The Number and Composition of Snags in the Pine-Spruce Stands of the Bialowieza National Park, Poland[1]

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Abstract

This paper documents data on standing dead trees (snags) in the pine-spruce (Norway spruce *Picea abies,* Scots pine *Pinus sylvestris*) natural stand in Bialowieza National Park (BNP) in northeast Poland. Trophically, this mostly coniferous stand represents one of the poorest habitats of the BNP, and this stand has never been cut. There are few tree species of significance, i.e., Scots pine, Norway spruce, hornbeam *Carpinus betulus* and two birch species *Betula verrucosa*, *B. pubescens*. Other tree species are scarce. Altogether 6.25 ha were measured within 25 samples. Among tree species, the proportion of dead standing trees was 0-58 percent of the total basal area and 0.9-59 percent of total density. The tree species dominance pattern shows a different pattern of change. Pine is declining, while hornbeam is invading the stand from bordering deciduous stands and now is a well regenerating tree species. Spruce regeneration slowed within the last 20 years. Until about 10 years ago, birches were not regenerating and were declining from the plot. Recently, within no more than the last 10 years, birches are regenerating within the plot again. All these changes reflect snag characteristics and composition.

Introduction

Most of the lowland forests of the European temperate zone underwent severe anthropogenic transformations before modern research started. However, the forests of the Bialowieza National Park are an exception. The Bialowieza Forest complex (total area 1,500 km^2) is situated on the Polish-Belarussian border *(fig. 1)*. Its western part (c. 600 km^2) belongs to Poland. This forest is a remnant of the vast lowland forest that once covered central parts of Europe. The majority of stands in the Polish part of the forest are now under management, but 47.5 km^2 of the best preserved primeval stands has been protected within the Strict Reserve of the Bialowieza National Park (SR BNP) (Falinski 1986, Tomialojc 1991). This part has never been cut because it was protected as hunting grounds for the Polish kings and later the Russian czars since the early 15th century. After World War I it became the first Polish national park. Human presence is very restricted to some tourist trails only.

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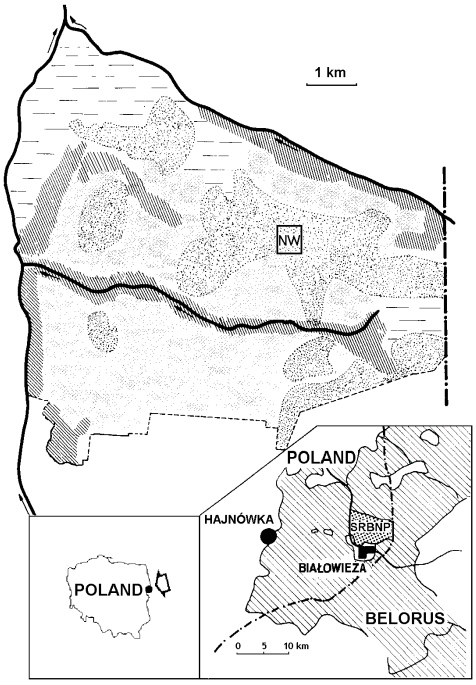

Figure 1_A map of the Polish part of the Bialowieza Forest showing the location of the strict reserve (SRBNP) and study plot (NW).

The old-growth preserved in SR BNP are mainly the linden-hornbeam *Tilio-Carpinetum* type (44.4 percent), swampy deciduous (26.6 percent), and dry coniferous (28.1 percent) stands. The old-growth stands of SR BNP are multi-storey, mixed-species, uneven-aged, composed of trees reaching exceptional height, and contain large amount of dead standing trees (snags) and uprooted trees. In spite of the fact that many authors stressed the high amount and the importance of the dead wood in this forest, the quantitive data are scarce and only general (Falinski and Herezniak 1977, Kirby and others 1991, Piotrowski and Wolk 1975). Although most of the SR BNP is covered by deciduous woodland, the coniferous stands (i.e., pine-spruce stands [Norway spruce *Picea abies,* Scots pine *Pinus sylvestris*]) contribute greatly to sustaining biological richness of BNP. For instance, several bird species are recorded mostly or exclusively in this conferous habitat (Tomialojc and others 1984).

Structure and dynamics of the BNP natural stands have been studied for almost 80 years (Falinski 1986, Paczoski 1925). Both deciduous and coniferous stands of SR BNP are not in a state of climax. In the linden-hornbeam *Tilio-Carpinetum* type, the spruce has decreased steadily in number (Falinski 1986). In coniferous forests, i.e. pine-spruce type, the pine share has decreased as well. Comparing tree distribution maps from 1903 and 1958, Czerwinski (1968) stated that during the investigated period, pine decreased substantially and it was replaced by the spruce and oak *Quercus robur*. Wloczewski (1972) and Kowalski (1972) also noticed directional change of the pine stands into the spruce stands. Even more, an increase of the hornbeam *Carpinus betulus* in number in coniferous stands has been noticed (Gunia 1972; Kowalski 1972, 1982).

This study aims to describe the occurrence and characteristics of the snags (i.e., dead standing trees) within the pine-spruce stands of the SR BNP under the dynamic process ongoing in this stand with time. Snag characteristics have never been described in details in these forests, and only Jakubowska-Gabara and others (1991) have assessed how many dead standing trees were among all trees in the same type of stand of BNP.

Study Plot

The NW 25-ha study plot (500 m x 500 m, located in compartment 318A; Tomialojc and others 1984) was chosen. It is covered by the pine-spruce natural stand, which has never been cut. The association of this kind usually develops on sandy soils in upper parts of the BNP. Trophically, it represents one of the poorest habitats in SR BNP. The main canopy is formed of pines, while the lower one is composed of spruces with few pines, birches *(Betula verrucosa, B. pubescens),* and oak. In the plot, spruce dominates numerically over pine. The young tree-layer is composed mostly of hornbeams and spruces. The herb layer is sparse, composed of *Oxallis acetosella* and *Vaccinium myrtillus*. Forest openings are dominated by *Calamagrostis arundinacea* and *Pteridium aquilinum*.

The plot has been subdivided into a 50-m grid. That area has been under ornithological investigation since 1975 (Tomialojc and others 1984). Since that time an increase of hornbeam in number is very visible. The young generation of *Carpinus betulus* invades the area from the north and especially from the south, i.e., from the transition border zones with the deciduous stands. This transition, where coniferous stands turn gradually into deciduous stands, is 50-80 m wide. Matuszkiewicz and Matuszkiewicz (1954) mapped the whole study plot as the pine forest *Pinetum Myrtylli* association.

Methods

In June and July 1998 I counted and measured the diameter at breast height (dbh) of all trees that reached at least 1.5 m tall within the 50 m x 50 m squares (samples). One such square (0.25 ha each) was chosen randomly within every ha of the study plot *(fig. 2).* Altogether 6.25 ha were measured within 25 square samples. Both live and dead trees were identified to species. The recognition of dead trees caused no serious problems, since there were only two coniferous and a few deciduous species. The exception is the two birch species, which I treat jointly since they were uncommon and I was unable to distinguish snags of those species.

Additionally, to illustrate the hornbeam invasion in the northwest plot, I compared the diameter distribution within the central part of the plot with that of the ecotonal (southern) part of the plot. For this, five samples were chosen in both parts *(fig. 2).*

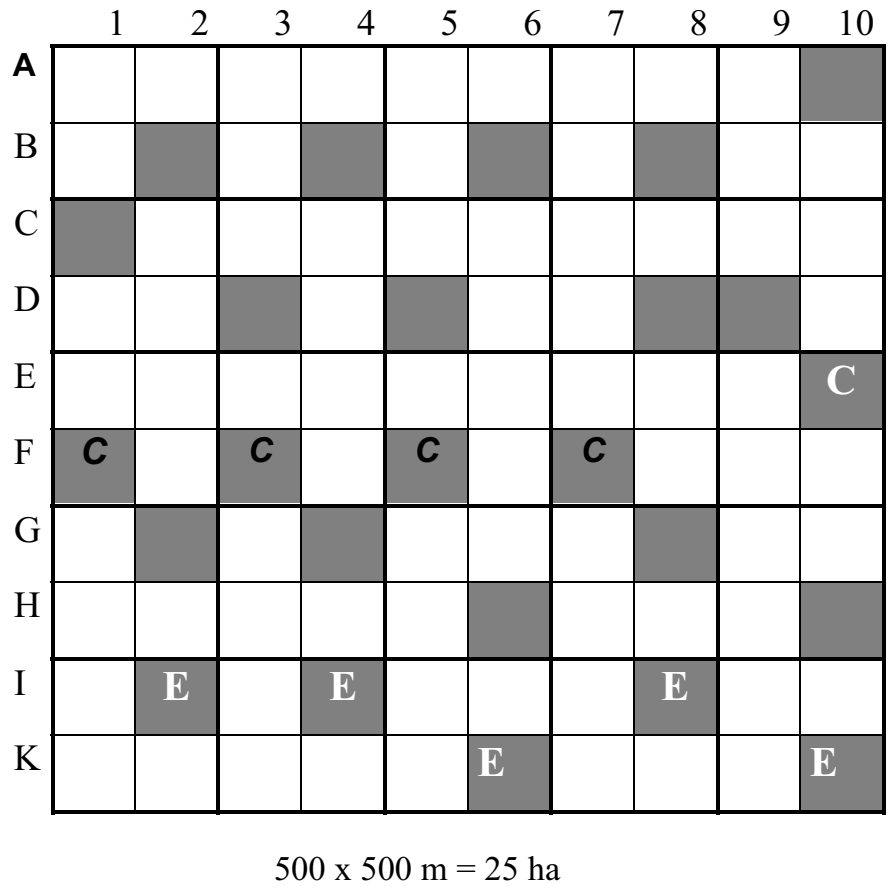

Figure 2_Distribution of measured squares within the study plot (E = ecotone, C = center).

Results and Discussion

Snag Density by Diameter Class

Among live trees, spruce and hornbeam together comprise 86 percent of the stand by number of trees. Pine (9 percent) is the third most abundant species *(fig. 3)*. Snag species composition is utterly different. Spruce and pine snags comprise 88 percent of all dead trees *(fig. 4)*. When considering only trees with diameter ≥ 10 cm, the share of spruce snags and pine snags altogether increased to 92 percent *(fig. 5)*. Together with birch, these three species compose 98 percent of all such defined snags. The very small share of the hornbeam among snags is easy to explain when I compare the dbh class distribution of pine, spruce, and birch with dbh distribution of the hornbeam *(figs. 6-9)*. The hornbeam is represented almost exclusively by trees with dbh not bigger than 20 cm *(fig. 8)*.

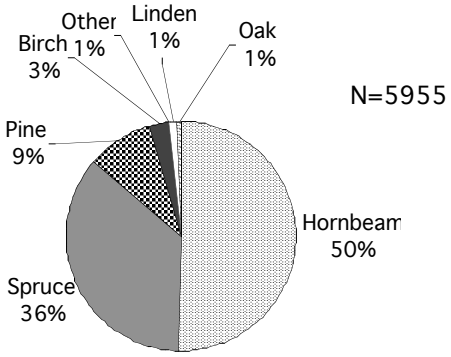

Figure 3_Share of different species in the living tree community.

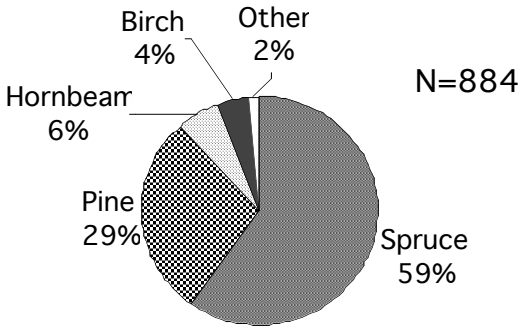

Figure 4_Share of different dead tree species among the snags within the study plot.

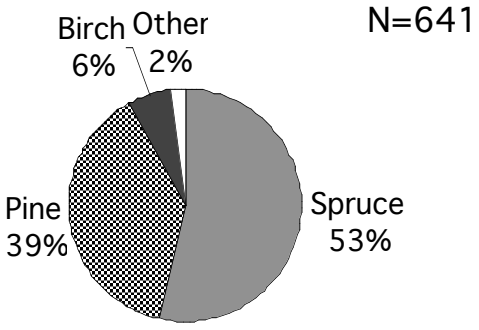

Figure 5_Share of different dead tree species with the ≥ 10 cm diameter classes.

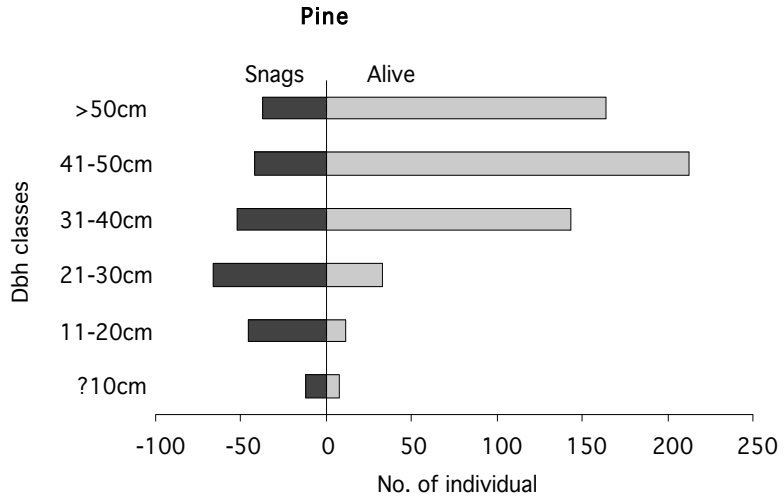

Figure 6_Structure of the pine tree stand according to diameter classes (dbh).

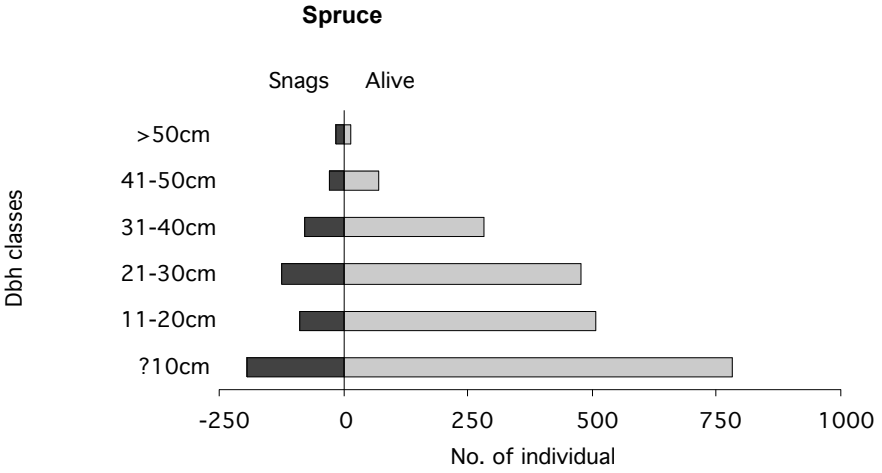

Figure 7_Structure of the spruce tree stand according to diameter classes (dbh).

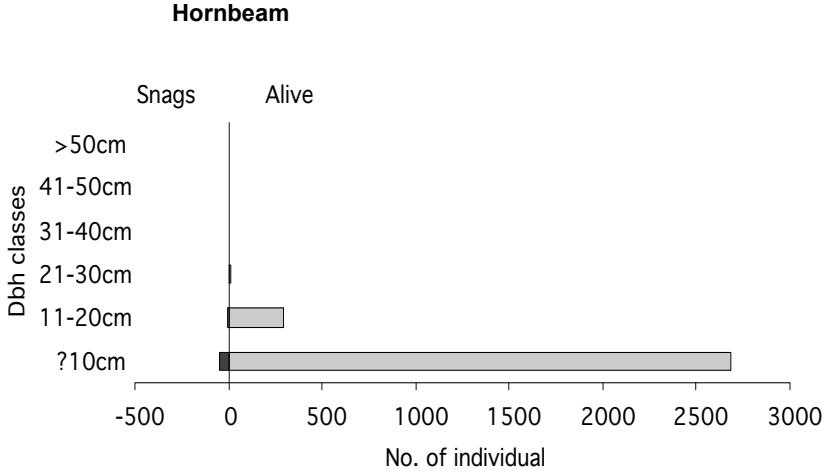

Figure 8_Structure of the hornbeam tree stand according to diameter classes (dbh).

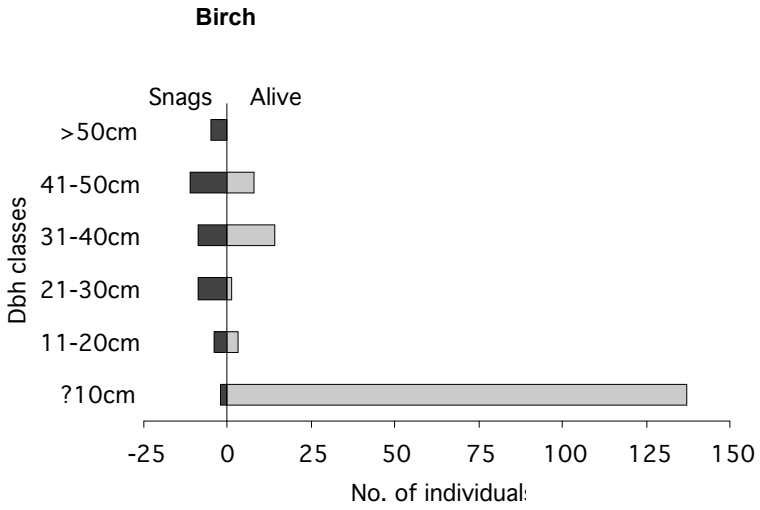

Figure 9_Structure of the birch tree stand according to diameter classes (dbh).

Total snag density concerning only trees with ≥ 10 cm dbh is 102.6/1ha. The spruce and the pine snags are the most numerous, reaching density 54.9/ha and 39.5/ha, respectively. Birch snags occur in much lower density (5.8/ha). High density of the spruce snags is a result of bark beetle *(Ips typographus)* outbreak in BNP during 1994-1996 years. Jakubowska-Gabara and others (1991) reported from 1990 (i.e., data collected before bark beetle outbreak appeared) that the same forest type in SR BNP had about three times lower spruce snag density. They also found that the pine snags were denser, exceeding 50 snags/1ha.

What Proportion of Standing Trees are Dead?

Pine and spruce compose 91.0 percent of the total basal snag area and 93.1 percent of standing dead trees. Total basal area of dead standing trees is relatively high compare to other measured stands (Tritton and Siccama 1990). The pine and spruce proportion of dead standing trees of the total basal area was similar *(table 1)*. Birches, which are uncommon, have high proportion of dead trees expressed either as basal area or percent of stand.

Table 1_*Basal area and density of living and dead steams ≥ 10 cm dbh, and standing dead trees as a percent of stand total.*

Species	Living	Dead m^2 ha^{-1}	Pct dead	Living	Dead stems ha^{-1}	Pct dead
Scots pine	15.5	4.2	21.3	89	40	31.0
Norway spruce	12.1	3.9	24.4	224	55	19.7
Hornbeam	0.9	0.0	0.0	56	0	0.0
Birch	0.5	0.7	58.3	4	6	60.0
Other	0.9	0.1	10.0	11	1	8.3
Total	29.9	8.9	23.1	384	102	21.0

Diameter of Snags (Dbh)

The diameter of the two birch species and pine (birch x = 37.1 cm, S.D. = 12.7, n = 38, pine x = 34.0 cm, S.D. = 14.5 n = 247) are greater than that of spruce (x = 27.8 cm, S.D. = 11.5, n = 343). This is because the pine and birch snags originated mostly from older trees *(figs. 6, 9)*. Spruce snags have thinner dbh because they originated mostly from trees of lower dbh classes, including young trees that died due to a self-thinning process *(fig. 7)*. The composition and characteristic of snags are affected by such processes as retreat (pine) and regeneration and competition (spruce, birch and hornbeam).

Regeneration of Different Tree Species

Within the smallest dbh class, 2,591 hornbeams, 649 spruces, 135 birches, and 8 pines were found. This suggests ongoing intense change in the composition of the stands that were analyzed.

According to Falinski (1986), the spruce regenerates fairly well in coniferous forests on dry hills of the BNP. The spruce diameter distribution, especially the high number of trees in the smaller diameter classes (1-2), indicates good regeneration of this species *(fig. 7)*. It is also the most numerous among tree species in the middle diameter classes (750 spruces versus 176 pines in diameter 21-40 cm). This species will likely remain an important component of the analyzed stand for many years.

The large number of pines in the larger (4-6) diameter classes and few in the lower classes (1-3) indicates that this species has ceased to regenerate and is retreating from the stand *(fig. 6)*. In the first diameter class only eight pine trees were found. The retreat of the pine from BNP has been well documented (Czerwinski 1968, Gunia 1972, Kowalski 1972, Matuszkiewicz 1952, Paczoski 1930, Wloczewski 1972). Some old pines occur in linden-hornbeam stands farther than 1 km from the conifer part of the forest (Walankiewicz, pers. observ.), suggesting that in the past the pine had much wider distribution than at present and that the area covered by pine has decreased. Korczyk (1994) found that this species lives up to 400 years in the Bialowieza Forest.

Although hornbeam is the most numerous tree species, it occurs almost only in the first and second dbh classes *(fig. 8)* (an average dbh of all hornbeams equals 4.0 cm, S.D. ± 4.17, n = 3,984 and 41 percent of all living hornbeams have dbh ≤ 2cm). Because it grows in SR BNP up to a diameter of 100 cm (Falinski 1977), this means that occurrence of this species within the plot is a new phenomenon. I have visited this plot several times a year from 1975 to 1998 conducting ornithological research (Tomialojc and others 1984). During that period, in the northwest plot, I observed a continuous increase of young hornbeams in number. The first hornbeam dbh class is three times more numerous than the same class of the spruce *(figs. 7, 8)*. Furthermore, 25 years ago many hornbeams in the study plot were shaped like trees that suffer poor growth conditions (i.e., poor soil). Currently, hornbeams look different, and they are shaped like young fast growing trees. Apparently this species is a very new invader in this stand. It is visibly more numerous in both the southern and northern parts of the plot, which border linden-oak-hornbeam stands, than it is in central part. Furthermore, within the study plot, there are few if any hornbeams old enough to produce seeds. As a matter of fact, well regenerating hornbeam originated mostly, if not only, from trees that are outside the study plot. Gunia (1972) and Kowalski (1972, 1982) noticed an increase in the number of hornbeam in coniferous

stands of the BNP, but they did not expect the fast transformation described in this work.

The birches are represented mostly in the youngest class. Older/mature birches were low in the plot *(fig. 9)*. Only 22 birches within classes 2-6 were found within the 6.25 ha studied. In the 2-6 dbh classes there are more dead (62.1 percent) than live (37.9 percent) birch trees. This shows that until 10 years ago birches were not regenerating and retreating from the plot. Every year since 1975, I conducted ornithological observations in the northwest plot and observed within no more than the last 10 years that the birches started to regenerate within this plot again *(fig. 9)*. It happened in gaps where spruces were knocked down by wind. Birches are very rare in neighboring linden-hornbeam stands as well.

Directional Changes in Tree Stand Composition

Each tree species within the study plot are showing a different pattern of change. Pine density is declining while spruce, hornbeam and birches all seem to be well-regenerating tree species. However, because young birches are 5-20 times less numerous than hornbeam and spruce, the two latter species are most important for the future of the stand. But is the proportion of spruce-hornbeam stable within the studied plot?

To answer this question I compared separately the stand diameter structure of both species the the central and ecotonal (southern) parts of the plot. Such comparisons reveal that hornbeam regenerates in ecotonal part very well, but the spruce regeneration there is poor *(fig. 10)*. Clearly in this part of the study plot, the smallest spruce dbh classes are less numerous than the middle diameter classes of this tree species. Within the first dbh class, 1,651 hornbeams were found and only 20 spruces *(figs. 10, 11)*. This suggests that spruce regeneration slowed down there within the last 20 or so years. It is very likely that hornbeam will soon overtake this part of the stand reducing substantially the proportion of spruce. In 1975, young spruces 1-1.5 m tall were common in this northwest plot (Tomialojc and others 1984; Walankiewicz, pers. observ.). In the central part of the plot, however, the number of spruce and hornbeam in the first dbh class are similar (96 spruces vs. 94 hornbeams; *figs. 10, 11)*. This means that in the future this part of the stand will be covered by mixed spruce-hornbeam forest with a mixture of some old pine.

Summing up, there are five visible processes/changes ongoing in the tree stand within the study plot:

- Decrease of the pine in density; this species does not regenerate.
- Spruce, which dominates numerically over pine, regenerates well in the central part of the plot.
- In the ecotone, close to deciduous stands, the spruce regeneration is hampered by invasive young hornbeams.
- Hornbeams invade the plot from bordering deciduous stands and regenerate very well between older spruces and pines.
- Birches, which were close to extirpation**,** show renewed regeneration within the study plot.

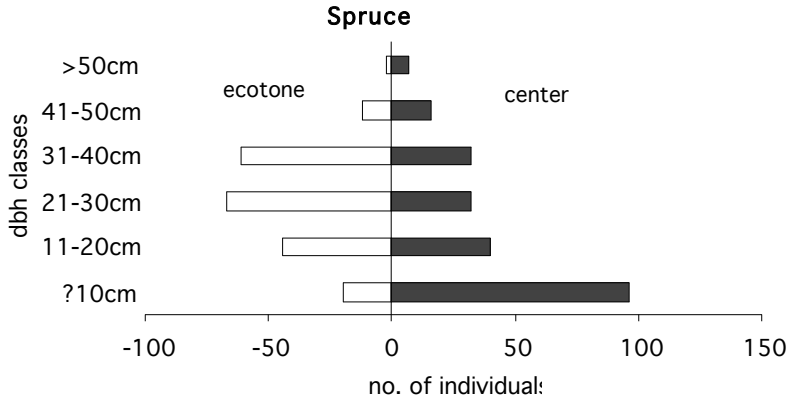

Figure 10_The structure of the spruce stand (live trees) in diameter classes within the central and ecotonal parts of the NW study plot.

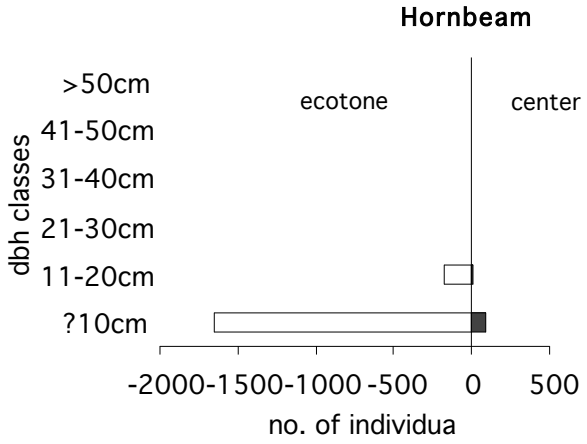

Figure 11_The structure of the hornbeam stand (live trees) in diameter classes within central and ecotonal parts of the NW study plot.

Durability of Snags and Ratio of Different Tree Species as Snags

Most of the snags (98 percent) are composed of spruce, pine, and birch. All of them are represented among live trees less numerously than among dead ones *(figs. 3, 5).* This is the result of the numerous occurrence of the hornbeam, which is too young to produce snags.

The ratio of different snag species tells us nothing about mortality of the different tree species. The relatively high share of pine among dead standing trees—39 percent among dead and only 9 percent among alive *(figs. 3, 5)*—does not mean high mortality of this species. Rather, it reflects high durability of pine snags. Many pine trees within northwest plot were dead in 1975 when the plot was

marked—after 25 years they remain standing. One well-known pine snag has been standing next to the tourist path more than 50 years. Spruce's high share of snags, among other dried trees, actually reflects the high mortality of this species that was caused by the bark beetle outbreak in 1994-1996. In May 2000, many spruce snags within the plot are fell after the previous winter. Spruce snags apparently stand only for a few years after the tree is dead.

Assuming that the observed tendencies of the tree stand development will last, I predict the following changes in the snag composition within the studied stand:

- Within 2-3 years, the number of spruce snags will decrease by about two-thirds. The spruce snags will fall down due to the rotting processes in lower part of trunk.
- Birch snags, which are much less numerous than other species, will gradually disappear from the stand.
- The number of pine snags will remain rather stable for many years because of their high durability.
- It will take another 20 or more years before the first hornbeam snags of diameter 20-30 cm appear in the stand.

Some processes within the study plot were recorded in other parts of the SR BNP, especially a decrease of the spruce and an increase of linden in deciduous stands. This change was explained as a return of the forest to its natural state after extensive disturbance from excessive game foraging (Falinski 1986), as a directional change caused by changing climate (Bernadzki and others 1991, Kowalski 1882), or as a result of marshland drainage in the Belarussian part of the BNP (Bucholz 1968). All those factors seem to be additive, not compensatory.

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