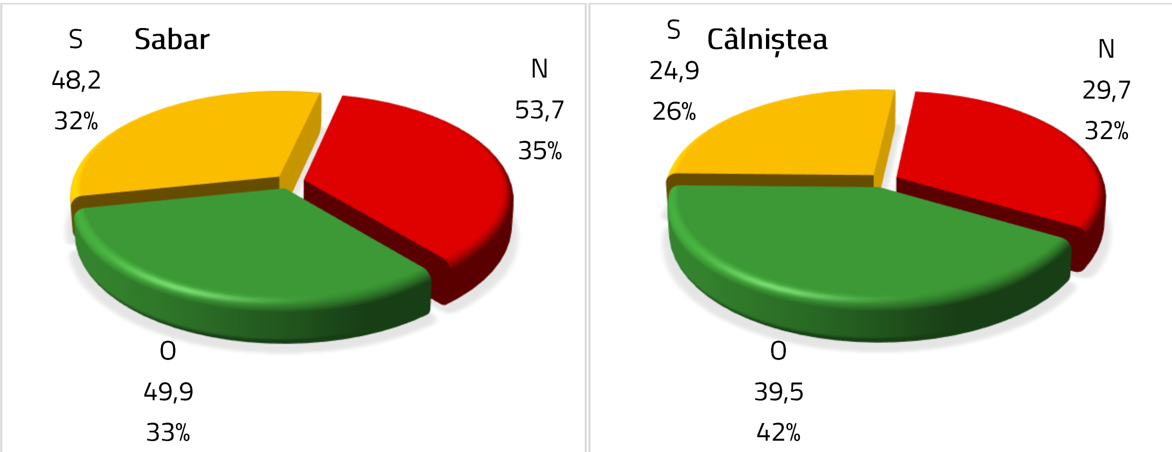
Dâmbovița River is the second-largest tributary of the Argeș River. The analyzed sectors of this river add up to 202.8 km, of which the vast majority are unfavorable sectors (110.1 km) and satisfactory sectors (55 km). Although only 37.6 km are optimal zones for beaver colonization (Figure 34), it is noteworthy that these zones are particularly favorable due to their lush vegetation and abundant water presence in the floodplains, making the riverbanks suitable for constructing shelters. One of these optimal sectors overlaps with the protected area of Comana, situated approximately 6 km from its confluence with the Argeș River.

Fig. 34. Râul Neajlov - Ponderea habitatelor pe categorii de bonitate

Neajlov River - Share of habitats by categories of creditworthiness

The analysis of the habitats of the secondary tributaries reveals notable features of the Sabar and Câlniștea rivers, which exhibit favorable conditions above the average of the Argeș River basin, with over 33% of optimal habitats. Glavacioc and Dâmbovnic, on the other hand, present less than 50% favorable habitats, of which 26-34% are optimal sectors for beaver colonization.

At the opposite end are the tributaries in the mountainous area, namely the Târgului and Doamnei rivers. The former is favorable in only 15% of the analyzed sector, while the latter has 19% of optimal habitats and 27% satisfactory habitats.



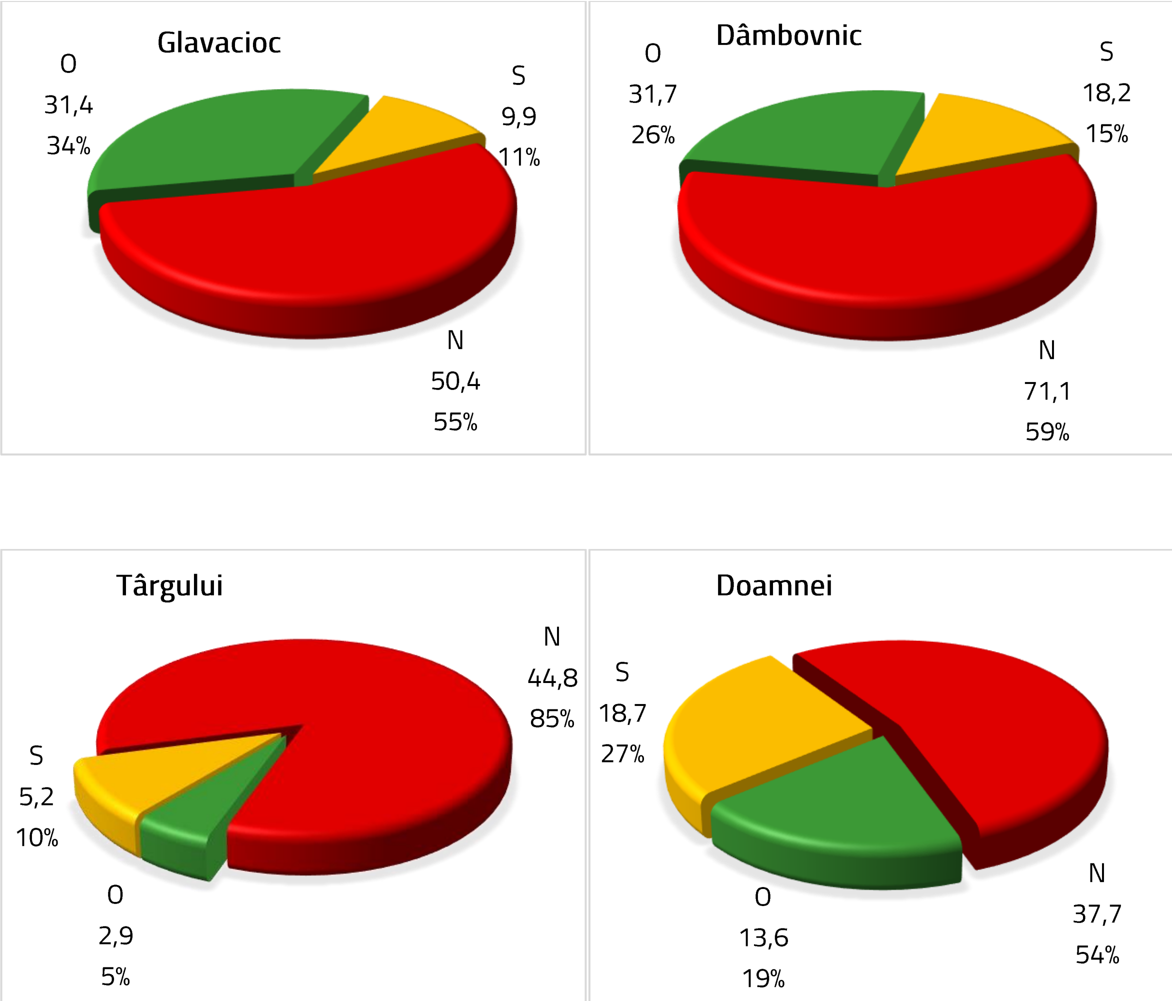


Fig. 36. Afluenții secundari ai râului Argeș - Ponderea habitatelor pe categorii de bonitate

Main afluents of Argeș River - Share of habitats by categories of creditworthiness

4.1.4. Mostiștea River Hydrographic System

General Description

Fig. 38. Râul Mostiștea - Ponderea habitatelor pe categorii de bonitate

Mostiștea River - Share of habitats by categories of creditworthiness

Hydrological conditions

Among the most important reservoirs are Iezerul, Frăsinet, Sărulești, Tămădăul mic, Fundulea, Hagiești, Cătrănești, etc. Over 30 water accumulations, lakes, and ponds have been created on the main course, providing both quantitative and qualitative optimal conditions for beavers (many of them being used for fishing purposes as well). The width of the lakes is over 80-100m on the main course, with the only narrower areas being the transitions between water basins.

Trofic conditions

Regarding trophic aspects, the percentage distribution of habitats indicates a dominance of unfavorable sectors (48%), which are poor habitats lacking both woody and hydrophilic species. Among the favorable sectors, only 14% are optimal, characterized by a uniform coverage of the banks with trees, shrubs, reeds, or rushes. Satisfactory zones present discontinuous vegetation but have at least 50% coverage with the species preferred by beavers.

Shelter conditions

Local factors are satisfactory for the creation of shelters throughout the hydrographic basin. The clay-sandy soil allows for easy digging of burrows, but sinkage phenomena are still inevitable in conditions of abundant rainfall or flooding of nests.

Anthropic factor

By populating the lake areas of the Mostiștea system with beavers, conflicts with the local population/water authorities, fishery domains, or recreational areas are expected.

Safety of the local population

The risk to the safety of the population represented by the population of beavers is low to medium. However, increased attention must be given to earth embankments, which are not concreted or gravelled and are at risk of being damaged by beavers. In those areas, preventive measures are necessary, such as graveling or the use of metal or modern materials nets or cladding with metal or PVC profiles, etc. (C. Pașca et al., 2019, 2022a). The solutions are detailed in chapter 4.3.

4.1.5. Ialomița River hydrographic system

The entire hydrographic basin was analyzed, totaling **762.0 km** of river courses, resulting in a total of 98 sectors with an average length of 7.8 km. The data indicate a clear dominance of unfavorable habitats, representing 48.6% (370.6 km), while the favorable habitats in the **optimal** and **satisfactory** categories sum up to 244.5 km (32.1%) and 147.3 km (19.3%), respectively.

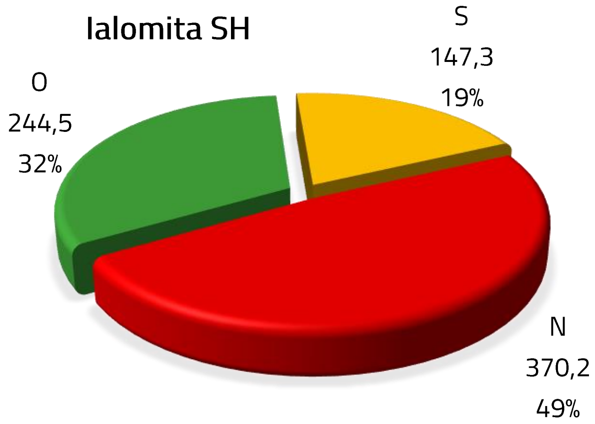


Fig. 41. Bazinul hidrografic Ialomița - Ponderea habitatelor pe categorii de bonitate
Ialomița River basin- Share of habitats by categories of creditworthiness

The distribution of optimal habitats along watercourses is highly uneven, with their proportion varying from 19.0% on the Teleajen River to 37.5% on the Ialomița River. The same observation applies to satisfactory habitats, with coverage percentages ranging from 6.9% (Teleajen) to 24.2% (Ialomița).

Regarding the Ialomița River, the habitat analysis in this study was considerably expanded, including previously evaluated sectors. As a result, 63 sectors were identified, covering a total length of 386.4 km.

The results indicate a relatively homogeneous distribution among the three categories of creditworthiness, with optimal habitats covering 37.5%, satisfactory habitats covering 24.2%, and unfavorable habitats representing 38.3%.

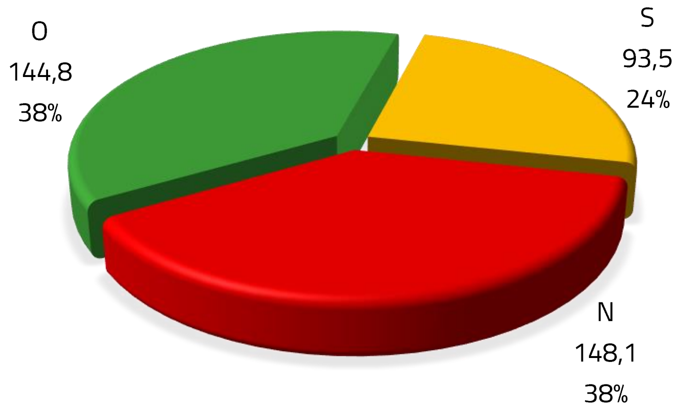


Fig. 43. Râul Ialomița - Ponderea habitatelor pe categorii de bonitate
Ialomița River - Share of habitats by categories of creditworthiness

Afluenții relevanți ai Ialomiței

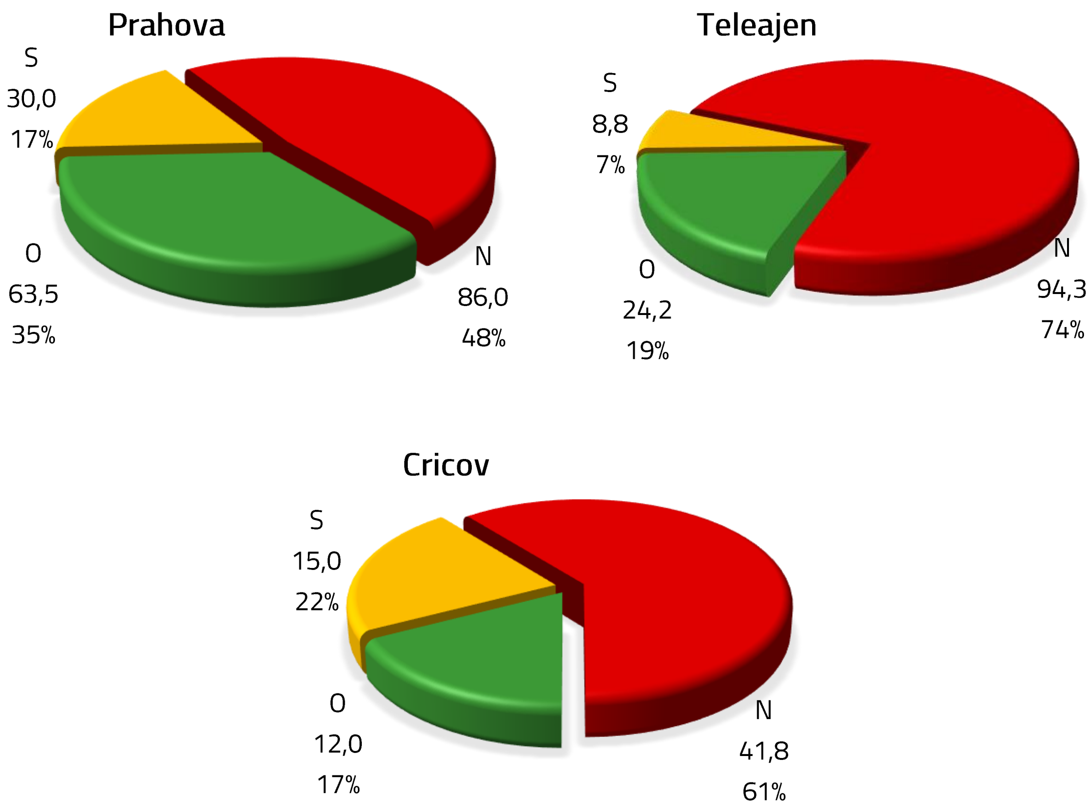


Fig. 45. Afluenții relevanți ai râului Ialomița - Ponderea habitatelor pe categorii de bonitate
Main afluents of Ialomița River - Share of habitats by categories of creditworthiness

Among the tributaries, the Prahova River stands out with particularly valuable habitats from the perspective of beaver colonization on the lower section, from its confluence with the Ialomița River to Stăncești. Approximately 52% of the analyzed sector in this area is favorable for beaver population. However, the upstream section is unsuitable for colonization.

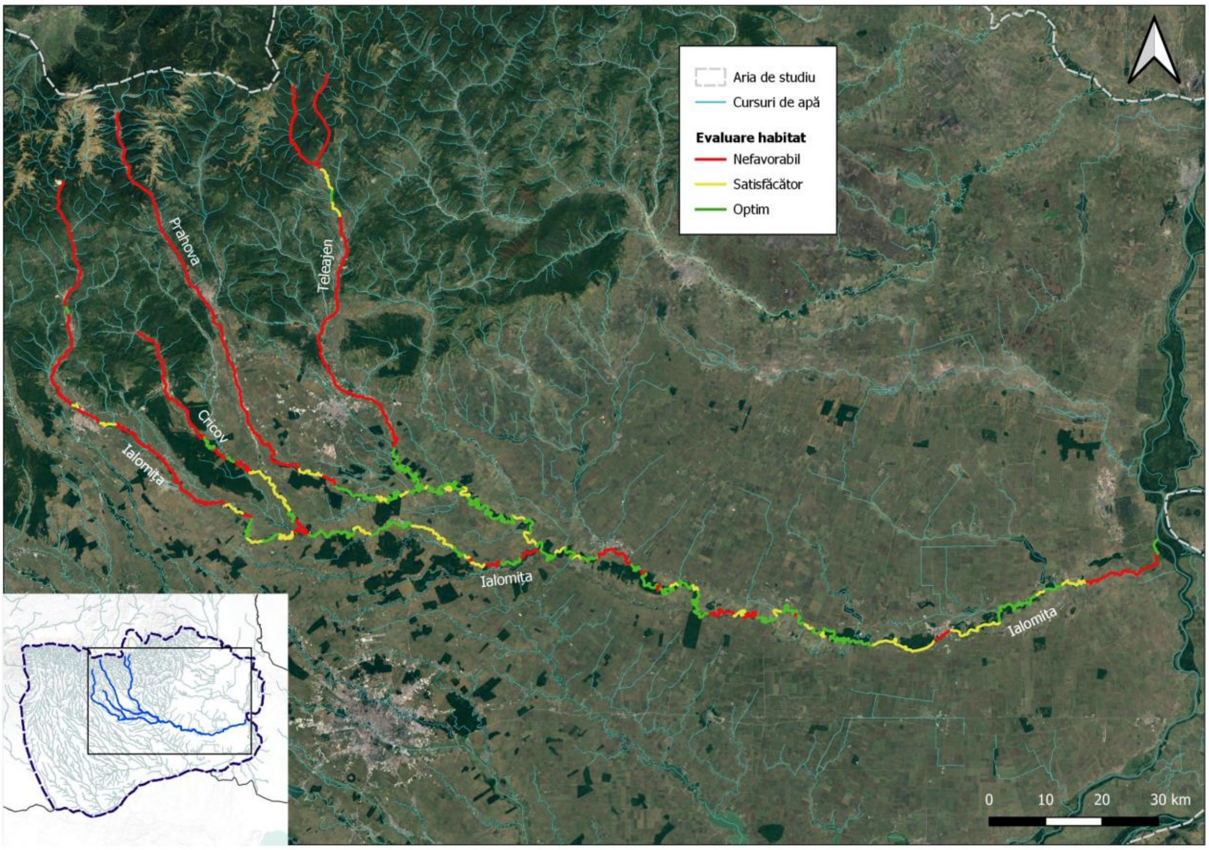


Fig. 42. Bazinul hidrografic Ialomița - Cartarea habitatelor pe categorii de bonitate
Ialomița River hydrographic basin - Mapping of habitats by creditworthiness categories

4.1.6. Călmățui River Hydrographic System (Brăila County)

Due to the unfavorable characteristics of the hydrographic system for this study, only the main course of the Călmățui River was analyzed. Thus, 15 sectors were delimited, totaling 129 km. The vast majority of habitats (83%) were classified as "unfavorable," while the remaining 17% were areas with medium favorability (Figure 46).

Habitat Analysis

Hydrological Conditions

The flow rate is relatively low, ranging between 1.2-1.4 m3/s, with part of the water volume coming from the superficial groundwater of the Buzău River. During periods of maximum flow, the discharge reaches values of about 20 m3/s (Ujvari, 1972). To prevent flooding during periods of high flow fluctuations, a large part of the river has been embanked.

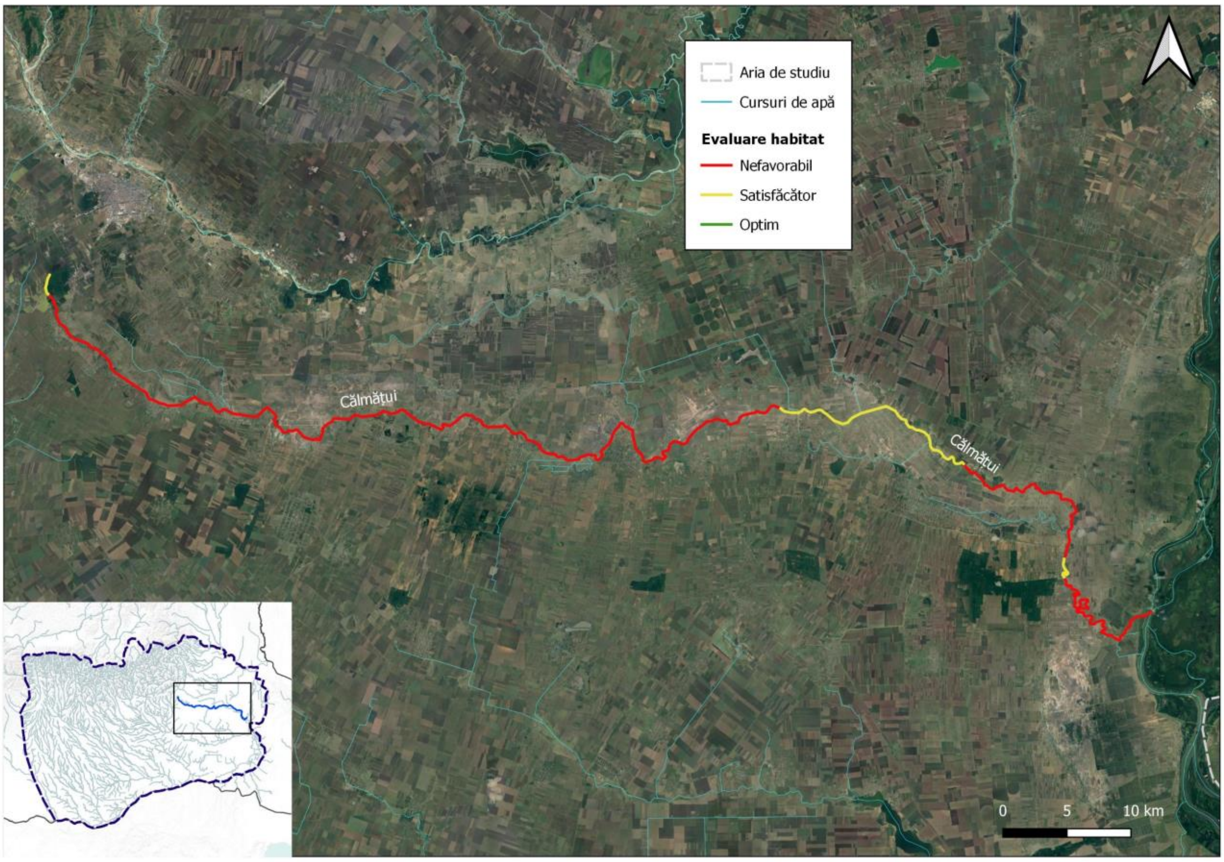


Fig. 46. Bazinul hidrografic Călmățui (BR) - Cartarea habitatelor pe categorii de bonitate
Călmățui River hydrographic basin - Mapping of habitats by creditworthiness categories

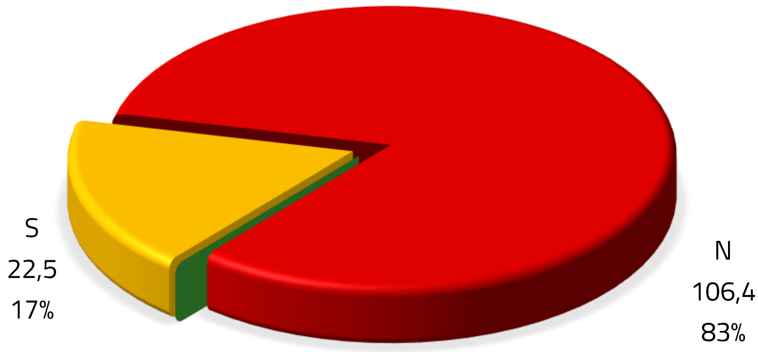


Fig. 47. Râul Călmățui (jud. BR) - Ponderea habitatelor pe categorii de bonitate
Călmățui River - Share of habitats by categories of creditworthiness

The minor channel width is 14-17m downstream and 6-8m upstream, and the water depth is suboptimal in many areas due to fluctuations during dry periods. Therefore, the entire course was classified as having a medium creditworthiness (satisfactory).

Trofic Conditions

From a trophic point of view, the Călmățui River is not very suitable for beavers, as a large part of the analyzed sectors lacks woody vegetation. Additionally, the herbaceous vegetation on the banks is heavily affected by dryness during drought periods, which, combined with extensive grazing along the banks, results in reduced favorability in most of the studied sectors. Approximately 60 km out of the total sectors, representing about 50%, are unfavorable in terms of trophic conditions. The other portions were classified as having medium creditworthiness, due to the presence of hygrophilous plants that cover most of the minor channel.

4.1.7. Buzău Hydrographic System

General Description

The Buzău system is one of the significant hydrographic basins in Muntenia, covering an area of over 5,500 km², with a main course length of 334 km, and an average discharge of 25 m/s. The sources of the Ialomița River are located in the Curvature Carpathians, in the Ciucaș Mountains, at an altitude of about 1800 m (Ujvari, 1972).

On the upper section, Buzău River has numerous tributaries, especially in the mountainous and piedmont areas, but many of them are unfavorable in terms of living conditions. To identify the relevant tributaries for the species, the habitats on the Slănic, Nișcov, Bâsca, and Chiojdu tributaries were classified.

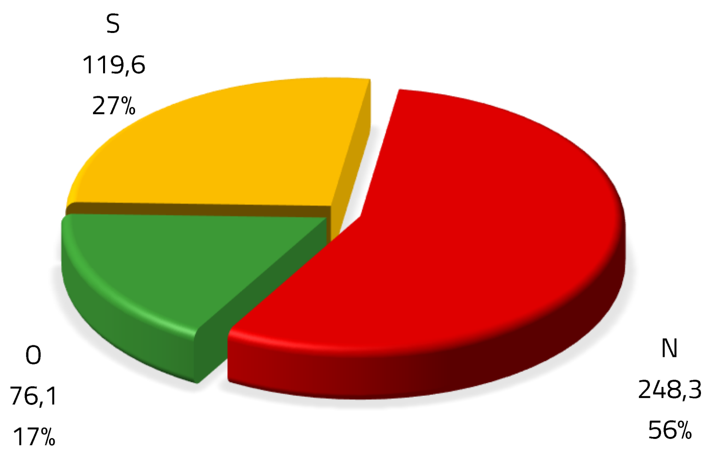


Fig. 51. Bazinul hidrografic Buzău - Ponderea habitatelor pe categorii de bonitate

Buzău River basin- Share of habitats by categories of creditworthiness

The Buzău hydrographic basin is one of the least favorable ones for the studied species among the large river basins in Muntenia. Out of the total analyzed habitats, which sum up to 444 km, only 76 km are optimal habitats, and 120 km are satisfactory habitats, together representing 44% of the total analyzed territories.

According to the records made at the Brusturoasa hydrographic station, the maximum water discharges are recorded in January and during the period from April to June, while the minimum discharges occur in September to December. The freezing phenomena are more prolonged than in the western part of the country at similar altitudes but are somewhat less intense than in the Moldavian region (Ujvari, 1972).

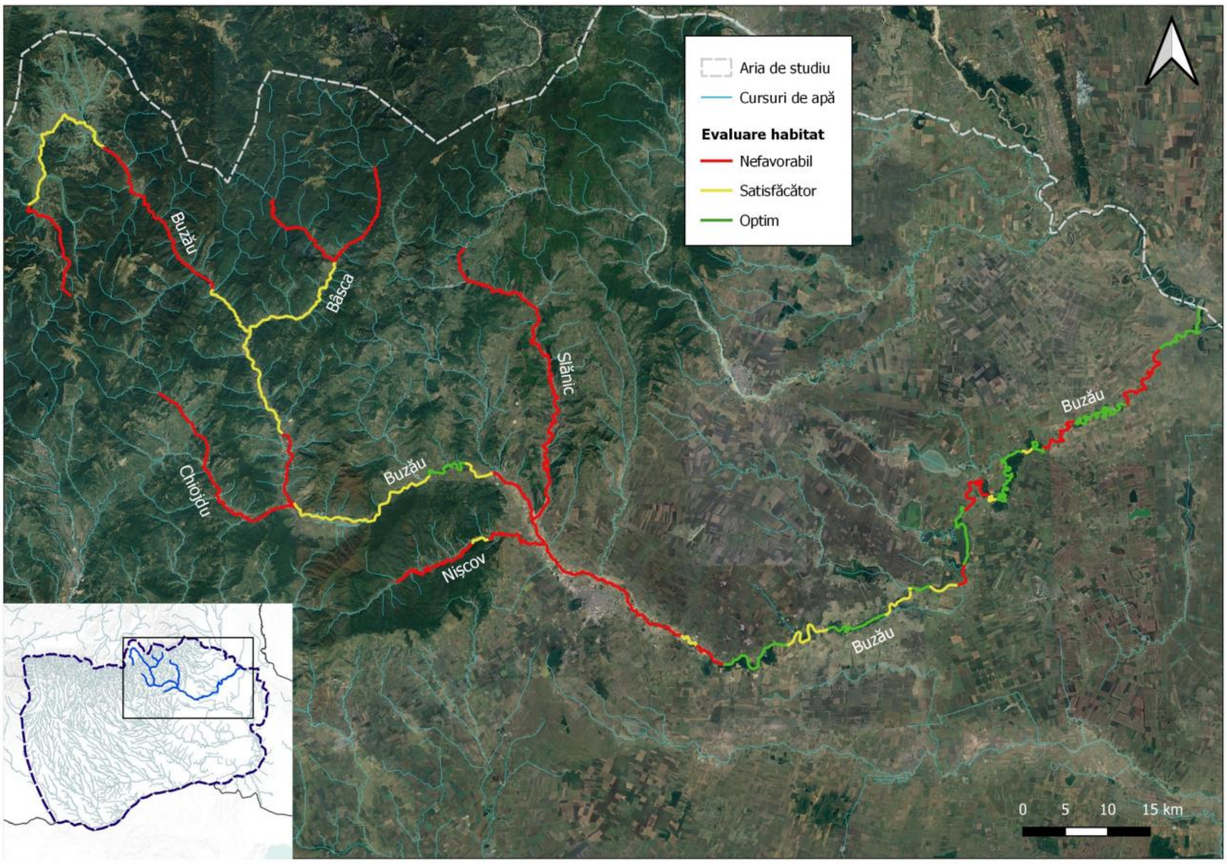


Fig. 52. Bazinul hidrografic Buzău - Cartarea habitatelor pe categorii de bonitate
Buzău River hydrographic basin - Mapping of habitats by creditworthiness categories

The Buzău River

Habitat Analysis

In total, habitats were evaluated along a length of 298 km on the main course of the river. Out of these, the largest proportion is occupied by unfavorable habitats, covering 122 km (40.9%), while satisfactory zones represent 34%.

Hydrological Conditions

On the section from the confluence with the Siret River to the Poșta locality, the hydrological conditions are favorable, with the riverbed characterized by a sinuous-meandering course and well-defined minor banks.

Continuing downstream, the river presents very intense erosion phenomena, leading to frequent changes in the riverbed and, in some sections, the splitting of the river into branches followed by their reunification downstream. Upstream of the city of Buzău, the river is canalized over a considerable portion, with a parallel channel created alongside the natural one. Starting from the locality of Berca, the riverbed resumes its natural character, displaying a sinuous longitudinal profile. It then enters the subcarpathian zone and later the Curvature Carpathians.

On the upper course, hydrological conditions are variable, alternating between favorable and unfavorable zones.

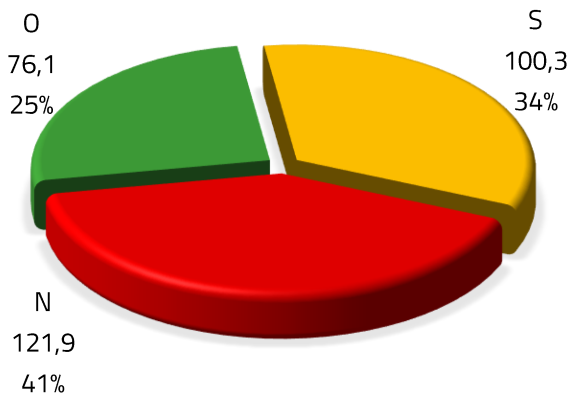


Fig. 53. Râul Buzău - Ponderea habitatelor pe categorii de bonitate
Buzău River - Share of habitats by categories of creditworthiness

Trofic Conditions

From a trophic perspective, the lower section is characterized by the presence of forests, which offer optimal or satisfactory conditions in terms of food availability. However, starting from the locality of Poșta, vegetation becomes less available and unevenly distributed, interrupted by numerous sand and gravel exploitations in the area around the city of Buzău.

Riverbank Conditions

Downstream, the riverbanks are mostly satisfactory, but from the Poșta area onwards, they become unfavorable. In the subcarpathian and mountainous areas, the quality of the riverbanks alternates.

Human Impact

The most significant anthropic activity is observed in the middle course of the river, where there is a large number of sand and gravel exploitations (in the area of Buzău city). Between Buzău and Pleșcoi, the construction of a canal that diverts a significant part of the river's flow results in large variations in water levels in the natural riverbed. Grazing is practiced in isolated areas near the river, but its impact is relatively low.

Relevant Tributaries of the Buzău River

The Bâsca and Niscov tributaries have some sections with satisfactory habitats, but their proportion is small. No representative sections with optimal conditions have been identified. The Chiojdu and Slănic streams are completely unfavorable for beaver colonization, mainly due to their hydrological characteristics and riverbed configuration.

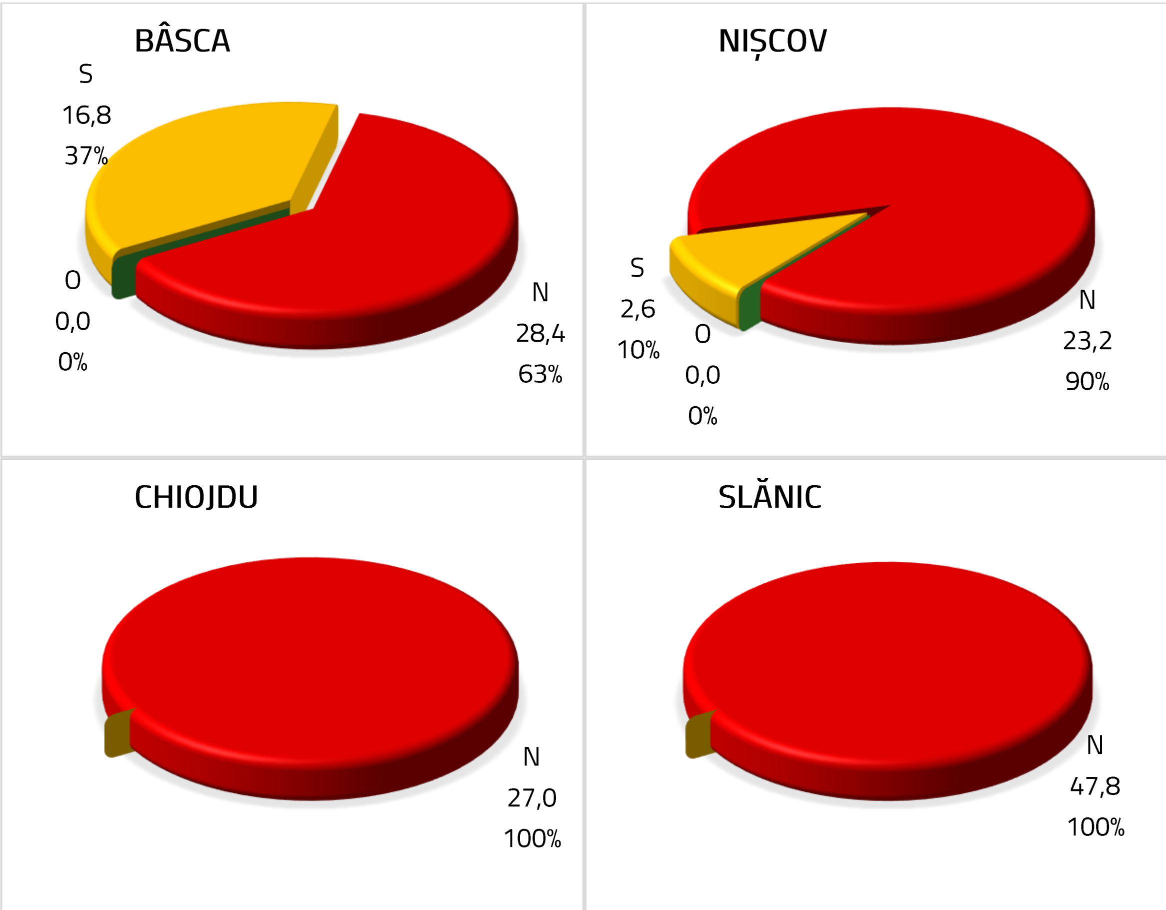


Fig. 56. Afluenții relevanți ai râului Buzău - Ponderea habitatelor pe categorii de bonitate
Main afluents of Buzău River - Share of habitats by categories of creditworthiness

4.1.8. Râmnicul Sărat Hydrographic System

General Description

Although the number of tributaries is quite significant for the present study, no relevant tributary watercourses have been identified that could be relevant in terms of potential beaver colonization. This does not exclude the possibility that, in their natural dispersion, beaver individuals may temporarily populate such habitats considered unsuitable.

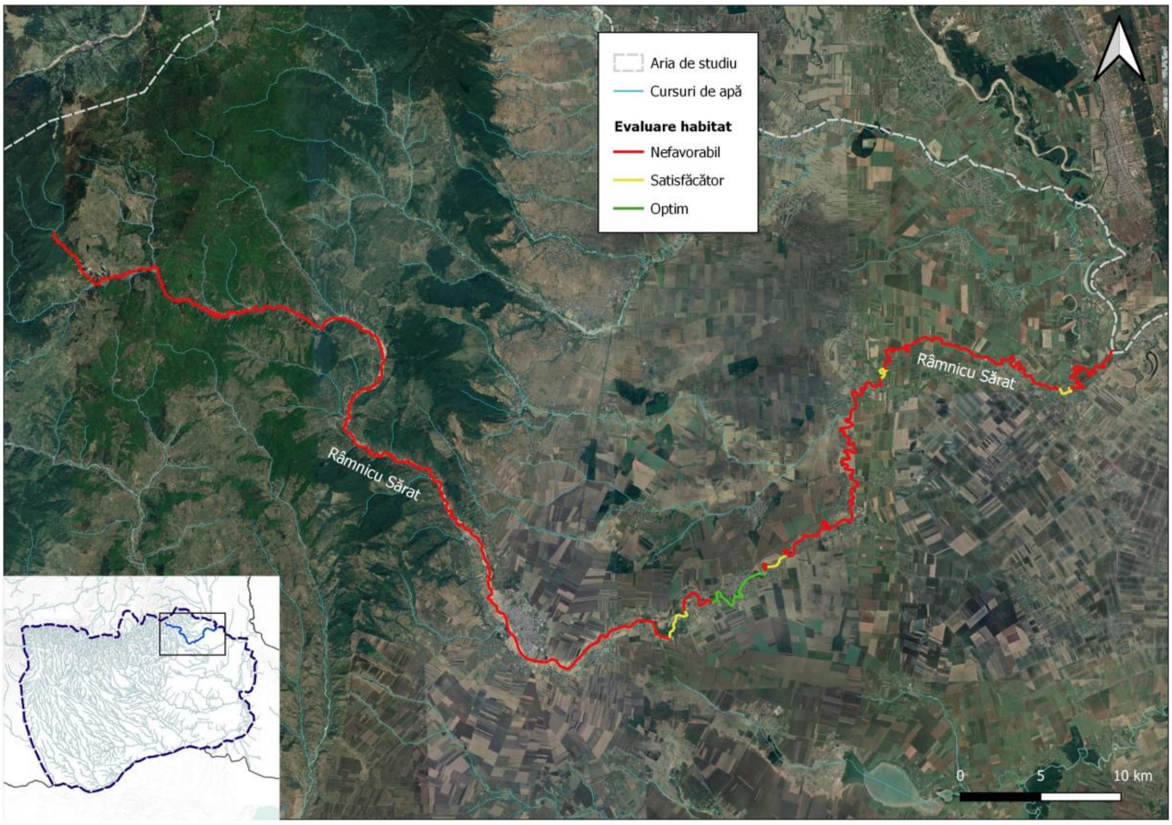


Fig. 58. Bazinul hidrografic Râmnicu Sărat - Cartarea habitatelor pe categorii de bonitate
Râmnicu Sărat River hydrographic basin - Mapping of habitats by creditworthiness categories

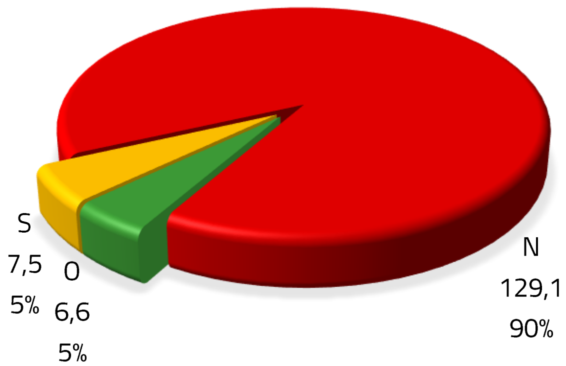


Fig. 57. **Râul** Râmnicul Sărat - **Ponderea habitatelor pe categorii de bonitate**
Râmnicul Sărat River - Share of habitats by categories of creditworthiness

Habitat Analysis

The Râmnicu Sărat River presents two main sections: one starting from the confluence with the Siret River, near the town of Măicănești, and extending somewhere in the Știubei area, while the second one is located from the Știubei area to the entrance to the Vrancea Mountains. Each of these two sectors has distinct hydrological characteristics. The first sector, situated in the plain **region, is** characterized by a very slight longitudinal slope, with the river mouth located at an altitude of about 11 m, while in the Știubei area, the altitude is about 67 m. On the next sector, the slope increases significantly, so that at the entrance to the Subcarpathian region, the altitude is already close to 700 m. This difference in level determines a very pronounced longitudinal flow, resulting in a highly meandering riverbed.

The Râmnic River is modest in terms of hydrology, so during dry periods, the width of the riverbed reduces significantly, from about 80 m under normal conditions to about 30 m. Nevertheless, it is considered that the river could be repopulated with beavers in areas where tree vegetation is present in sufficient quantity to provide food during the winter season.

4.2. Calculation of the carrying capacity of the environment for the analyzed habitats

4.2.1. Calculation of density indices for the Ialomița River

In order to determine the carrying capacity of the environment for the rivers under study, in addition to the available densities in the national publications mentioned in Chapter 3.1.2., a set of data was processed, which includes the number of shelters and the estimation of populations for the Ialomița River, on the sector between the locality of Dridu and the confluence with the Danube, collected in 2013, as part of the CLMAN project (Vișan et al., 2015). Unlike the calculated values for the Olt River, this dataset showed lower average values for the number of families and individuals per kilometer of river length. Thus, for unfavorable habitats, the average density of individuals per kilometer is 0.38, for satisfactory habitats, it is 1.48, and for optimum habitats, it is 1.51.

4.2.2. Calculation of the carrying capacity of the environment

By applying the density indices (individuals/km) obtained from the two sources (Olt and Ialomița) to the total and risk-free length of the habitats (sectors with major risks excluded), four values of the optimal population were obtained, corresponding to the carrying capacity of the environment.

The hydrographic system of Călmățui (Teleorman County)

Table 13. Natural and social carrying capacity for the Călmățui hydrographic system (Teleorman County)

Habitat Quality	Total habitats (km)	Habitats no risk (km)	Carrying cap. DI Ialomița* (individuals)		Carrying cap. DI Olt* (individuals)	
			K	KS	K	KS
O	0	0	0	0	0	0
S	42,5	42,5	63	63	93	93
N	192,9	166,9	73	63	199	172
Total	**235,4**	**209,4**	**136**	**126**	**292**	**265**

* DI= Density indices (individuals/km)

The hydrographic system Vedea

Table 14. Natural and social carrying capacity for the Vedea system

Habitat Quality	Total habitats (km)	Habitats no risk (km)	Carrying cap. DI Ialomița* (individuals)		Carrying cap. DI Olt* (individuals)	
			K	KS	K	KS
O	131,9	123,4	199	186	302	283
S	194,8	113,2	288	168	427	248
N	527,6	385,5	200	146	543	397
Total	**854,3**	**622,1**	**688**	**500**	**1272**	**928**

The hydrographic system Argeș

Table 15. Natural and social carrying capacity for the Argeș system

Habitat Quality	Total habitats (km)	Habitats no risk (km)	Carrying cap. DI Ialomița* (individuals)		Carrying cap. DI Olt* (individuals)	
			K	KS	K	KS
O	394,5	394,5	596	596	903	903
S	317	317	469	469	694	694
N	643,3	611,4	244	232	663	630
Total	**1354,8**	**1354,8**	**1309**	**1297**	**2260**	**2227**

The hydrographic system Mostiștea

Table 16. Natural and social carrying capacity for the Mostiștea system

Habitat Quality	Total habitats (km)	Habitats no risk (km)	Carrying cap. DI Ialomița* (individuals)		Carrying cap. DI Olt* (individuals)	
			K	KS	K	KS
O	15,2	15,2	23	23	35	35
S	40,5	40,5	60	60	89	89
N	51,8	41,7	20	16	53	43
Total	**107,5**	**97,4**	**103**	**99**	**177**	**167**

The hydrographic system Ialomița

Table 17. Natural and social carrying capacity for the Ialomița system

Habitat Quality	Total habitats (km)	Habitats no risk (km)	Carrying cap. DI Ialomița* (individuals)		Carrying cap. DI Olt* (individuals)	
			K	KS	K	KS
O	244,5	244,5	369	369	560	560
S	147,3	147,3	218	218	323	323
N	370,2	331,6	141	126	381	342
Total	**762**	**723,4**	**728**	**713**	**1264**	**1225**

The hydrographic system Călmățui (Brăila county)

Table 18. Natural and social carrying capacity for the Călmățui system (Brăila county)

Habitat Quality	Total habitats (km)	Habitats no risk (km)	Carrying cap. DI Ialomița* (individuals)		Carrying cap. DI Olt* (individuals)	
			K	KS	K	KS
O	0	0	0	0	0	0
S	22,5	22,5	33	33	49	49
N	106,4	84,9	40	32	110	87
Total	**128,9**	**107,4**	**74**	**66**	**159**	**136**

The hydrographic system Buzău

Table 19. Natural and social carrying capacity for the Buzău system

Habitat Quality	Total habitats (km)	Habitats no risk (km)	Carrying cap. DI Ialomița* (individuals)		Carrying cap. DI Olt* (individuals)	
			K	KS	K	KS
O	76,1	76,1	115	115	174	174
S	119,6	119,6	177	177	262	262
N	248,3	122,3	94	46	256	126
Total	**444,1**	**318,1**	**386**	**338**	**692**	**562**

The hydrographic system Râmnicul Sărat

Table 20. Natural and social carrying capacity for the Râmnicul Sărat system

Habitat Quality	Total habitats (km)	Habitats no risk (km)	Carrying cap. DI Ialomița* (individuals)		Carrying cap. DI Olt* (individuals)	
			K	KS	K	KS
O	6,6	6,6	10	10	15	15
S	7,6	7,6	11	11	17	17
N	129,1	57,1	49	22	133	59
Total	**143,3**	**71,3**	**70**	**43**	**165**	**91**

Carrying capacity calculated for the historical region of Muntenia

Table 21. Natural and social carrying capacity for the historical region of Muntenia

Habitat Quality	Total habitats (km)	Habitats no risk (km)	Carrying cap. DI Ialomița* (individuals)		Carrying cap. DI Olt* (individuals)	
			K	KS	K	KS
O	868	860	1312	1299	1989	1970
S	892	810	1320	1199	1954	1775
N	2270	1801	862	685	2338	1856
Total	**4030**	**3504**	**3494**	**3183**	**6281**	**5601**

4.3. Synthetic Guide for Mitigating Human-Beaver Conflicts in Muntenia

Main Conflict Mitigation Measures

The main measures that can be adopted have been previously described in international specialized literature and applied in practice and national literature (A. Pașca et al., 2022; C. Pașca et al., 2019).

Protection Nets and Fences

One of the most commonly used methods to safeguard crops, forest vegetation, yards, gardens, orchards, or ornamental plants is by blocking access.

Fig. 60. Gard improvizat la limita unei grădini de legume
Improvised fence at the border of a vegetable garden

Thus, to control the population growth in areas where the presence of the species is undesirable, it is essential to protect forest vegetation from being consumed by beavers. Simultaneously, it is crucial to restrict access to the food source, and if necessary, consider relocating or removing some beaver families. In cases where the population continues to increase despite all efforts, it will result in a rising number of conflicts.

Fig. 61. Plasă metalică pentru protecția trunchiului arborilor
Metal mesh for tree trunk protection

Metal nets, physical fences, or electric fences can be used for protection. Metal nets are particularly useful for safeguarding valuable trees, both economically and aesthetically. This type of protection involves encircling the tree trunk with metal nets starting from the base up to a minimum height of 80 cm. The net should have 5 cm mesh size and a wire thickness of at least 1.5 mm to withstand beaver damage.

Electric fences designed to block beavers' access should consist of a minimum of four wires fixed on sturdy posts, starting at a height of no more than 15 cm from the ground, with a 20 cm distance between wires, forming a barrier with a height of 75-80 cm. Low-height electric nets can also be effectively used if preventing movement of larger species (e.g., deer) is not desired. However, these may require periodic maintenance as they can be damaged by larger wild animals.

Maintenance of the electric fence includes mowing the grass in the fence's operating area, which can be time-consuming for property owners. Without proper and timely maintenance, the electric fence may lose its effectiveness as the base wires can lose tension by touching objects on the ground, failing to protect crops, vegetation, or other targeted objects.

Water level regulation systems are assemblies consisting of plastic pipes and metal protective grilles that can be installed in the dam built by beavers to maintain a constant water level, thereby avoiding flooding in nearby areas. These systems are suitable for streams with relatively constant flow, and the diameter of the pipes should be adapted to the required water discharge.

Fig. 62. **Sistem de reglare a nivelului apei**
Water level control system

At the upstream end, the pipe is protected by a metal net to prevent it from being clogged by beavers since they constantly seek to block any openings through which water is lost from the created lake.

The system requires constant maintenance, as it becomes non-functional otherwise. Branches, leaves, or other obstacles that may clog the water intake are removed.

The use of repellent substances and devices is another option. Various repellent products are available in the form of solutions that can be brushed or sprayed onto the tree trunks that need protection. This treatment needs to be periodically repeated as the repellent effect gradually diminishes.

Repellent devices have electronic components that emit sounds at different frequencies to keep animals away. In some cases, animals can become accustomed to the sounds, and the effectiveness of these devices may decrease or disappear.

Paving or graveling can be employed to protect hydrotechnical structures. Metal profiles, metal or composite nets can be used to create barriers to limit beavers' access to protection dikes or earth dams. Additionally, the riverbanks can be covered with stones, allowing for a natural or semi-natural landscape by covering unfriendly materials with soil and vegetation.

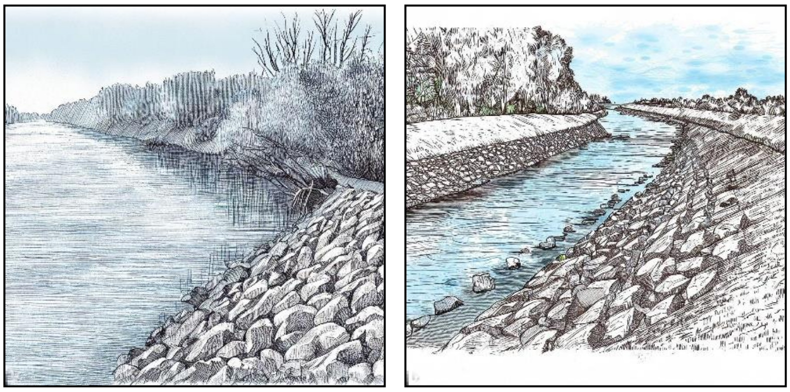


Fig. 63. Modalități de protejare a malurilor prin pietruire (desene Bing Image Creator)

Various ways to protect banks by paving (drawings Bing Image Creator)

Relocarea exemplarelor problemă

În cazul exemplarelor care nu pot fi menținute într-o zonă, datorită riscului pe care îl reprezintă pentru populația locală sau datorită pagubelor deosebit de mari pe care le produc, soluția este relocarea lor în conformitate cu legislația în vigoare, cu parcurgerea tuturor etapelor necesare. Relocarea se realizează în zone libere de castori, contribuind la refacerea distribuției istorice a speciei.

Fig. 64. **Capcană pentru capturarea castorilor**

Live beaver trap

Elimination of problematic individuals

It is highly likely that over the medium to long term, the beaver population in Romania will fully recolonize its historical habitats. However, in the absence of relocation areas, the solution will be to eliminate individuals that create significant problems and cannot be mitigated through the methods described above. In this case, population management through hunting will be necessary, similar to other game species. Failure to address the population effectively may lead to reduced acceptance of the species, and local communities may resort to clandestine actions to reduce the numbers, which would have a negative, boomerang effect on the species.

Chapter 3. FINAL CONCLUSIONS. ORIGINAL CONTRIBUTIONS. FUTURE RESEARCH DIRECTIONS. DISSEMINATION OF RESULTS.

5.1. FINAL CONCLUSIONS

- The Eurasian beaver, historically known as "breb," was once widespread in most aquatic systems of Muntenia, with numerous evidence to support this claim, such as toponyms, hydronyms, family names, archaeological zoological collections, etc.
- In order to determine the suitability for beaver repopulation using the expedited classification method supplemented in this study, riparian habitats can be analyzed with sufficient precision. This method offers significant advantages, such as the ability to analyze a large volume of data at reduced costs, both in terms of personnel salaries and travel expenses.
- In the historical region of Muntenia, there are significant differences in the proportion of suitability categories, determined by environmental and anthropogenic factors analyzed. For some rivers/streams in the plain region, the absence of water flow during periods of low rainfall classifies them as unsuitable. On the other hand, rivers regulated by dams present more favorable conditions.
- The analysis of variance was used to test the differences between different sectors of the same hydrographic basin, between hydrographic basins, and between sectors of the same river, with the identification of criteria for which there are significant differences.
- The sectors of rivers located in the submontane and mountain areas are mostly unsuitable for the species due to low scores obtained in one or more of the three main environmental criteria.
- In terms of quantity and quality, the habitats in Muntenia are distributed as follows: out of a total of 4030 km of river evaluated, 868 km are optimal habitats, 892 km are satisfactory habitats, and 2270 km are unsuitable habitats. It should be noted that the study does not include the entire hydrographic network across the entire historical region.
- The density indices calculated for the dataset from Ialomița are lower compared to those derived from the literature (previously calculated for the Olt river), hence they were used to calculate the lower limit of the interval for carrying capacity (K and KS), while the upper limit was taken from the literature.
- Although riparian zones have been affected by anthropogenic activities over time, the hydrographic basins of Muntenia remain a valuable reservoir of favorable habitats for beaver repopulation. The natural carrying capacity (K) for the entire region ranges between 3500-6300 individuals, while the social carrying capacity (KS) ranges between 3200-5600 individuals.
- In certain areas, riparian vegetation requires ecological restoration measures to increase local diversity and, consequently, the quality and quantity of available habitats for beavers.

- The future evolution of the species will require the implementation of concrete measures to maintain a positive attitude of the local population towards the species. As the historical range is restored, the population needs to be informed and educated to maintain conflict levels at acceptable levels.
- This study should be extended nationwide to create a national database on carrying capacity, which would support authorities and stakeholders involved in riparian areas or beaver (Castor fiber) management.

5.2. ORIGINAL CONTRIBUTIONS

A critical study of relevant aspects of published literature was conducted for the proposed objectives, complementing information related to archaeological and toponymic evidence of the species' presence in Romania. An up-to-date bibliographic study on the population and evolution of Eurasian beaver populations in neighboring countries was also conducted, along with simulations of short-term population trends based on existing data.

During the study, the method for evaluating habitat suitability using satellite images was completed, tested, and adapted.

The evaluation, classification into suitability classes, and description of potentially favorable habitats for beaver repopulation in the historical region of Muntenia were conducted based on satellite images. The analysis included the hydrographic basins of the following rivers: Călmățui (TR), Vedea, Argeș, Mostiștea, Ialomița, Buzău, Călmățui (BR), and Râmnicu Sărat.

The carrying capacity for beaver repopulation in the historical region of Muntenia was calculated, including the hydrographic basins of the following rivers: Călmățui, Vedea, Argeș, Mostiștea, Ialomița, Buzău, Călmățui (BR), and Râmnicu Sărat.

A concise guide of action was developed to mitigate human-beaver conflicts in various situations, with the aim of maintaining a favorable conservation status of the species and an optimal level of acceptance among human populations.

5.4. DISSEMINATION OF RESULTS

During the doctoral studies, the author has published the following articles and books as the primary author:

Articles:

Paşca, C., Ungureanu, L., Ionescu, G., Popa, M., & Gridan, A. (2016). Riparian habitat modelling in the context of beavers (Castor fiber) repopulation in Braşov, Romania. Russian Journal of Theriology, 15(1), 49–54. https://doi.org/10.15298/rusjtheriol.15.1.08

Pașca, C., Popa, M., Grodan, A., Ionescu, G., Vișan, D., & Ionescu, O. (2019). Solutions for protection of hydrotechnical dikes in the areas populated by beavers. Revista de Silvicultura Și Cinegetica, XXIV(45). http://progresulsilvic.ro/wp-content/uploads/RSC_45_2019.pdf

Paşca, C., Ionescu, G., Teșileanu, R., Popa, M., & Ionescu, O. (2021). Testarea unei metode rapide de evaluare a habitatelor favorabile pentru castorul eurasiatic (Castor fiber L.). Revista de Silvicultură Şi Cinegetică, XXVI(48). http://progresulsilvic.ro/wp-content/uploads/RSC_45_2019.pdf

Pașca, C., Ionescu, G., Fedorca, A., Jurj, R., Sîrbu, G. A., Popa, M., Gridan, A., & Ionescu, O. (2022). Beaver management in Romania between challenges and perspectives. The National Action Plan for the Conservation of the Eurasian beaver population (Castor fiber L.) – synthesis. Revista de Silvicultura Si Cinegetica, XXVII(50), 109–118. http://progresulsilvic.ro/wp-content/uploads/RSC_nr_50_2022.pdf

În curs de publicare.

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