Strødam Reservatet. Årsberetning 2003

Administration og drift

Strødamlaboratoriet

Strødamlaboratoriet har fungeret godt i 2003. Der er ikke sket væsentlige lokalemæssige ændringer og belægningen har været god, især i forårsperioden, hvor bioakustikerne arbejder fra den meget tidlige morgen og derfor i vid udstrækning er indkvarteret i laboratoriet.

2003 var det sidste år under den gamle lejekontrakt med Jarlfonden, og året, hvor der foregik forhandlinger om laboratoriets fremtid. Flere mulige løsninger blev overvejet for at forlige Jarlfondens ønske om øget husleje og Københavns Universitets stadig strammere økonomi. Mod årets slutning opnåedes der enighed om en ny treårig lejekontrakt, der kunne underskrives inden nytår.

På grundlag af den nye lejekontrakt kunne også aftalen med bestyrerparret Pernille Lærkedal Sørensen og Peter Jannerup forlænges.

Strødamreservatet

Ved en prisværdig indsats af bestyrer Frank Thulsted og hans elever fra Frihedslund er hegningerne omkring Grundtvigs Vænge, samt afdelingerne 1c og 14b blevet fjernet. Hermed er alle hegn fjernet, bortset fra dem der hegner græsningsarealer.

Ved årets slutning gik Frederiksborg Amt i gang med at forny hegningen omkring engene langs Pøleå, dvs. også langs Strødam Engsø. En del kreaturer havde tilbragt sommeren på urokse-vis inde i skoven, hvor kokasser vidnede om deres færden, ikke mindst lige syd for Granmosen. I forbindelse med den nye hegning fik amtet lov at lade linjeføringen gå over knolden med nordmannsgran i afdeling 12b, idet overgangen mellem engenes sydlige og nordlige del var blevet så sumpet at kreaturerne vægrede sig ved at gå igennem. Den nye hegning er solid, men er efter Strødamudvalgets opfattelse sket ved en temmelig hårdhændet behandling af skovbrynet med store maskiner. Hegningen er i forståelse med Strødamudvalget og Jarlfonden videreført mod nord, vest om Granmosen og med en linjeføring, der inddrager hele afdeling 1 i græsningsområdet. Samtidigt er der dog ført hegn ned til Jordkrebse-søen fra øst og nordvest, således at Strødam-udvalget fremover kan regulere intensiteten af afgræsningen på jordkrebse-området øst for søen.

Katrine Hahn's undersøgelser af lysbrønde afsluttedes i 2003. En fremlæggelse af projektet er tilføjet som appendiks til denne årsberetning. Jarlfonden bevilgede indkøb at rustfri stålstænger, der skal gøre forsøgets prøveflader virkeligt permanente, således at det bliver muligt at følge op på projektet på et senere tidspunkt. På grund af frost og efterfølgende travlhed vil udskiftningen dog først finde sted i 2004.

Bekæmpelsen af bjørneklo og frøbærende ær er fortsat i 2003.

En storm d. 6. december væltede en del af de udgåede elmetræer vest for Grundtvigs Vænge, og de stammer, der blokerede vejen, blev efterfølgende fjernet.

Døde elmestammers svampe blev behandlet af lektor Thomas Læssøe fra Biologisk Institut, Københavns Universitet. Han samlede svampe på stammerne i 15 minutter d. 15. november og tilbragte derefter tre dage foran mikroskoperne og med litteraturen inden for rækkevidde. Resultatet var et overvældende artsantal - 48

- på trods af at forudgående frost havde taget livet af bladhattene. Hans studier er publiceret i tidsskriftet Svampe i 2004.

Årets måske mest interessante fund blev gjort på en askestamme i reservatets nordvestlige del. Et 20 cm stort individ af lavarten gulgrøn skållav (*Flavoparmelia caperata*) omgivet af 15 mindre individer, der formentlig var spredt fra den store. Gulgrøn skållav er senest set på Sjælland i 1940 ved Stenholt, og ellers kun kendt fra ét andet fund på Sjælland, nemlig fra Jægersborg Dyrehave i 1922. I 2004 er der fundet ét individ på Bornholm, hvor den sidst har været set i 1800-tallet. Det interessante ved denne sjældne lav er, at dens hovedudbredelse er i varmere dele af verden, og at den her i landet ligger på sin nordgrænse. Det nye fund og den meget sunde og kraftige vækst signalerer temperaturstigning, hvilket stemmer godt overens med at den årlige gennemsnitstemperatur i Danmark er steget med ½ grad de seneste 20 år, og i øvrigt er steget med én grad gennem de seneste 130 år. Fundet af gulgrøn skållav er rapporteret i tidsskriftet Graphis Scripta i 2004.

Forskning

• Natugleprojekter:

1. Ligesom i 2002 blev der som led i Peter Sundes natugleprojekt samlet data ind om hvordan fødetilgangen påvirker juvenile natuglers overlevelse og vitalitet på kort og lang sigt. I forbindelse hermed er natuglebestanden på Strødam blevet moniteret. Desuden blev et enkelt ungekuld radiomærket. Da der i efteråret 2002 var oldenår, var det forventet at 2003 ville blive en særdeles god ynglesæson. Dette viste sig at holde stik. Så at sige alle kendte par i Gribskovområdet lagde store kuld (4-6 æg), som fløj af reden i løbet af april. Yngleforløbet for de fire ynglepar i reservatet var som følger:

	Æg	Redeunger	Udfløjne	Selvstændige
Sydlige Strødam (Karpedam)	6	5	5	ca. 2
Avlsgård (radiomærket)	?	4	1	1
Rankeskov	- (tilsyneladende intet yngleforsøg)			
Nordlige Strødam	+ (hun rugede på knuste æg ved første besøg)			

Som det fremgår af tabellen var ugleparrene i Strødamreservatet kun moderat succesfulde i 2003 i forhold til de øvrige par i Gribskov. Der er ingen umiddelbar forklaring på hvorfor Rankeskovparret tilsyneladende ikke forsøgte at yngle overhovedet. Det er også meget sjældent at alle æg går i stykker under rugningen som observeret i det nordlige par. Den eneste unge som fløj ud af Avlsgårdkassen (de øvrige døde af sygdom) lever fortsat (april ´04) i bedste velgående og har slået sig ned nær reservatets nordligste grænse, hvor den muligvis har etableret et territorium. Alle territoriehævdende ugler, med undtagelse af hannen i det nordligste territorium, blev fanget og aflæst i vinteren/foråret ´03. De var alle de samme individer, som blev fanget året før.

2. Byttedyrselektion af natugler på småpattedyr - en undersøgelse af mulige sammenhænge mellem predationsrisiko hos mus I forhold til kondition, immunokompetance og parasitbelastning (Peter Sunde, Kristian Overskaug & Jan-Åke Nilsson).

3. Projekterne om natuglens tuden er blevet fortsat med yderligere forsøg og lydoptagelser af tuden fra beslægtede og ikke-beslægtede ugler. Rikke Vienbergs speciale fra 2002 havde demonstreret at tuden fra fædre og sønner ligner hinanden mere end de ligner fremmede hanners tuden. Studiet er nu blevet videreført mhp. at komme dybere ind i problematikken både omkring slægtsgenkendelse vha. tuden og tudens anvendelighed til individuel identifikation af natuglehanner over længere tid (P. Riis Hansen, R. Vienberg, P. Sunde & T. Dabelsteen, Biologisk Institut, KU.

- Musvittens lydkommunikation:

Tidligere forsøg med interaktiv sangafspilning har vist at musvithanner aflurer sangdueller imellem rivaler, og at lureren får information om de duellerende hanners indbyrdes styrkeforhold ved at lytte til hvordan de overlapper hinandens sange (synger i "næbbet" på hinanden) og skifter imellem forskellige sangtyper. Duellanter der således bliver overlappet ignoreres i senere konfrontationer med lureren, mens duellanter der overlapper modparten udløser høj aggression i senere konfrontationer med lureren. På samme måde udløser duellanter, der skifter sangtype under en duel, mere aggression i en efterfølgende konfrontation med lureren end duellanter der ikke skifter sang under duellen. I nye forsøg udført i 2003 har man forsøgt at kombinere overlapning og sangtypeskift på forskellig måde for at finde ud af hvilken af de to sangmønstre der var vigtigst for en aflurer af sangdueller. Alt tyder på at det er overlapningsmønsteret de giver mest opmærksomhed (T. M. Peake, A. M. R. Terry, G. Matessi, D. S. Pope, P.K. McGregor & T. Dabelsteen, Biologisk Institut, KU).

- Test af indeksbaserede metoder til vurdering af skovstruktur (Erik Buchwald & Peter Friis Møller).

- Svampe på væltede elmestammer på Strødam (Thomas Læssøe).

- Mikrobiel biodiversitet i natur/kulturskov. Fagprojekt i Generel Mikrobiologi, vejl. Annelise Kjøller (Lars Høy Hansen, Morten Bredsgaard Randers & Anders Sækmose).

- Makroarthropoder i naturskov versus kulturskov af bøg. Fagprojekt i Jordbundsbiologi (Maria Dirchsen, Anne Christensen, Marie-Louise Olsen).

- Coprofile svampe på gnavergødning. Successionsforsøg med mosegrisegødning. Projekt i Svamperiget, vejl. Thomas Læssøe (Mita Eva Sengupta).

- Kernesvampeslægten *Helminthosphaeria* i Danmark. Projekt i Svamperiget, vejl. Thomas Læssøe (Jan Gert Borgergren Nielsen).

<u>Kursusundervisning fra Københavns Universitet</u>

- Laver - identifikation og økologi. Kursusweekend 29-30. marts for 10 studerende fra Københavns Universitet v. U. Søchting.

- Svamperiget. Kursusweekend 7-9. november for 9 studerende ved Københavns Universitet v. Thomas Læssøe og Ulrik Søchting.

Møder og ekskursioner

Offentlige ekskursioner

- 18. 5. Forårsekskursion. (Torben Dabelsteen).
- 8. 6. Ekskursion for Gadevang Beboerforening v. Torben Dabelsteen, 30 deltagere.
- 26. 10. Efterårsekskursion. 120 deltagere (Ulrik Søchting, Torben Dabelsteen, Peter Milan Petersen, Pernille Lærkedal Sørensen og Peter Jannerup).

Gruppe-ekskursioner

- 21. 3. Ekskursion i forbindelse med A-modulkursus i Adfærdsbiologi, 10 deltagere (Torben Dabelsteen).
- 8. 6. Ekskursion for Gadevang Beboerforening, 30 deltagere (Torben Dabelsteen).
- 19. 6. Rundvisning for ERFA-gruppe for fonde med landbrug og skovbrug (incl. Jarlfonden), 12 deltagere (Torben Dabelsteen).
- 20. 6. Helsinge byråds- og direktionssekretariat, 19 deltagere. (Torben Dabelsteen).
- 16. 8. Farum Naturparks Venner v. Richard Pedersen, 40 deltagere (Peter Milan Petersen).
- 9. og 10.9. Skov- og landskabsingeniørstuderende, 18 deltagere (Anne-Kristine Lauridsen og Henrik Jørgensen).

Strødam-publikationer modtaget i år 2003

Balsby, T.J.S., Dabelsteen, T. & Pedersen, S.B. 2003. Degradation of Whitethroat vocalisations: Implications for song flight and communication network activities. *Behaviour* **140**, 695-719

Blumenrath, S.H. 2003. Sound degradation and vocal recognition in the great tit *Parus major*. Specialerapport, Adfærdsgruppen, Biologisk Institut, Københavns Universitet, pp. 146. Vejleder: T. Dabelsteen.

Blumenrath, S.H. & Dabelsteen, T. 2003. Do locations inside nest boxes constrain song reception in great tit females? *1st Int. Conf. Acoust. Comm. Anim. Extended abstratcs*, 25-26.

Christensen, A.M. & Olsen, M.-L. 2003. En undersøgelse af makroarthropoder i natur-og kulturskov. Fagprojekt rapport i Jordbundsbiologi, Biologisk Institut, Københavns Universitet. Vejleder: P. Holter.

Christensen, M. & Hahn, K. (eds.) 2003. A study on dead wood in European beech forest reserves. *Nat-Man Working Report 9*.

Christensen, M. & Vesterdal, L. 2003. Physical and chemical properties of decaying beech wood in two Danish forest reserves. *Nat-Man Working Report 25*. 16 pp.

Dabelsteen, T. 2003. Do birds have strategies that facilitate or counter eavesdropping on vocal interactions? *1st Int. Conf. Acoust. Comm. Anim. Extended abstracts* 55-56.

Fléron, G. M. W. 2003. Stille sang hos solsorten *Turdus merula*. Specialerapport, Adfærdsgruppen, Biologisk Institut, Københanvs Universitet, pp. 87. Vejleder: T. Dabelsteen.

Hansen, L. H. , Randers, M. B. & Sækmose, A. 2003. Natur- og kulturskov: Sammenlignende undersøgelse af mikrobielle samfund i to bøgeskovshabitater. Fagprojektrapport. Afdeling for Generel Mikrobiologi, Københavns Universitet. 29 pp.

Heilmann-Clausen, J. 2003. Wood-inhabiting fungi in Danish deciduous forests - Diversity, habitat preferences and conservation. Ph. D. thesis.

Lampe, H., Dabelsteen, T., Larsen, O. N. & Pedersen, S. P. 2003. Degradation of pied flycatcher (*Ficedula hypoleuca*) song in Norwegian and Danish habitats: implications for polyterritorial behaviour. *Revista Etologia Suplemento* **5**, 110.

Sunde, P. Bølsted, M. S. & Desfor, K.B. 2003. Diurnal exposure as a risk sensitive behaviour in tawny owls *Strix aluco? Avian Biol.* **34**, 409-418.

Sunde, P., Bølstad, M. S. and Møller, J. D. 2003. Reversed sexual dimorphism in tawny owls, *Strix aluco*, correlates with duty division in breeding effort. *Oikos* **101**: 265-278.

Vienberg, R.J. 2003. Comparisons of territorial hoots among related tawny owl (*Strix aluco*) males. Specialerapport, Adfærdsgruppen, Biologisk Institut, Københavns Universitet, pp. 69 + appendixer. Vejleder: T. Dabelsteen.

Anden formidling

Arbejdet i Strødam Reservatet med fuglesang er desuden blevet formidlet i ind- og udland igennem interviews og radioprogrammer:

National Geographic's radio program "Pulse of the Planet", USA (S. Blumenrath).

University of Maryland Newsdesk: "Sounds of Birds, Bullfrogs, Bats and Baboons" (23 July 2003) (S. Blumenrath).

Interview til Horsens Folkeblad "Fuglenes små sidespring" by Lonnie Findal - sangens rolle i seksuel selektion (A. Poesel, T. Dabelsteen).

Interview til Ringnyt (2003, 4, s. 8) af Jan Skriver - Musvitter synger rent besked (T. Dabelsteen).

Ynglefugletællinger i Strødam Reservatet syd for Skolestien

af Torben Dabelsteen

Fuglelivet syd for Skolestien blev for 18. år i træk moniteret af Benny Gert Hansen. Moniteringen blev udført på samme måde som i de foregående år, dvs. i yngletiden (maj-juni), og vha. kortlægningsmetoden. Metoden er velkendt og når den som her anvendes af samme person og på samme måde over en lang årrække får den ekstra værdi. Udover at give en indikation af de enkelte arters status samt reservatets almene tilstand fra år til år, kan de indsamlede data indgå i langtidsstudier af f.eks. svingninger i fuglefaunaens sammensætning og hvad der styrer denne.

For den enkelte art afhænger metodens styrke selvfølgelig af hvornår på året optællingerne udføres. F.eks. bevirker de relativt sene optællinger, at flere af de tidligt ynglende standfugles antal undervurderes. Benny Gert Hansen har derfor også i år givet to tal for hver art, ét der opnås med kortlægningsmetoden, og ét der estimeres ud fra iagttagelser, som ikke direkte lader sig anvende i kortlægningsmetoden. Det sidste tal har en grad af subjektivitet over sig, men kommer nok nærmest sandheden for de fleste arter. For en af arterne, gærdesmutten, har der ikke været iagttagelser, som giver anledning til også at give et estimeret tal i 2003. Den synes at være gået lidt ned i 2003.

Tabel 1. Top-10 liste over fuglearterne syd for Skolestien. Antallet af par for hver art er angivet som gennemsnitsværdier for de første 15 års optællinger (1986-2000) og faktiske værdier for 2001, 2002 og 2003. Første tal er det estimerede antal, tallet i parentes er det v.h.a. kortlægningsmetoden fundne antal.

Art	**(1986-2000)**	**(2001)**	**(2002)**	**(2003)**
Musvit	45 (38)	36 (33)	40 (31)	52 (46)
Bogfinke	31 (28)	31 (31)	34 (31)	37-39 (35)
Solsort	30 (29)	31 (30)	32 (30)	34 (27)
Rødhals	29 (22)	21 (17)	29 (18)	29 (17)
Blåmejse	27 (20)	26 (25)	25 (18)	33 (20)
Munk	22 (21)	21 (21)	25 (23)	22 (18)
Gærdesmutte	19 (18)	19 (19)	(16)	(14)
Stær	19 (16)	13 (13)	(9)	11 (9)
Ringdue	15 (8)	17 (7)	16 (9)	28 (15)
Havesanger	13 (11)	13 (11)	13 (10)	17 (14)

2003 var tilsyneladende et rigtig godt år for mange af de almindelige arter. De store forekomster af bog har måske haft direkte eller indirekte indflydelse på den store fremgang for arter som ringdue, bogfinke, musvit og blåmejse. For en art som havesanger er det sværere at gætte på årsagen til den relativt store fremgang.

Mange andre arter klarede sig også godt, som det ses af de estimerede tal (i parenteser vises tal for 03 efterfulgt af tal fra 02) for spætmejse (22, 15), træløber (16, 14), sangdrossel (18, 10), gransanger (11, 9) og sumpmejse (13, 8). Da habitatet udgøres af gammel blandet løvskov er der også mange hulrugende arter, hvoraf de fleste klarede sig godt (estimeret 03, estimeret 02): Huldue (8, 6), stor flagspætte (6, 5), allike (12, 4), rødstjert (3-4, 6).

Desværre blev der hverken observeret grå eller broget fluesnapper eller løvsanger i den sydlige del af reservatet i 2003. Stæren synes stagneret på et i forhold til tidligere lavt niveau, som gør at den ikke længere er blandt de 10 mest almindelige arter.

Hvinanden, som er under indvandring i Grib Skov området pga. opsætning af redekasser, fandt formodentlig igen i 2003 et naturligt redehul på Strødam. En anden sjælden ynglefugl, lille flagspætte, ynglede sandsynligvis også i reservatet i 2003.

Natural regeneration in two gaps in Rankeskoven, Strødam Reservatet, Denmark

Reporting part of WP3 in the NatMan project

By Katrine Hahn, Skov & Landskab, KVL

24-03-2004

1 Summary

The effect of gap formation on natural regeneration, flora, light, and soil water availability was studied in Strødam Reservatet together with four other deciduous forests (Suserup Skov, Ravnsholte Skov, Als Nørreskov, Rude Skov) in Denmark in 2000-2002 as part of the research studies on natural regeneration in gaps in the EU-financed NatMan project (www.flec.kvl.dk/natman). Two gaps located in Strødam Reservatet were included in the study. The aim was to study the gap dynamics in forest gaps in both managed and unmanaged forests to increase the knowledge on which factors affect gap regeneration, as this has implications for practical forestry. The light and soil water availability were clearly affected by gap formation, with higher light levels and higher soil moisture content in and around the gap centre than under the surrounding forest canopy. Natural regeneration was sparse and consisted mainly of beech and ash. No clear differences between gaps and closed canopy were found. The flora was, in contrast, somewhat affected by the presence of a gap.

2 Introduction

The interest in and need for silvicultural systems, which rely on natural regeneration has increased within the last decade in most of Europe. The gap-phase, which is the most dynamic part of the forest mosaic-cycle, is essential to natural regeneration, and the processes taking place in the gap phase have consequences for both short-term and long-term forest dynamics. Research has aimed at improving the understanding of the patterns and processes involved in gap regeneration (Ryel & Beyschlag 2000) and studies in natural and artificially created gaps has been carried out in several forest types. In Denmark, specific studies on gap regeneration are relatively new (Emborg 1998, Emborg et al. 2000), despite the important role of gaps in deciduous forests. However, information on natural regeneration in other beech (*Fagus sylvatica*) silvicultural system, such as shelterwoods are well studied (Madsen 1995a, Madsen & Larsen 1997).

In order to gain a more specific knowledge of the processes and patterns in gaps as well as evaluating the seedling growth and survival, there is a need for quantification of the microclimate and the microclimatic variability, as stressed by Madsen (1995a). Light intensity and soil moisture as well as their interactions are important factors for the success of natural regeneration (Madsen 1994).These biotic factors influencing seedling growth offer a potential explanation of regeneration

patterns and seedling responses to changed growth conditions. Likewise, browsing can damage newly emerged seedlings (Madsen 1995b) as well as older plants significantly.

The overall aim of the study was to contribute to the improvement of ecologically based forest management, specifically the natural regeneration of beech and other broadleaved tree species, asking questions like

- How does the creation of gaps in various sizes affect the availability of light and soil moisture?
- How well is the establishment and growth of tree seedlings in the gap correlated to light and soil moisture?
- How does the floristic composition respond to gap formation?

3 Materials and methods

3.1 Research sites

The study was carried out in Strødam Reservatet (55°57' N, 12°17'E), Denmark. The reserve is a semi-natural strict forest reserve (160 ha) in northern Zealand, owned by the Jarl foundation (related to the University of Copenhagen), which became a forest reserve in 1925 with the specific purpose of scientific research. The forest is located at 10-30 m above sea level and consists of deciduous species, mainly beech and is presently growing out of its former high forest structure. It is situated in a larger forest-complex, mostly state-owned forest, hosting large populations of roe deer (*Capreolus capreolus*), red deer (*Cervus elaphus*) and fallow deer (*Dama dama*). The climate is cool-temperate, sub-oceanic (Table 1).

Table 1 Climatic information for Strødam reservatet (Frich et al. 1997, Laursen et al.1999)

Mean annual temperature (°C)	Mean annual precipitation (mm)	Climatic stations
7.7	697	Gribskov and Lille Dyrehavegaard (55°56' N, 12°18'E), average values 1961-1990

3.2 Methods

In Strødam Reservatet two gaps were studied (Figure 1, Table 2). Both gaps were created by natural processes, typically breakdown of single trees. The reference for gap size was Suserup Skov, where Emborg (1995) has estimated the average gap size of the innovation phase to be app. 500 m^2, ranging from 100 m^2 to 1500 m^2. No soil preparation was done in any gaps. Within each gap, a N-S grid system was laid out, with 5x5 m distance between sample plots (Figure 3). The grid system covered the full gap as well as some ground under closed canopy. Each sample plot was 1m^2 and circular. Sample plot recordings were done in either 63 plots (small gap) or 99 plots (large gap) (Figure 2 and 3).

Table 2. Description of gaps, establishment year, species of felled trees, gap size and fencing status. *A gap is defined as the vertical projection downward of any canopy opening in the forest that extends through the vegetation strata down to the vegetation of the forest floor.

Gap #	Year of establishment	Gap makers	Gap size (m^2)*	Fence
1	1999	1 x beech	150	No
2	1999	2 x beech	250	No

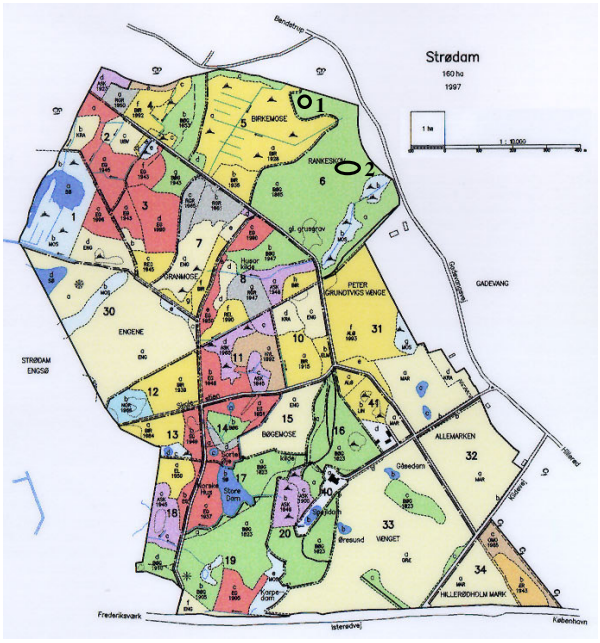

Figure 1. The location of the two gaps (1 and 2) within Strødam Reservatet

Relating the two gaps to the established grid-net of Strødam Reservatet gap 1 is situated between coordinates S2 and S3, and gap 2 is situated between V6 and V7.

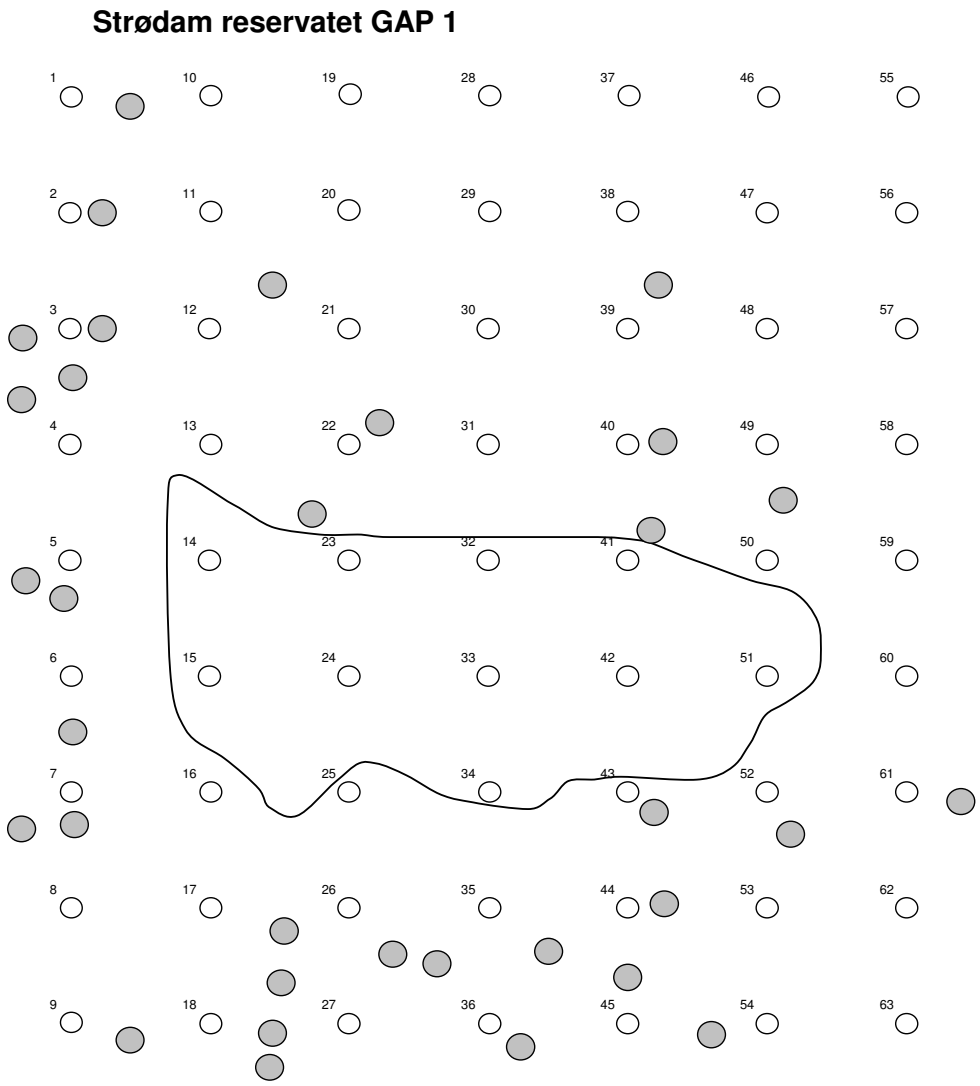

Figure 2. Gap 1 has 63 sample plots a 1 m^2 (white circles) within a 5 m x 5 m grid net. The gap outline is marked with black line, surrounding, living trees are marked with grey circles.

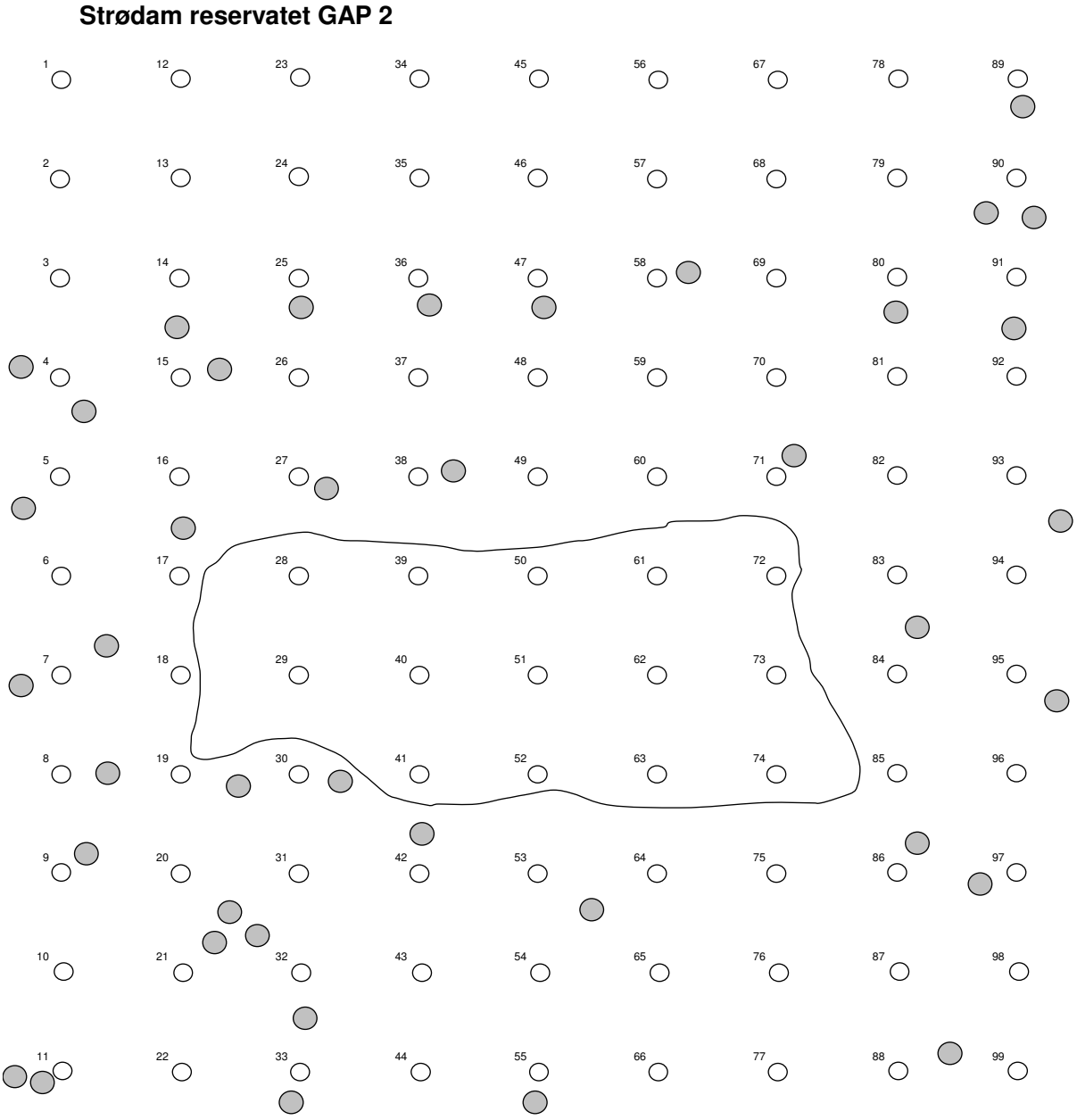

Figure 3. Gap 2 has 91 sample plots a 1 m^2 (white circles) within a 5 m x 5 m grid net. The gap outline is marked with black line, surrounding, living trees are marked with grey circles.

Regeneration was recorded in all sample plots on annual basis. Recordings of seedling number and height class took place in October- November in 2000, 2001, and 2002. In each plot, total number of seedlings per species as well as height classes was recorded. Abundance values were determined as absolute numbers (i.e. seedlings m^2). Flora (species and percent cover) was recorded in the

sample plots in spring (April-May) and summer (July-August) in 2001 and 2002. Species nomenclature for all species followed Hansen (1991).

Leaf area index (LAI) of the canopy was determined indirectly by the use of the Li-Cor LAI-2000 instrument (Welles & Norman 1991) in August 2001. LAI-2000 measurements were obtained under overcast sky conditions or during the short periods with diffuse light before sunrise and after sunset to avoid direct light or stem reflections reaching the sensors. Two simultaneous measurements were taken with cross-calibrated sensors; one sensor was placed in the open and one sensor was used for measurements under the forest canopy 1 m above ground. View restrictors of 90° were fitted on the sensors, both orientated in the same direction, in order to avoid error from the person operating the below-canopy sensor. Light conditions were measured along the centre line of all gaps. If the weather conditions were good, all grid points were measured. The LAI measurements provided an inverse measure of the percent transmittance of diffuse light (DIFN), which were converted to relative light intensity (photosynthetic photon flux densities) (PPFD) (μmol m^{-2} s^{-1}) in the 400-700 nm waveband. This was done using an equation based on correlation tests of LAI and PPFD from measurements in similar beech dominated forests in eastern Denmark (Madsen & Larsen 1997).

Volumetric soil moisture content was measured at all sample plots along the N-S base line in both gaps. The measurements were carried out along two sets of probes at each plot for 0-30 cm depth using time domain reflectometry (TDR) (Topp et al. 1980). A cable tester (Tektronix 1502C) was used for the measurements. The average soil water content was expressed in percent of field capacity. Measurements were performed in 2001 and 2002 following a dry spell in the late summer. It was assumed that soil water content was strongly correlated with water supply for the seedlings.

4 Results

4.1 Variability of light climate and soil moisture

The relative light intensity (RLI) was, in both gap 1 and 2, higher in the gap centres than under closed canopy, with a RLI of 10% in the gap centre compared to 2-5% RLI under closed canopy (Figure 4). The between-gap variation of light conditions was rather high due to differences in gap structure, e.g. the presence of suppressed trees in and around the gap.

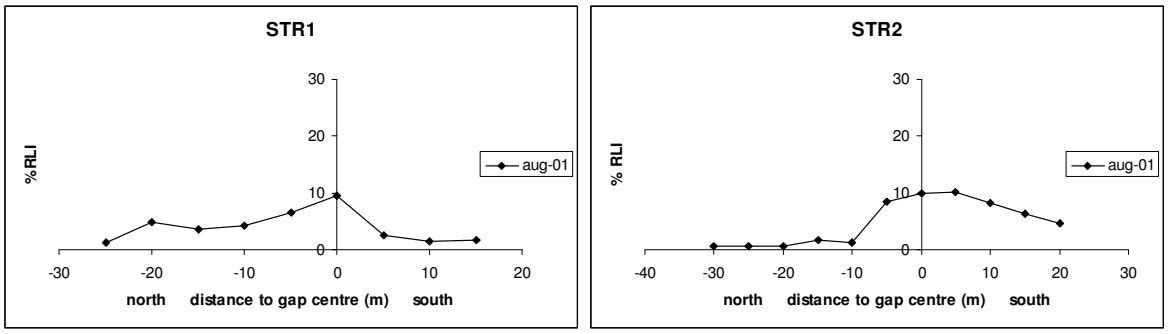

Figure 4. Relative light intensity measured along the north-south base line of gap 1 and 2 in 2001.

The soil moisture content varied in space and time. The soil moisture content was generally higher in 2002 than 2001, but in both years and for both gaps, the soil moisture content was higher in the gap centres than under closed canopy (Figure 5). The correlation between light and soil moisture showed that plots with a high relative light intensity also had high soil water content (Figure 6).

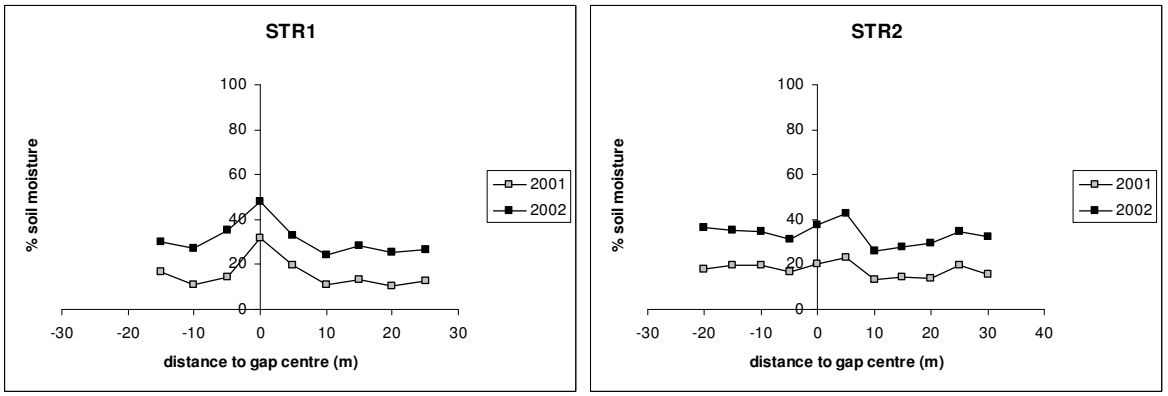

Figure 5. Soil moisture content measured along the north-south base line of gap 1 and 2 in 2001 and 2002.

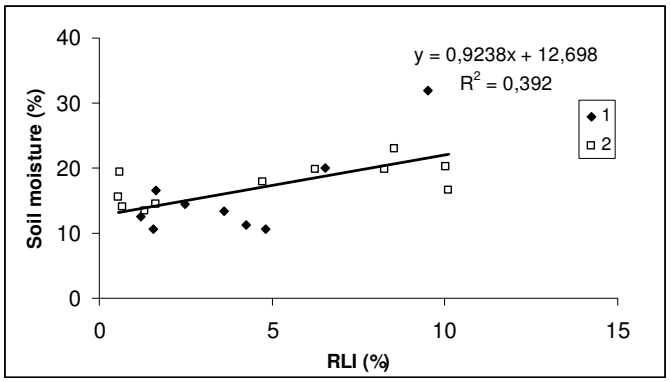

Figure 6. The correlation between relative light intensity (RLI) and soil moisture content in 2001.

4.2 Flora

The flora in and around the gaps in Strødam Reservatet was rather sparse, especially in spring. In spring, ground vegetation covered 1.5-3.4% of the forest floor, and in summer ground vegetation covered 5.8-12.7% of the forest floor (Table 2). Most species present in and around the two gaps are characteristic for nutrient poor soils in beech forests (Table 3). In comparison with other Danish deciduous forests, where gap vegetation has been studied, the gaps in Strødam Reservatet are very sparsely vegetated (Figure 7).

Table 2. Average ground cover in and around gap 1 and 2

Gap	Spring 2001	Spring 2002	Summer 2001	Summer 2002
1	1.5	1.9	8.7	5.8
2	3.4	3.2	12.7	9.4

Table 3. All species present with an average cover of > 0.1%

	Spring vegetation	Summer vegetation
Gap 1	Anemone nemorosa	Carex pilulifera
	Carex pilulifera	Deschampsia caespitosa
	Deschampsia flexuosa	Deschampsia flexuosa
	Oxalis acetosella	Fagus sylvatica
	Melica uniflora	Fraxinus excelsior
	Majanthemum bifolium	Melica uniflora
		Oxalis acetosella
		Sorbus aucuparia
Gap 2	Anemone nemorosa	Acer pseudoplatanus
	Calamagrostis epigos	Agrostis tenuis
	Carex pilulifera	Anemone nemorosa
	Deschampsia flexuosa	Athyrium filix-femina
	Dryopteris dilatata	Calamagrostis epigos
	Festuca gigantean	Carex pilulifera
	Galium aparine	Deschampsia caespitosa
	Lactuca muralis	Fagus sylvatica
	Melica uniflora	Festuca gigantea
	Milium effusum	Fraxinus excelsior
	Oxalis acetosella	Melica uniflora
	Poa nemoralis	Milium effusum
	Rubus idaeus	Oxalis acetosella
	Urtica dioica	Poa nemoralis
		Rubus fruticosus
		Rubus idaeus

Analyses at the average ‘gap’ or ‘non-gap’ level showed that the average spring vegetation cover was slightly lower in non-gap plots than in gap plots (Figure 7). The summer flora was characterised by a more pronounced difference between gap and non-gap plots. Thus, the ground

vegetation appears to have responded to gap formation to a certain degree, most clearly seen for the summer vegetation cover (Figure 7).

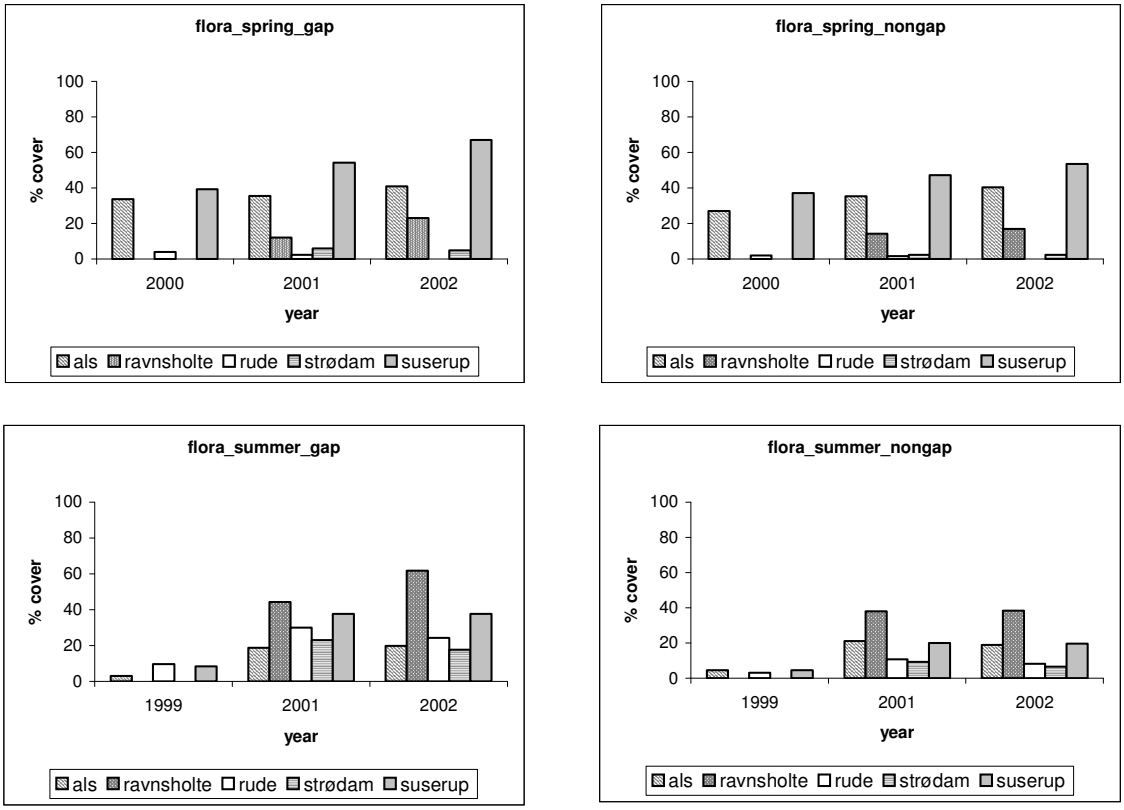

Figure 7. Percent cover of spring and summer ground vegetation in gaps and non-gap areas over time.

Analyses at the individual plot level showed a less distinct pattern. A linear statistical model, which included effects of block (the gaps within a forest), gap (each plot was characterised as either 'gap' or 'non-gap'), year (2001-2002), and their interaction effects did not reveal any significant effects.

4.3 Woody regeneration

The woody regeneration in and around the two gaps was generally very sparse, and consisted primarily of beech and ash. For beech, the average regeneration density was < 1 tree m^{-2} in both gaps. For ash, regeneration was 1-3 trees m^{-2} in gap 1 and < 1 tree m^{-2} in gap 2. Sycamore maple and cherry were present in very low numbers in gap 2 only (Table 4-7).

Table 4. Beech: Sum and average number of trees per year and gap

		SUM							AVERAGE (trees m^{-2})							
Year	Gap	< 1 year	<20 cm	21-50 cm	51-90 cm	91-130 cm	131-200 cm	201-300 cm	< 1 year	<20 cm	21-50 cm	51-90 cm	91-130 cm	131-200 cm	201-300 cm	*Total*
2000	1	4	10	7	5	2	5	2	0.06	0.16	0.11	0.08	0.03	0.08	0.03	*0.55*
2001	1	0	9	4	8	3	2	2	0.00	0.14	0.06	0.13	0.05	0.03	0.03	*0.42*
2002	1	0	7	2	10	1	1	2	0.00	0.11	0.03	0.16	0.02	0.02	0.03	*0.37*
2000	2	0	19	9	10	0	1	3	0.00	0.18	0.10	0.10	0.00	0.01	0.03	*0.42*
2001	2	0	50	11	12	0	1	1	0.00	0.51	0.11	0.12	0.00	0.01	0.01	*0.76*
2002	2	1	27	7	9	4	1	1	0.01	0.27	0.07	0.09	0.04	0.01	0.01	*0.50*

Table 5. Ash: Sum and average number of trees per year and gap

		SUM						AVERAGE (trees m^{-2})						
Year	Gap	< 1 year	<20 cm	21-50 cm	51-90 cm	91-130 cm	131-200 cm	< 1 year	<20 cm	21-50 cm	51-90 cm	91-130 cm	131-200 cm	*Total*
2000	1	55	0	0	0	0	0	0.32	0.87	0.00	0.00	0.00	0.00	*1.19*
2001	1	16	207	0	0	0	0	0.25	3.29	0.00	0.00	0.00	0.00	*3.54*
2002	1	16	60	0	0	0	0	0.25	0.95	0.00	0.00	0.00	0.00	*1.20*
2000	2	2	3	0	0	0	0	0.03	0.50	0.00	0.00	0.00	0.00	*0.53*
2001	2	2	26	1	0	0	0	0.02	0.26	0.01	0.00	0.00	0.00	*0.29*
2002	2	1	5	5	1	0	0	0.01	0.05	0.05	0.01	0.00	0.00	*0.21*

Table 6. Sycamore maple: Sum and average number of trees per year and gap

		SUM					AVERAGE (trees m^{-2})					
Year	Gap	< 1 year	<20 cm	21-50 cm	51-90 cm	91-130 cm	< 1 year	<20 cm	21-50 cm	51-90 cm	91-130 cm	*Total*
2000	1	0	0	0	0	0	0.00	0.00	0.00	0.00	0.00	*0.00*
2001	1	0	0	0	0	0	0.00	0.00	0.00	0.00	0.00	*0.00*
2002	1	0	0	0	0	0	0.00	0.00	0.00	0.00	0.00	*0.00*
2000	2	0	0	0	0	0	0.00	0.00	0.00	0.00	0.00	*0.00*
2001	2	0	3	0	0	0	0.00	0.03	0.00	0.00	0.00	*0.03*
2002	2	1	1	0	0	0	0.01	0.01	0.00	0.00	0.00	*0.02*

Table 7. Wild cherry: Sum and average number of trees per year and gap

		SUM		AVERAGE (trees m^{-2})		
Year	Gap	< 1 year	<20 cm	< 1 year	<20 cm	*Total*
2000	1	0	0	0.00	0.00	*0.00*
2001	1	0	0	0.00	0.00	*0.00*
2002	1	0	0	0.00	0.00	*0.00*
2000	2	0	0	0.00	0.00	*0.00*
2001	2	0	2	0.00	0.02	*0.02*
2002	2	0	2	0.00	0.02	*0.02*

A statistical analysis showed that there was a significant difference ($p < 0.01$) between gap and non-gap for beech with least significant means of 0.87 trees m^{-2} within the gaps and 0.46 trees m^{-2} outside the gaps. For ash, no significant differences between gap and non-gap were found, but there were significant differences between the two gaps ($p < 0.0001$), with gap 1 (close to the bog) having a higher proportion of ash than gap 2 (1.89 trees m^{-2} versus 0.05 trees m^{-2}). For ash, there was also a significant effect of year ($p<0.01$), with a fluctuation from 0.60 in 2000 up to 1.66 in 2001 and down again in 2002 to 0.64 trees m^{-2}.

The relation between regeneration, light and soil moisture availability was less significant. The only significant relationship was found between light and ash regeneration ($p<0.05$), with increasing light availability correlated to increasing abundance of ash regeneration.

5 Discussion

The study showed that the presence of a gap in a natural forest caused considerably different micro-climatic conditions within the gap than in the surrounding closed forest. However, the response to gap formation was rather low in the two studied gaps. The main reasons are expected to be a combination of severe browsing by deer, and partly unfavourable establishment conditions (thick moor layer, poor soil). The browsing in many places caused formation of small, ball-shaped 'bonsai' beech trees of a height less than 0.5 m.

The study in the unmanaged Strødam Reservatet has practical application for managed forests where it is desirable to shift towards more heterogeneous stand structure. Because the correlation between relative light intensity and soil water content was relatively high, the availability of those two factors appears relatively easy to control by felling practice. In practical forestry, the removal of 2-3 canopy trees would make the relative light intensity and soil moisture content much higher within the gap than under closed canopy. The effect typically reaches 10-15 m from the gap centre making a micro-site for regeneration of 300-400 m^2. Although increased soil water content as well as higher light intensity was observed in the gap centre, the prediction of seedling abundance and height was low. Thus, on poor sites, with site conditions similar to Strødam Reservatet, larger gaps may be necessary in order to start the process of natural regeneration.

In practical forestry, it may therefore be necessary to perform soil preparation at certain sites to reduce the thickness of the litter layer and expose the mineral soil on problematic sites with poor soil conditions and high browsing pressure, in order to obtain acceptable densities of seedlings. Also fencing should be considered, as it may increase the establishment rate, influence the stem density and provide a more diverse species composition.

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7 References

Emborg, J. 1998: Understorey light conditions and regeneration with respect to the structural dynamics of a near-natural temperate deciduous forest in Denmark. Forest Ecology and Management. 106:83-95.

Emborg, J., Christensen, M. and Heilmann-Clausen, J. 2000: The structural dynamics of Suserup Skov, a near-natural temperate deciduous forest in Denmark. Forest Ecology and Management. 126(2):173-189.

Frich, P., Rosenørn, S., Madsen, H. and Jensen, J.J. 1997: Observed precipitation in Denmark, 1961-90. Technical report 97-8. Danish Meteorological Institute. Ministry of Transport. 1-40.

Hansen, K. (ed.) 1991: Dansk Feltflora. Gyldendalske Boghandel, Copenhagen.

Laursen, E.V., Thomsen, R.S. and Cappelen, J. 1999: Observed air temperature, humidity, pressure, cloud cover and weather in Denmark – with climatological standard normals, 1961-90. Technical report 99-5. Danish Meteorological Institute. Ministry of Transport. pp. 142.

Madsen, P. 1994: Growth and survival of Beech seedlings in relation to light intensity and soil water content. Scandinavian Journal of Forest Research. 9:316-322.

Madsen, P. 1995a: Effects of soil water content, fertilization, light, weed competition and seedbed type on natural regeneration of beech (Beech). Forest Ecology and Management. 72:251-264.

Madsen, P. 1995b: Effects of seedbed type on wintering of beech nuts (Beech) and deer impact on sprouting seedlings in natural regeneration. Forest Ecology and Management. 73:37-43.

Madsen, P. & Larsen, J.B. 1997: Natural regeneration of beech (Beech L.) with respect to canopy density, soil moisture and soil carbon content. Forest Ecology and management. 97:95-105.

Ryel, R.J. & Beyschlag, W. 2000: Gap Dynamics. p.251-279. In: Marshall, B. & Roberts, J.A. (eds.) 2000:Leaf development and canopy growth. Sheffield Academic Press.

Topp, G.C., Davis, J.L. & Annan, A.P. 1980: Electromagnetic determination of soil water content: Measurements in coaxial transmission lines. Water Resources Research. 16(3):574-582.

Welles, J.M. & Normann, J.M. 1991: Instrument for indirect measurement of canopy architecture. Agronomy Journal. 83:818-825.