One park, two owners—Inconsistencies in forest stewardship

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Abstract
Appropriate management of European spruce forests in this time of climate change is a significant challenge. Uniform principles of quality forest practice must be applied, essentially in forests that are valuable from a conservation point of view. However, this may be problematic in protected areas with mixed ownership and disparate priorities. Managerial decision-making is often based on personal knowledge, previous experience, priorities other than conservation, or political influence. Clear management guidelines at the European and national levels are lacking in many protected areas. In this article, we use data from the Šumava NP to elucidate varied management approaches applied by state and private municipal owners in forests of high conservation value. We used high-resolution aerial photographs to evaluate the effects of forest management practices applied, and compared the status of spruce habitats before and after a major windstorm and large-scale bark beetle outbreak. We found that follow-up forest management measures have significantly affected forests in the Šumava NP negatively. However, changes are not equally spread across the area of study, with forest ownership important for the type and intensity of changes. Kašperské Hory Municipality, managed their forests more as a productive commercial forest as contrasted to the state owned forest. We compare our findings with experiences from other Central European national parks with similar forest management challenges. Options for improving and unifying the management of conservation-valuable forests held in state and private ownership are discussed in the conclusion. Wide political consensus and stability together with long-term mutual trust and a willingness to collaborate among conservationists, forest managers and forest owners were recognized to be essential for the successful achievement of conservation goals.

Keywords
bark beetle, clear-cut, forest ecosystem management, national park conservation policy, national park stewardship, Natura 2000
1 | INTRODUCTION

In European forests, discourse on appropriate forest management is escalating, hand in hand with the increasing frequency and intensity of natural disturbances and other effects of climate change (Dale et al., 2001; Kulakowski, 2016; Logan et al., 2003; Rocca & Romme, 2009; Seidl et al., 2017). Forests are a common heritage of all Europeans, and the current EU 2030 Forest Strategy must include decisions on appropriate forest management from the national to the European level. Therefore, there is an urgent need to strengthen pan-European cooperation on responsible forest management. Principles of good practice should be applied uniformly, but in forests that are valuable from a conservation point of view (e.g., national parks, nature reserves, old growth forests), this is essential. Implementation of the most appropriate management measures is especially challenging in protected areas with mixed ownership, which often leads to disparate priorities (Loeb & D’Amato, 2020). Private owners of forests often prefer traditional forestry and their own economic interests to nature conservation (Buijs & Lawrence, 2013; Eriksson & Fries, 2020), even if the losses caused by the latter are financially compensated by the state (Bergseng & Vatn, 2009).

Many valuable European forests are organized within Natura 2000, a unique EU-wide network of protected areas, which aims to maintain European biodiversity, or at least prevent its worsening, by implementing two Directives: 1992 Habitats Directive and 2009 Bird Directive (Sundseth & Creed, 2008). As these areas include the most valuable sites, the problems inherent with mixed ownership and disparate priorities may be even larger here and attracting international attention (e.g., Stokstad, 2016). Spruce Natura 2000 forests (especially habitat 9410—Acidophilous montane spruce forests) may serve as a good example. These forests have been significantly stressed by drought, wind and large-scale bark beetle outbreaks during the last two decades in many EU countries (e.g., Bussotti & Pollastrini, 2017; Schurman et al., 2018). A large proportion of montane spruce forests occur in national parks or other protected areas, where natural processes are supposed to be maintained. Whether nonintervention management practices, after a natural disturbance, are optimal in the long-term in protected areas is widely argued in a pan-European context (Bláha et al., 2013; Husslein et al., 2009; Sommerfeld et al., 2021). It is well-documented though, that forests successfully regenerate after large-scale disturbances (e.g., Hlášny et al., 2021; Jonášová et al., 2010; Svoboda et al., 2010). Scientists have demonstrated that post bark beetle outbreaks, nonintervention management is optimal for ecosystem recovery in mountain spruce stands. Benefits include nutrient recycling, preventing mineralization of the soil and the providing of shade, humidity, and cooling favoring natural regrowth (e.g., Bače et al., 2012; Bernes et al., 2015; Dyderski et al., 2018). Logging diminishes biodiversity and limits natural regeneration (Büssler & Müller, 2010; Lehner et al., 2013; Lindemayer et al., 2004; Müller et al., 2007, 2008, 2010; Novákůvá & Edwards-Jonašová, 2015; Thorn et al., 2016, 2017). However, scientific results and recommendations are insufficiently accepted in practice. Clear management guidelines at European and national levels are lacking in many protected areas.

The consequences of the lack of clear management guidelines can be illustrated by this example from the Šumava National Park, Czechia. Long-lasting debates on the future of nature conservation in Czechia’s largest national park linked with discussions on zoning and appropriate management of natural stands of mountain spruce (Křenová & Hruška, 2012; Křenová & Vrba, 2014), resulted in the lack of a long-term management strategy for the Šumava NP. After the Kyrill windstorm, which uprooted thousands of trees in local mountain spruce forests in January 2007, a nonintervention management approach was finally suggested for certain areas of the Šumava NP, but this was not always mandatory. Final decisions were left to local managers and/or owners. One area of the park is owned by the state, the other privately. Managers from different parts of the park preferred different management strategies and their decision-making was often based on personal knowledge, previous experience, or political influence. Due to mixed ownership and disparate priorities, forest dynamics differed across the Šumava NP (Janík & Romportl, 2018). Private owners more often prefer classical forest management measures (e.g., clearcuts, salvage logging, sanitary felling of bark beetle infested trees, removal of dead wood) to more sensitive conservation management (i.e., a nonintervention strategy or debarking and leaving wood to decompose) for mitigating the effect of a bark beetle outbreak even in protected areas (Zýval et al., 2016). While accepting various financial compensations from the state to preserve local biodiversity, private forest owners nevertheless maximize economic profit instead.

In this article, we compare the forest management practices of the state and private owners in the central area of the Šumava NP, where the most valuable Natura 2000 habitats occur. We used high resolution aerial photographs to evaluate the effects of the forest management applied and compared the status of Natura 2000 habitats, that is, the state and structure of habitats and their current ecological conditions, in 2006 and 2007 (summer before and after the Kyrill windstorm), in 2012 (5 years after the Kyrill windstorm, when the post-wind storm forest management measures had more or less ceased), and in 2017 (when no post-wind storm measures were applied). The results are
presented and compared with forest management strategies applied in other Central European national parks, with similar forest management challenges.

2 | MATERIALS AND METHODS

2.1 | Study area

The Šumava NP (established in 1991; 68,064 ha), the largest national park in the Czech Republic, together with the Bavarian Forest National Park (BF NP) (Germany; established in 1969 and enlarged in 1997 to 24,250 ha) constitutes the largest cross-border forested protected area in Central Europe (Figure 1.; Křenová & Kindlmann, 2015). Both NPs are the largest terrestrial Natura 2000 sites in these two countries and a significant part of the Natura 2000 network. The Šumava NP is a part of the Natura 2000 “Site of Community Importance” (SCI Šumava; designated under the Habitat Directive in 2004; 171,925 ha) and “Special Protection Area” (SPA Šumava; designated under the Bird Directive in 2004; 96,844 ha). Nine bird species are protected in SPA Šumava and twenty one habitats of Annex I of Habitats Directive together with eleven species of Annex II of Habitats Directive are protected in SCI Šumava (for a full list of protected habitats and species see Table A1).

**FIGURE 1** Study area and physical-geographical types

![Map of Study Area](image1)
Forests cover over 80% of the Šumava NP. The great variability in local conditions (mountain plate, marshlands, hills, rocky slopes, river canyons, etc.) result in varied forest types, most of which are habitats cited in Annex I of the Habitats Directive. Forests together with peat bogs, glacial lakes and mountain meadows are the most important habitats in this area. They form a unique complex of natural and seminatural habitats acting as a refuge for many endangered species of plants and animals: elements of the northern boreal forest represented here include capercaillie (*Tetrao urogallus*), Urals owl (*Sis ura lensis*), and three-toed woodpecker (*Picoides tridactylus*). This transboundary area is also home to several iconic species, such as lynx (*Lynx lynx*), wolf (*Canis lupus*), moose (*Alces alces*), peregrine (*Falco peregrinus*), or freshwater pearl mussel (*Margaritifera margaritifera*), each of which now occurs in few viable populations in Central Europe.

In 1991, when the Šumava NP was established, all forests were owned by the state and managed by the Šumava NP Authority (ŠNP Authority), as was stated by the Act no. 114/1992 Coll., on Nature and Landscape Protection (i.e., the Czech Nature and Landscape Protection Act). In 2000, restitution proceedings were carried out and some of the Šumava NP forests were transferred to private owners and municipalities. The largest area (5021 ha, 7.4% of the Šumava NP area) has been restituted to the Kašperské Hory Municipality (KH Municipality). After this transition, the ŠNP Authority manages 48,780 ha (88%) of forests in the Šumava NP.

KH Municipality, as well as other non-state subjects managing forests in national parks, annually receive financial contributions to compensate for the difficulties caused by the management of protected areas. Annual payments are paid for (i) timber that has not been harvested and left in the ecosystem for decomposition, (ii) use of more expensive environmentally friendly measures, and (iii) uncollected taxes on forest land located in the core zone of the NP, which are exempt from this tax payment. Between 2010 and 2017, KH Municipality received more than 4.8 million EUR. The amount of money has changed annually; the highest compensation (866,849 EUR) was paid in 2014 and the lowest (321,674 EUR) in 2017. The annual revenue of the KH Municipality budget is approximately 2.3 million EUR. However, this private owner has not always applied appropriate conservation measures in their forests. Zýval et al. (2016) studied forest management shortly after the Kyrill windstorm in the Modrava forest department, jointly managed by the ŠNP Authority and KH Municipality. They found that KH Municipality cleared a significantly higher proportion of disturbed forests in the Modrava forest department than the ŠNP Authority did.

For purposes of comparison, we divided our study area into several geographical frameworks based on ownership, abiotic conditions of the environment and presence of selected key Natura 2000 habitats. We compared a forested area owned by KH Municipality (henceforward “KH forest”; 5021 ha) with forests managed by the ŠNP Authority (henceforward “state forest”). Only state forests occurring in the north part of the Šumava NP (43,357 ha; Figure 1) were included in this comparison. Forests from the south part of the Šumava NP were not included because of the different forest types and dynamics of the bark beetle outbreak there. Within our study area, we used typological classification by Janík and Romportl (2016) for setting a comparable typological framework of analysis. The most abundant types occurring in the KH forest and state forest are “high plateaus,” “higher foothills,” “edge of plateaus,” and “mid-slopes” (Table 1). A “lower foothills” type, rare and almost missing in the KH forest, was excluded from the analysis. Within the same study area, we also used data from the mapping of Natura 2000 habitats and compared changes in Natura 2000 habitats managed by different owners.

### 2.2 Data

We used data on forest cover changes recorded between 2006 and 2017 to illustrate the dynamics of forest habitats during the decade after the Kyrill windstorm, which strongly disturbed the area in January 2007. Therefore, we used four forest status milestones:

- 2006—initial state prior to the windstorm;
- 2007—state immediately post windstorm;
- 2012—5 years after the windstorm, when the bark beetle outbreak was already attenuating and post-wind storm forest management measures had more or less ceased;
- 2017—10 years after the windstorm, when common forest management measures were reapplied.

| Table 1 | Typological classification in KH and state forests. Definition of types were adopted from Janík and Romportl (2016) |
|---------|-------------------------------------------------------------|
|         | % in KH forest | % in state forest |
| High plateaus | 45.91          | 37.41          |
| Edge of plateaus | 19.57          | 12.76          |
| Mid slopes | 12.69          | 27.81          |
| Higher foothills | 20.24          | 14.29          |
| Lower foothills | 1.59           | 7.73           |

TABLE 1 Typological classification in KH and state forests. Definition of types were adopted from Janík and Romportl (2016)
Forest cover change data in the Šumava NP was adopted from a spatial–temporal database of forest changes (Janík & Romportl, 2018). This was prepared by an integration of consolidated layer of ecosystems (KVES—a Czech land cover database; Honigová & Chobot, 2014) and detailed data about forest change and its management prepared by the SNP Authority (Němčák & Slačilková, 2016). A new database contained year-to-year changes from 2006 to 2017 with several categories of forest status: clear-cuts, clear-cuts with dead wood, dead standing and dead lying forests and windfalls for each year. Through integration with KVES, 18 categories of land (forest) cover were distinguished (Janík & Romportl, 2018). For our analysis, we differentiated and chose five categories of forest status:

- Category 0 = unaffected areas: No visible changes in forest texture; green forest; no logging, no clearings or other visible disturbances.
- Category 1 = area with standing and lying dead trees attacked by bark beetle, dead trees; no sanitation falling of bark beetle infected trees, nonintervention management.
- Category 2 = area with windfall: windfall area, no salvage logging of damaged trees; nonintervention management.
- Category 3 = area with logged and debarked trunks: trees attacked by bark beetles were logged and debarked trunks left on the ground to decompose.
- Category 4 = area with clear-cuts: uprooted or standing trees attacked by bark beetles, trees logged, wood removed.

The changes in each category were expressed as a percentage of the total area of the segment.

To better describe changes in different forest types, we used data from mapping of Natura 2000 habitats. To determine a list of suitable Natura 2000 sites, the habitats and species in the whole country were mapped by experts, using a common methodology in 2001–2004 (Härtel et al., 2009). Several years of detailed mapping thus delivered maps of Natura 2000 biotopes (Chytrý et al., 2010) and descriptions of their quality. This consisted in dividing the country into segments (polygons on the map), each of which contained only one forest/grassland/marshland biotope. Biotopes were more detailed vegetation units than habitats. One or more biotopes in sensu Chytrý et al. (2010) were later aggregated to habitats in sensu Annex I of Habitats Directive. Mapping was repeated in 2006–2016 and updated maps were published (Lustyk & Oušková, 2011). Several methodological changes and updates have not allowed us to just simply compare data from the first and the second mapping and describe changes of Natura 2000 habitats in our study area. In our study, we focused primarily on biotopes with a high proportion of spruce trees and used the areas of selected biotopes from the second Natura 2000 mapping layers (Table 2), because time of mapping corresponds more closely to our study period. Only segments with 100% coverage of selected biotopes, no mosaics, were included in the following analysis. For a better understanding of the changes in our study area, we also referred to the data from the first Natura 2000 mapping. Some spruce forests occurring in the area are mapped as forest plantations (X9A) and forest clearings (X10; Table 2) as well. We do not include these results in this article because of their minor conservation importance.

2.3 Statistical analyses

Thus, we prepared data about forest cover and its change for both areas (i.e., comparison of KH and state forests on a landscape level), selecting physical-geographical types and Natura 2000 habitats, respectively. These data, calculated as percentage share of a target forest status from a total area of two forest owners, selected physical-geographical types or Natura 2000 biotopes, were used for statistical analyses. Within these frameworks (i.e., landscape, physical-geographical types, Natura 2000 habitats), we compared the share of land cover categories in each milestone (i.e., 2006, 2007, 2012, 2007). In particular, we focused on dynamics of forest changes immediately after the Kyrill windstorm (2007–2012) and during the following 5 years (2012–2017) when the bark beetle outbreak abated. We used forest structure data from 2006 as a baseline for comparison of cumulative changes in target forest units during the entire study period.

Forest status data were repeatedly collected in the same segments of the landscape, physical-geographical types and Natura 2000 biotope. Therefore, to test for changes in time, we have performed a repeated measures ANOVA with factors “owner” (KH forest and state forest) and “time” in STATISTICA 12 (Anonymous, 2012). G-tests (McDonald, 2014) were used to compare cumulative changes in forests managed by the SNP Authority and privately owned forests.

3 RESULTS

Results are structured into subchapters according to three target frameworks within which forest management
measures of state and private owners were compared. In the first subchapter, we compare differences between territories of the Sumava NP managed by state and municipality on the landscape level; in the second, differences of changes among physical-geographical types are considered; and in the third subchapter, differences among Natura 2000 habitats are assessed.

### 3.1 Two owners

In our study area, proportions of five forest status categories (Categories 0, 1, 2, 3, and 4) significantly changed in time (Table 3; \( p < .05 \)); however, there were no statistically significant differences in the changes between KH and state forests, with the exception of Category 4, that is, clear-cuts (\( p < .001 \)). Clear-cuts increased both in KH and state forests; nevertheless, expansion of clear-cuts was significantly larger in the KH forest (Figure 2). In 2006, before the Kyrill windstorm, clear-cut areas were mapped in only 4.5% of spruce forest habitats in the KH forest and 7.4% in the state forest. A decade later, in 2017, clear-cuts were reported from 18.7% of spruce forest habitats in the KH forest and 12.9% of the state forest. Proportions of clear-cuts have increased four times in the KH forest and 1.7 times in the state forest. The highest increase of clear-cut in the KH forest was in the years

### TABLE 2 Selected Natura 2000 forest habitats. Priority biotopes in sensu Habitats Directive are marked by *. Areas of selected biotopes adopted from the second Natura 2000 mapping in KH forests and state forest, the Šumava NP are shown

| Habitats of Annex I of Habitats Directive | Biotope units mapped (see Chytrý et al., 2010) | KH forest (ha) | State forest (ha) |
|------------------------------------------|-----------------------------------------------|----------------|------------------|
| 9110 Luzulo-Fagetum beech forests        | L5.4—Acidophilous beech forests               | 1390           | 6072             |
| 9410 Acidophilous Picea forests at montane to alpine levels (Vaccinio-Piceetalia) | L9.1—Montane Calamagrostis spruce forests L9.2B—Waterlogged spruce forests | 1145           | 10,039           |
| 91DO* Bog woodland                       | L9.2A—Bog spruce forests X9A—Forest plantations of allochthonous conifer trees X10—Forest clearings | 32             | 657             |
|                                           |                                               | 750            | 8154            |
|                                           |                                               | 252            | 1150            |

### TABLE 3 Repeated measures ANOVA of five forest categories distinguished in KH and state forests. Category 0 = unaffected forest, no changes; Category 1 = dead trees, no logging; Category 2 = windfall area, no logging; Category 3 = trees logged, debarked trunks left on ground to decompose; Category 4 = clear-cut, wood removed. Significant \( p \)-values \( (p < .05) \) are in bold

| Forest status category | Effect | Mean square | \( F \)-test | \( p \) |
|------------------------|--------|-------------|--------------|-------|
| Category 0             | TIME   | 548.0       | 32.3         | .000  |
|                        | TIME × Owner | 1.1       | 0.1          | .978  |
| Category 1             | TIME   | 38.9        | 4.1          | .023  |
|                        | TIME × Owner | 20.7       | 2.2          | .127  |
| Category 2             | TIME   | 0.0         | 4.1          | .044  |
|                        | TIME × Owner | 0.0       | 3.0          | .09   |
| Category 3             | TIME   | 16.6        | 19.2         | .000  |
|                        | TIME × Owner | 2.5       | 2.9          | .067  |
| Category 4             | TIME   | 162.7       | 57.9         | .000  |
|                        | TIME × Owner | 35.1       | 12.5         | .000  |

**Figure 2** Proportion of clear-cuts in spruce forest habitats in Kašperské Hory (abbreviated as “KH,” red points) and state (abbreviated as “ST,” gray points) forests during the decade after the Kyrill windstorm (years 2006, 2007, 2012, 2017 stated below the figure). Means and SD are shown. Repeated measures ANOVA showed significant differences between the two forest owners: \( F (3,18) = 12.497, p = .00012 \)
immediately after the Kyrill windstorm. In 2006–2017, proportions of unaffected forest (Category 0) declined in time in all forests of both owners, while proportions of all other four forest status categories increased.

3.2 | Physical-geographical types

The largest changes were recorded in high plateaus (Figure 3), where only 44.26% of spruce state forest and 70.32% of spruce forests in the KH forest were mapped as Category 0 (unchanged, without wind and bark beetle disturbances) in 2017. The remainder of the spruce forests was affected by disturbances and managers had to decide what measures to apply. In 2017, 26.4% of spruce forests in the state forest and 27.9% of spruce forests in the KH forest were cut down (Categories 3 and 4). Twenty percent of this logged area in the high plateaus state forest were logged and debarked trunks were left on the ground to decompose (Category 3). In the KH forest, only 6% of logged areas were in Category 3. The remainder of the logged area was clear-cut, no wood was left for decomposition. We found a statistically significant difference ($G$-test, 8.60, $p < .05$) in the increase in the percentage of the area of Category 4 between the KH and state forests during our study period. In the KH forest located in high plateaus, the percentage of clear-cuts (i.e., Category 4) increased from 6.3% of spruce forests in 2006 to 26.2% in 2017. In the state forest located in high plateaus, the percentage of clear-cuts (i.e., Category 4) increased from 16.2% of spruce forests in 2006 to 21.1% in 2017.

In high plateaus, the largest bark beetle area left without management, that is, nonintervention area, (Categories 1 and 2), was recorded. Unmanaged windfall areas (Category 2) left after the Kyrill windstorm or later weather events were rare. More than 90% of the nonintervention areas were standing spruce forests attacked by bark beetles and left without management for natural regeneration (i.e., no sanitation felling was applied). A significant majority were in state forests ($G$-test, 16.14, $p < .05$), where 9.3% of spruce habitats mapped as Category 1 in 2006 increased to 27.2% in 2017.

Similar trends appeared also in lower elevations, that is, a physical-geographical type “edge of plateaus,” where 21% of spruce forests of KH forest and 20.5% state forest were recorded as logged (Categories 3 and 4) in 2017. Again, only a smaller proportion of these logged trees were debarked and left for decomposition (Category 3) with a greater number of clear-cuts in the KH forest (Figure 3). In 2017, nonintervention areas (Categories 1 and 2) were mapped at 8.5% of spruce habitats in the state forest and 2.2% of the KH forest. However, these differences between the KH and state forests were not statistically significant.

Smaller changes of forests were recorded in physical-geographical segments of lower elevation, that is, in mid slopes and higher foothills (Figure 3). No statistical
significant differences between changes in the KH and the state forests were found in these two physical-geographical segments.

### 3.3 Natura 2000 habitats

We studied forest changes in differing Natura 2000 biotopes to better describe changes in multiple forest types (in sensu Chytrý et al., 2010). This aided us in testing whether some forest types, for example rare or priority Natura 2000 habitats, were managed differently.

We found that forest cover changes were large in all three Natura 2000 biotopes with dominant spruce abundances (L9.1, L9.2A, L9.2B).

Biotope L9.1, the most common spruce biotope in our study area, was strongly affected. In 2017, nearly one third of this biotope was mapped as logged (Figure 4) and another one third of this biotope, primarily in the state forest, was attacked by bark beetles and left without sanitation felling for natural regeneration (Categories 1 and 2). Repeated measures ANOVA confirmed significant differences between two owners in the proportion of logged areas ($p < .05$). Biotope L9.1 is a dominant biotope of spruce forest in our study area and therefore the results for biotope L9.1 were similar to trends described in Figure 2. We found a statistically significant difference ($G$-test, 11.87, $p < .05$) in the increase in the percentage of the area of Category 4 between KH and state forests during our study period. Originally, a lower proportion of logged L9.1 biotope in the KH forest increased in time and exceeded the proportion of logged L9.1 biotope in the state forest during the post-Kyrill storm period. In 2006, 5.1% of this biotope in the KH forest and 17.8% in the state forest were mapped as clear-cuts (Category 4) and only very small areas were Category 3. In 2012, when the post-Kyrill storm activities were more or less complete, 26.2% of this biotope in the KH forest and 23.8% in the state forest had been logged (Categories 3 and 4), and again only a small proportion (7% of logged L9.1 biotope in the KH forest and 12.4% in the state forest) were Category 3, that is, logged and debarked wood left for decomposition. A similar situation, with only small increases, was recorded in 2017 (Figure 4).

Comparable changes of forest cover were recorded in L9.2B biotope (Figure 4), however the changes were not so large. We found no significant differences between the owners in logging. The logged area of this biotope (Categories 3 and 4) increased from 5.2% in 2006 to 15% in 2017 in the KH forest and from 10.7% in 2006 to 18% in 2017 in the state forest, that is, the increase in KH forest was by a factor of almost 3, while in state forests it was less than 2. There were significant differences (w-test, 13.14, $p < .05$) in the increase of the nonintervention area between the KH and state forests during our study period. In the state forest, 3.8 and 22.5% of this biotope was managed as a nonintervention area (Categories 1 and 2) in 2006 and 2017, respectively. In the KH forest, it was only 0.01% in 2006 and 2.6% in 2017. In this biotope, large areas were mapped as forest without changes
(Category 0) in 2017–82.2% of L9.2B biotope in the KH forest and 59.4% in the state forest.

As well, L9.2A, a priority Natura 2000 habitat, which was rare in our study area (Table 2) was strongly affected during the post-Kyrril bark beetle outbreak. In the KH forest, where only 32 ha of this biotope occur, changes were not too visible. However, differences between owners were statistically significant (G-test, 19.39, \( p < .05 \)) in the increase of the nonintervention area (Categories 1 and 2). Category 1, that is, without sanitation felling of bark beetle infected trees, dominated in the nonintervention area and only a very small part of this area were forests of Category 2, that is, without salvage logging of damaged trees. In the state forest, 14.4% of L9.2A biotope were mapped as Category 1 in 2006 and increased to 42.7% in 2017 (Figure 4). In the KH forest, only 0.65% of biotope L9.2A was mapped as Category 1 in 2006. This category increased to 4.04% in 2017. There were no significant changes between the owners in the logging of this habitat. During our study period, the percentage of logged habitat L9.2A (Categories 3 and 4) has increased by less than 1% of the area both in the KH and state forests. In 2006, 2.4% of this biotope in the KH forest was mapped as logged (Categories 3 and 4) and less than half of this area was clear-cut (Category 4). In 2012, 3.2% of the habitat was mapped as logged and again half of this area was clear-cut. In the state forest, 8.5% of this priority habitat was mapped as a logging area (Categories 3 and 4) in 2006. Three quarters of this area was Category 3, that is, a logged area with wood left for decomposition. In 2012, 9.3% of the L9.2A biotope in the state forest were logged and one third of this area was considered Category 3. There were very small changes between 2012 and 2017. The largest happened between 2007 and 2012 (Figure 4).

Changes of forest cover were not as visible in beech and mountain mixed forests (L5.1 and L5.4, respectively); however, clear-cuts were recorded in these habitats too. In L5.4 biotope, where changes were more frequent, 14.2% of this biotope was mapped as a logged area (Categories 3 and 4) in the KH forest and 12.7% in the state forest in 2017. Again, only a small portion of logged wood was left for decomposition and over 90% of logged L5.4 biotope in the KH forest and 62% in the state forest were clear-cuts (Category 4, Figure 4). In these two habitats, there were insignificant differences between owners.

### DISCUSSION

#### 4.1 | Dichotomies in state- and private-owned forests

We have studied the changes in forest cover and structure in territories of the Šumava NP owned and managed by both state and municipality during the 10 years following the Kyrril windstorm, which strongly disturbed the area in January 2007. In all three frameworks of our study (i.e., landscape, physical-geographical types and Natura 2000 habitats), we have identified significant changes in spruce forests and results confirmed the often discussed assumption that a bark beetle outbreak is a major challenge for Central European forests as well as an opportunity for natural restoration and enhancing biodiversity (Müller et al., 2008). Significant changes were recorded in both KH and state forests. However, there are different tendencies in municipal and state forest management.

High plateaus, a physical-geographical type of the highest elevation, have been the most dynamically affected. Higher altitudes with predominantly spruce forests are more vulnerable to disturbances (Brůna et al., 2013; Macek et al., 2017). However, different
owners applied different measures in disturbed spruce forests occurring in high plateaus. The KH municipality more significantly applied salvage logging and sanitation felling, that is, created clear-cuts, measures common in commercial forests, while the ŠNP Authority preferred greater conservation measures. Large parts of disturbed spruce forests, especially in a core zone of the Šumava NP, were left without active measures and marked as nonintervention areas. Most of these bark beetle forests successfully regenerated (Čízková et al., 2020). The ŠNP Authority also often applied certain sensitive nature conservation measures, for example debarking of cut trees and leaving them for decomposition. Differences between owners gradually decreased with elevation. Consequences of disturbance were not as strong in lower elevations where mixed forests can grow. The courage of the ŠNP Authority in applying a nonintervention regime decreased with decreasing altitude and approaching the border of the national park. Some large clear-cuts were recorded in physical-geographical types of lower elevations as well (Janík & Romportl, 2018).

We found that Natura 2000 habitats with dominant spruce abundances (L9.1, L9.2A, and L9.2B) were much more affected than beech forest habitats (L5.4 and L5.1). This corresponds to the higher vulnerability of coniferous forest to disturbances (Janík & Romportl, 2018). Despite the conservation priority of Natura 2000 habitats, they were managed interventionally. We can summarize that Natura 2000 habitats were strongly affected during the post-Kyrill bark beetle outbreak. Partially, differing changes were recorded in different habitats (Table 4). If forest status of Categories 0, 1, and 2 is accepted as a favorable condition of the Nature 2000 habitats in sensu the Habitats Directive (Anonymous, 2000; Hernando et al., 2010) and Category 4 is understood as an unfavorable condition of the Natura 2000 habitats, we could propose to accept Category 3 as a slightly favorable condition. However, we can see that significant proportions of all spruce Natura 2000 habitats were in poor condition at the end of the post-Kyrill windstorm decade (Table 4). Especially the L9.1 biotope, the largest in the study area, had the highest increase of clear-cuts (Category 4). Again, clear-cuts of L9.1 biotope are significantly higher in the KH forest than in the state forest. Losses of Natura 2000 habitats in the order of a few percent are considered to be a serious problem (in sensu 92/43/EEC). Here we found a significant proportion of all spruce habitats in unfavorable conditions and their future management should be carefully recalibrated. The losses of Natura 2000 habitats and the unfavorable conditions caused by inappropriate management have been already reported in some areas of the Šumava NP (Zýval et al., 2016) and our results documented these problems in a large part of this national park. Smaller changes, and more careful decisions about appropriate management, were detected in the disturbed L9.2A biotope, a priority Natura 2000 habitat. The KH Municipality, managing only 32 ha of this biotope, adopted a nonintervention strategy more often in this biotope than in the others, while the ŠNP Authority preserved a nonintervention regime in more than 95% of this disturbed L9.2A biotope.

Despite these latter peculiarities, we can summarize that management in the KH forest has been leading to a more homogeneous ecosystem with, for all practical purposes, only two statuses—forest and clear-cuts. Management is traditional forestry-oriented with a predominance of clear-cuts and planting of young trees; selective cutting and natural regeneration are uncommon. Among all changes, there is a clear dominance of new clear-cuts (Category 4) after the Kyrill windstorm. An increasing percentage of clear-cuts is significantly higher in KH than in state forests, which corresponds to Zýval et al. (2016) who studied the situation shortly after the Kyrill windstorm in the Modrava forest department (15,073 ha), where the first nonintervention zone of the Šumava NP was established in 1997 at the time of a large bark beetle outbreak in the neighboring BF NP. Our more complex study, conducted in a larger area and covering a longer period, demonstrates that KH Municipality decisions and priorities in management of forests in the Šumava NP have changed little over time.

On the other hand, the state forest in the Šumava NP shows greater heterogeneity. There are clear-cuts together with other management approaches such as nonintervention dead standing and dead lying forest (Categories 1 and 2) or debarked cut trees left for decomposition (Category 3). At times, there are unclear borders between differently managed areas or multiple measures were applied consecutively in the same location (Janík & Romportl, 2018). Various approaches of forest management were applied during the 30-year history of the Šumava NP, which has resulted in heterogeneous and ambiguous approaches without a clear and consistent conservation concept (Křenová & Hruška, 2012; Křenová & Vrba, 2014).

Environmental heterogeneity is a prerequisite for ecosystem resilience and vital biodiversity (Hutchings et al., 2000). In addition to maintenance of natural processes, preserving diverse and resilient ecosystems and supporting high biodiversity should be the key aims of national park management. However, our results show that the dichotomy in ownership of forests leads to differing management practices—unification and rather intensive use on the one hand and promotion of diversity and heterogeneity on the other. Private owners prefer more classical forest management measures (e.g., salvage logging and clear-cuts) rather than more sensitive conservation measures (i.e., nonintervention strategy or debarking...
and leaving wood to decompose), even in cases where they receive financial subsidies and compensation from the state. However, even in state forests, the most appropriate measures are not always applied and decisions are certainly not completely independent from the interventions of politicians (Kindlmann & Křenová, 2016).

4.2 | Who can we learn from?

It is unnecessary to go far to see other approaches; the BF NP is the 20 year older brother of the Šumava NP. These transboundary national parks share the same habitats and populations of many species, including the bark beetle and its requisite management challenges. However, they differ in their main concepts of forest and wildlife management (Janík, 2020) and ownership. Almost the entire area of BF NP is owned by the state and managed by the BF NP Authority. Natural disturbances there are undoubtedly incorporated into management practices (Thorn et al., 2017) and preservation of natural processes is a cornerstone of the Bavarian conservation concept. Large parts of BF NP, deemed “Naturzone,” are managed as nonintervention areas; active measures are applied only in a buffer zone along the national park border. There is a political consensus to achieve a nonintervention regime for 75% of the NP territory by 2027.

Similarly, some Austrian national parks (e.g., the Kalkalpen NP) have large nonintervention core areas. However, setting up proper forest management in Austrian NPs has been also a national and political challenge. In 2010–2012, a group of experts established at the initiative of the Council of National Parks (advisory and consulting body of the state authorities) addressed the issue of adequate management of bark beetle-infested forest stands in national parks and other areas dedicated to the protection of natural processes (wilderness areas). The Council subsequently adopted the recommendations of the experts unanimously (Anonymous, 2013). The working group led by the director of Vienna Municipality forests was composed of experts from the Federal Ministry of Agriculture, Forestry, Environment and Water Management, representatives of federal states, and representatives of the Kalkalpen, Gesäuse and Hohe Tauern NPs, which are challenging the bark beetle management. Expert consultations were provided by representatives of the state authorities, federal nature conservation agencies, academics (Vienna University BOKU, Munich University of Technology), and NGO representatives. Working group members agreed that: (1) A conservation approach aimed at protecting natural processes is important especially in forests, because a significant part of forest biodiversity can only be preserved by eliminating human interventions. In Austria, special attention is paid to this concept, and for this purpose, so-called core nonintervention zones are being set up in national parks, biosphere reserves, wilderness areas and some forest nature reserves. (2) Spontaneous development in protected areas also brings new knowledge for forest ecology, sustainable forestry, phytosanitation strategies, and so forth. (3) The mission of protected areas is also to offer visitors an experience of nature in all its forms, including encounters with nature unaffected by human intervention. (4) It is necessary to accept that active protection measures in the buffer zones are legitimate protection measures, without which the nonintervention regime could not be applied. Properly set protection measures in the buffer zone increase the acceptability of nonintervention access in the core area. The working groups members also stressed that high quality of monitoring, research, and open communication are necessary for acceptance of nonintervention regimes in core zones of protected areas. The Austrian approach can be understood as socio-political consensus on the future of the most valuable protected areas. This consensus was reached at a time of a growing bark beetle outbreak.

We can find another experience in Slovakian national parks. They have proceeded through many legislative, political, and economical changes since 1993 when Czechoslovakia was separated. As in the Czech Republic, part of the original state forests were transferred to the ownership of the municipalities. Moreover, the remainder of the state forests in national parks have not been managed by NP authorities (and supervised by the Ministry of Environment), but have been managed by the State Forests of the Slovak Republic, an enterprise under the Ministry of Agriculture until April 1, 2022. Thenceforth, amendments of the Slovak Nature Conservation Act transferred the state forests growing in the most strictly protected zones of the Slovak national parks from the Ministry of Agriculture to the Ministry of Environment control. State forests occurring in zones of lower protection are still managed by the State Forests of the Slovak Republic. The priorities of these two ministries are not identical; the Ministry of Agriculture prioritizes economic returns over all other forest values. Illegal and large-scale harvesting and suboptimal logging have been common for many years (Mikoláš et al., 2017). Until now, management of the Slovak protected areas is fragmented into many owners with even multiple state organizations managing single areas differently. The negative changes and degradation of ecosystem quality was recorded in many protected areas, including national parks, for example Nízké Tatry NP (Zoncová, 2020) and in the whole of the Carpathians as well, where it caused loss and fragmentation of valuable habitats (Mikoláš...
Recently, a new law transferring management of national parks forests under the Ministry of Environment is under discussion. It could improve the situation; however, social-political consensus is still missing.

Finally, we mention the long-term negotiations about the appropriate management in the iconic Białowieża old-growth forest. It should be emphasized that the non-intervention strategy is now applied in almost the whole area of the Białowieża NP. However, many valuable segments of old-growth forest are outside of Białowieża NP and managed by the State Forests Enterprise. Although this is a Natura 2000 and UNESCO World Heritage Site, sanitary felling of bark-beetle infested trees together with other forest management measures, including building new roads, are used in this area (Mikusiński et al., 2018; Źmihorski et al., 2018). The European Commission as well as UNESCO World Heritage Site Board have already intervened in the Polish establishment, however lobbying from the forestry industry is strong. This cause also strongly divides Polish society. On the other hand, a nonintervention regime has been adopted and implemented in some Polish national parks for decades (e.g., Tatra NP—Grodzki et al., 2006; Gorce NP—Przepióra et al., 2020).

We can conclude that in Central Europe, the situation is very diverse. Clearly defined conservation aims, open negotiation with local representatives and long-term political stability support long-term nonintervention concepts in the BF NP. In Austria, the situation was perhaps more politically sensitive, however the bark beetle challenge was seized as an opportunity and social-political consensus was found. On the contrary, situations in Czech, Slovak and Polish protected areas are more complex and seeking consensus and a positive solution is not easy. Strong disagreements in conservation goals and long negotiations over nature conservation objectives appear even in parts of national parks and other protected areas owned by the state. The immaturity of society, including personal selfishness, together with the lack of political responsibility of involved partners, stakeholders, politicians, and state authority representatives in postcommunist countries can explain these troubles (Křenová & Kindlmann, 2015).

5 | CONCLUSION

We can see that large parts of valuable and typical Šumava NP forests including Natura 2000 habitats are affected by unsuitable management and are in unfavorable conditions after the Kyrill windstorm. Changes recorded in forest cover and structure are not equally spread across the area and forest ownership was important for the type and intensity of changes. Kašperské Hory Municipality managed their forests more as a productive commercial forest. Compensation and subsidies from the state, which can be used for more expensive and conservation sensitive measures, have rarely affected decision-making of their forest managers. On the other hand, state forests managed by the ŠNP Authority, are more heterogeneous. We also noticed many clear-cuts in these forests; however, there were also large areas with nonintervention management and other more nature friendly approaches. We can conclude that inconsistent concepts of protection and the lack of clear management guidelines lead to different approaches in the management of the same protected habitats occurring in one national park.

**FIGURE 5** (a, b) Field monitoring cooperation increases trust between the various stakeholders and harmonizes the management of mixed-ownership protected areas. The national park forester, a university researcher and a representative of the municipality forests jointly monitor the bark beetle infestation and the occurrence of natural parasites in the nonintervention part of the national park.
However, experience with L9.2A biotope, a priority Natura 2000, which is rare in the region, brings hope for the future. Well-documented successful natural regeneration in nonintervention areas, where this rare habitat occurs, supports the acceptance of greater conservation sensitive measures both in state and private forests. Sharing data on successful natural restoration and joint field monitoring led to greater alignment of the attitudes of different owners. It also increases the chances that not only a priority Natura 2000 habitat, but all forests in the Sumava NP can be managed, regardless of ownership, with greater respect to natural regeneration suitable for enhancing biodiversity and sufficient for forest restoration (Nováková & Edwards-Jonášová, 2015).

Experiences from the Sumava and other Central European national parks show that wide political consensus and stability are essential to achieve this goal though. Following scientific recommendations and implementing the most appropriate management in state-owned protected areas should encourage private owners to improve their care of valuable sites. Examples of good practice applied in state owned forests together with clear political commitment and well-targeted and more tightly controlled financial incentives can effectively reduce the differences between private and state owners in management of protected areas. And, of course, long-term mutual trust and a willingness to collaborate among conservationists, forest managers and forest owners (Figure 5) is essential for the successful achievement of conservation goals.

AUTHOR CONTRIBUTIONS
Zdenka Křenová conceived the idea, Tomáš Janík and Dušan Romportl collected data and created database. All three together analyzed the data, developed and designed methods, wrote and edited the original draft and prepared the final version.

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CONFLICT OF INTEREST
All authors disclose any actual or potential conflict of interest including any financial, personal or other relationships with other people or organizations that could inappropriately influence, or be perceived to influence, their work.

DATA AVAILABILITY STATEMENT
Data are available from the authors upon request.

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**Table A1** Habitats and species which are subject to protection in SCI Šumava. Priority habitats and species are marked by *.

| Code | Habitats of Annex I of Habitats Directive | Biotop units for mapping (see Chytrý et al., 2010) |
|------|------------------------------------------|--------------------------------------------------|
| 3130 | Oligotrophic to mesotrophic standing waters with vegetation of the *Littorelletea uniflorae* and/or of the *Isoëto-Nanojuncetea* | M2.2—Annual vegetation on wet sands  
M3—Vegetation of perennial amphibious herbs  
V6—*Isoëtes* vegetation |
| 3150 | Natural eutrophic lakes with *Magnopotamion* or *Hydrocharition*—type vegetation | V1—Macrophyte vegetation of naturally eutrophic and mesotrophic still waters |
| 3160 | Natural dystrophic lakes and ponds | V3—Macrophyte vegetation of oligo lakes and ponds |
| 3260 | Water courses of plain to montane levels with the *Ranunculion fluitantis* and *Callitricho-Batrachion* vegetation | V4A—Macrophyte vegetation of water streams with currently present aquatic macrophytes |
| 4030 | European dry heaths | T8.2B—Secondary submontane and montane heaths without *Juniperus communis* |
| 5130 | *Juniperus communis* formations on heaths or calcareous grasslands | T8.2A—Secondary submontane and montane heaths with *Juniperus communis* |
| 6230* | Species-rich *Nardus* grasslands, on siliceous substrates in mountain areas (and submountain areas, in Continental Europe) | T2.1—Subalpine *Nardus* meadows  
T2.3B—Submontane or montane *Nardus* meadows without *Juniperus communis* |
| 6410 | *Molinia* meadows on calcareous, peaty or clayey-siltladen soils (*Molinietea caeruleae*) | T1.9—Intermittently wet *Molinia* meadows |
| 6430 | Hydrophilous tall herb fringe communities of plains and of the montane to alpine levels | A4.2—Subalpine tall-forb vegetation  
A4.3—Subalpine tall-fern vegetation  
T1.6—Wet *Filipendula* grasslands |
| 6510 | Lowland hay meadows (*Alopecurus pratensis*, *Sanguisorba officinalis*) | T1.1—Mesic *Arrhenatherum* meadows |
| 6520 | Mountain hay meadows | T1.2—Montane *Trisetum* meadows |
| 7110* | Active raised bogs | R3.1—Open rised bogs  
R3.3—Bog hollows |
| 7120 | Degraded raised bogs still capable of natural regeneration | R3.4—Degraded raised box |
| 7140 | Transition mires and quaking bogs | R2.2—Acidic moss-rich fens  
R2.3—Transition mires |
| 8220 | Siliceous rocky slopes with chasmophytic vegetation | S1.2—Chasmophytic vegetation of siliceous cliffs and boulder scree  
A6B—Acidophilous vegetation of alpine cliffs |
| 9110 | Luzulo-Fagetum beech forests | L5.4—Acidophilous beech forests |
| 9130 | Asperulo-Fagetum beech forests | L5.1—Herb-rich beech forests |
| 9180* | *Tilio-Acerion* forests of slopes, scree and ravines | L4—Ravine forests |
| 91D0* | Bog woodland | L9.2A—Bog spruce forests  
L10.1—Birch mire forests  
L10.2—Pine mire forests with *Vaccinium*  
L10.4—*Pinus rotundata* bog forests  
R3.2—Raised bogs with *Pinus mugo* |
| 91E0* | Alluvial forests with *Alnus glutinosa* and *Fraxinus excelsior* (*Alno-Padion*, *Alnion incanae*, *Salicion albae*) | L2.1—Montane gray alder galleries  
L2.2 Ash-alder alluvial forest |
| 9410 | Acidophilous *Picea* forests of the montane to alpine levels (*Vaccinio-Piceeta*) | L9.1—Montane *Calamagrostis* spruce forests  
L9.2B—Waterlogged spruce forests  
L9.3—Montane *Anthyrium* spruce forests |

Species of Annex II of the Habitats Directive

*Lampetra planeri, Myotis myotis, Margaritifera margaritifera, Lynx lynx, Carabus menetriesi pacholei, Cotts gobio, Rhinolophus hipposideros, Lutra lutra, Gentianella bohemica, Hamatocaulis vernicosus, Buxbaumia viridis*