Spatial variation of local stand structure in an Abies forest, 45 years after a large disturbance by the Isewan typhoon

By Ryota KOSUGI (B4)

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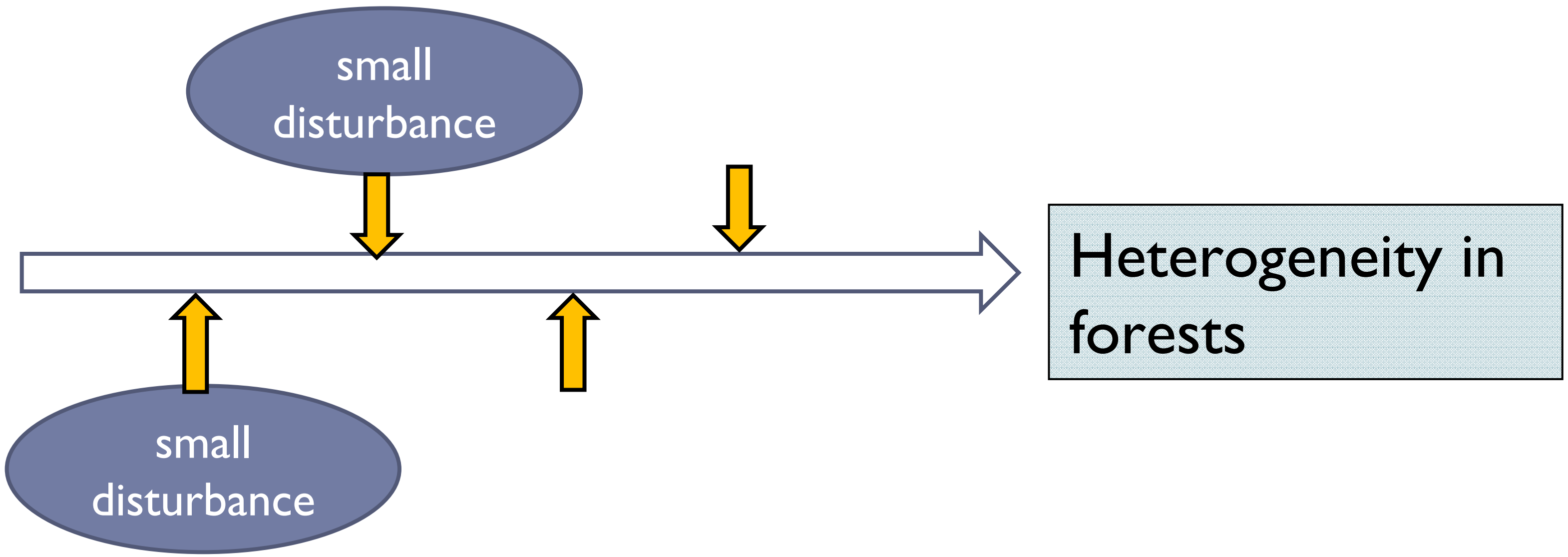
Introduction



- 小規模攪乱の繰り返しが森林の不均質性を作り出す
  (repeated small disturbance can generate forest heterogeneity)

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- 単一の大規模攪乱も構造の不均質性を作り出すかもしれない(a stand-replacing disturbance may create extreme variation in the structure of forests)(Turner et al. 1998)

Introduction

大規模攪乱後の林分

攪乱後に侵入した実生・生存した実生、稚樹で成り立つ(Turner et al. 1998; Franklin et al. 2002)
(consists of seedlings recruited after the disturbance, and any seedlings and saplings surviving the disturbance)

攪乱後の実生の侵入・生存した実生、稚樹の量や分布が不均質であれば、初期の林分構造も多様になる(Because the abundance and distribution of the seedlings and saplings are spatially heterogeneous, the initial forest structure after a stand-replacing disturbance is likely to vary among local sites in the area affected by the disturbance)

初期の林分の多様性は、森林が発達する何十年、何世紀にわたっても残り続ける(Kashian et al. 2005; Lecomte et al. 2006)
(Effects of this initial structural variation may persist for several decades or even centuries during forest development)

Introduction

- 「密度」･「蓄積」･「種数」によって構成される森林空間の多様性は、撹乱後の動態を理解するために評価されるべきだ(Cattelino et al. 1979; Kashian et al. 2004; Lutz and Halpern 2006)

  (Spatial variability in forest structure that consist of variation in density, biomass, or species composition should be evaluated to understand the dynamics of the forest after a stand-replacing disturbance)

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- 一方で、「サイズ分布」･「空間分布」のパターンが、プロットレベルの動態に影響を与えている(Antonovics and Levin 1980; Hutchings 1997; Law et al. 2001; Turnbull et al. 2007)

  (Although the size distribution and the spatial distribution pattern substantially affect local stand dynamics)

⇒研究事例が少ない (few studies have evaluated...)

Introduction

- 八ヶ岳北部、亜高山帯針葉樹林における林分構造のパターン(We explored the structural variation within a subalpine Abies forest in northern Yatsugatake, Japan)

> ➢ 優占種(dominated species)
> シラビソ　(*Abies veitchii*)
> オオシラビソ　(*Abies mariesii*)

⇩

> ➢ 1959年の伊勢湾台風によって、数平方kmの樹木がなぎ倒された(Any canopy trees in subalpine forests in the region were completely blown down over an area covering a few square kilometers in 1959 by the Isewan super-typhoon)

⇩

> ➢ 優占種(dominated species)
> シラビソ　(*Abies veitchii*)
> オオシラビソ　(*Abies mariesii*)

Introduction

- 一度大攪乱を受けた、林分構造の多様性を調べるのに適している(The forest is suitable for study of structural variation within a forest that experienced a single disturbance)

- 二種のモミ属が優占しているので、種構成の違いや攪乱への応答性の違いが少ない(The forest consists mostly of two *Abies* species, so that its structural variation is less likely to be affected by differences in species composition or the different responses of species to disturbance)

シラビソ(*Abies veitchii*)
オオシラビソ（*Abies mariesii*)

Introduction

仮説

「大規模単一攪乱後の森林では、樹木の分布がきわめて不均質となる」

(We hypothesized that tree distribution is highly heterogeneous in a forest that regenerated after a stand-replacing disturbance)

予測

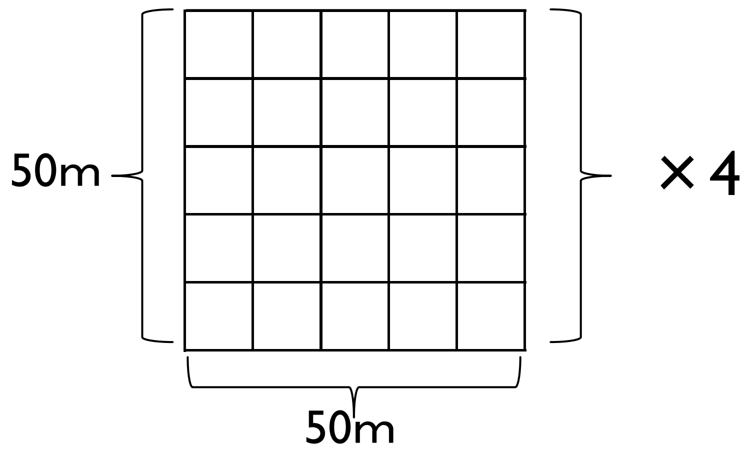
1. サブプロットレベルの胸高断面積は、密度が高いほど小さい (local stand basal area would be smaller in stands with a clumped distribution pattern for trees than in stands with a non-clumped pattern)
2. 平均個体サイズは、密度が高いほど小さい(mean tree size would be smaller in clumped than in non-clumped stands)
3. サイズのばらつきは、密度が高いほど大きい(size variation would be larger in clumped than non-clumped stands)

Study sites and Field methods

- 縞枯山(Mt. Shimagare)

  2つのサイトに50m×50mプロットを2つずつ設置・計4カ所

  それぞれのプロットに10m×10mのサブプロットを25個設置・計100カ所(2004年～)



- Site 1 (36° 4′ 30″ N、138° 19′ 25″ E、海抜2230m)
- Site 2 (36° 3′ 57″ N、138° 19′ 33″ E、海抜2135m)

Analysis(50m×50m)　調査地：八ヶ岳連峰

- stem density
- stand basal area
- mean DBH
- CV of DBH

➢ 空間分布パターンの解析に $L(t)$ function を使用

$L(t)$ *function* ← *Ripley's* $K(t)$ *function* (Diggle 1983)

$L(t)>0$: clumped pattern of individuals
$L(t)<0$: regular pattern

(t=0.2m–25.0m; 0.2m intervals)

↓

➢ Monte Carlo simulations: 99%信頼区間

(approximate 99% confidence envelopes)

Analysis(10m×10m)

- stem density
- stand basal area
- mean DBH
- CV of DBH

➢ 空間分布パターンの解析に $L(t)$ function

$L(t)$ *function* ← *Ripley's* $K(t)$ *function* (Diggle 1983)

classify the pattern into three types: clumped, random, or regular⇒clumped(集合) or non-clumped(非集合)

(t=0.2m–5.0m; 0.2m intervals)

Results

Table 1 Species composition, number of trees, basal area at breast height, mean diameter at breast height (DBH), and coefficient of variation (CV) of DBH in the four plots

	Number of trees (stems 0.25 ha^{-1})	Relative frequency (%)	Basal area (m^2 ha^{-1})	Relative basal area (%)	Mean DBH (cm)	CV of DBH (%)
Plot 1-1					9.78	48.05
Abies veitchii	788	68.3	35.5	83.2		
Abies mariesii	202	17.5	5.4	12.6		
Betura ermanii	55	4.8	1.0	2.3		
Sorbus commixta	71	6.2	0.4	1.0		
Prunus nipponica	36	3.1	0.4	0.9		
Picea jezoensis var. *hondoensis*	2	0.2	0.0	0.0		
Total	1,154	100.0	42.7	100.0		
Plot 1-2					8.15	52.02
Abies veitchii	1,051	64.0	35.9	82.6		
Abies mariesii	286	17.4	4.9	11.4		
Sorbus commixta	200	12.2	1.5	3.4		
Prunus nipponica	81	4.9	0.8	1.8		
Betura ermanii	23	1.4	0.4	0.9		
Acer tschonoskii	1	0.1	0.0	0.0		
Total	1,642	100.0	43.5	100.0		
Plot 2-1					7.01	46.40
Abies veitchii	1,428	65.8	32.1	78.9		
Abies mariesii	699	32.2	8.2	20.1		
Picea jezoensis var. *hondoensis*	11	0.5	0.3	0.6		
Betura ermanii	23	1.1	0.1	0.2		
Sorbus commixta	10	0.5	0.1	0.2		
Total	2,171	100.0	40.8	100.0		
Plot 2-2					6.05	53.49
Abies veitchii	1,479	53.7	26.9	65.9		
Abies mariesii	1,240	45.0	13.6	33.5		
Sorbus commixta	9	0.3	0.2	0.4		
Betura ermanii	27	1.0	0.1	0.1		
Picea jezoensis var. *hondoensis*	1	0.0	0.0	0.0		
Total	2,756	100.0	40.8	100.0		

Results

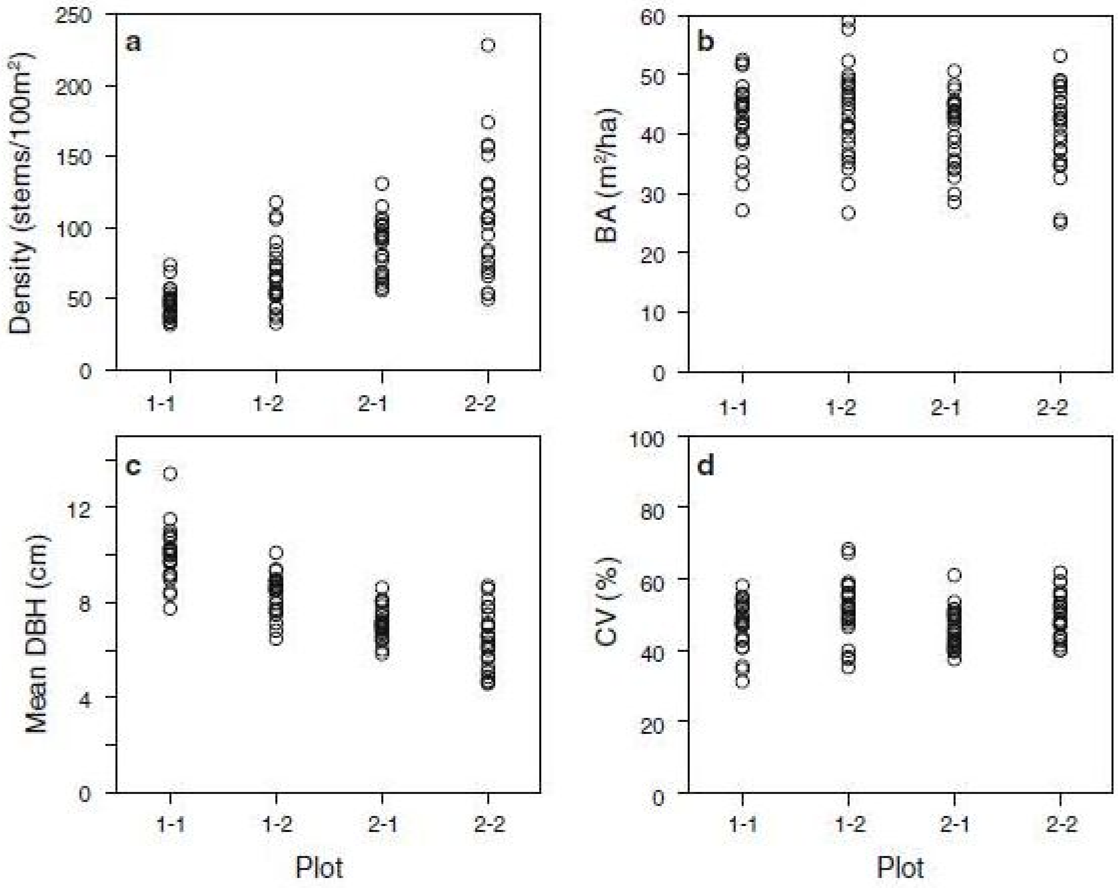


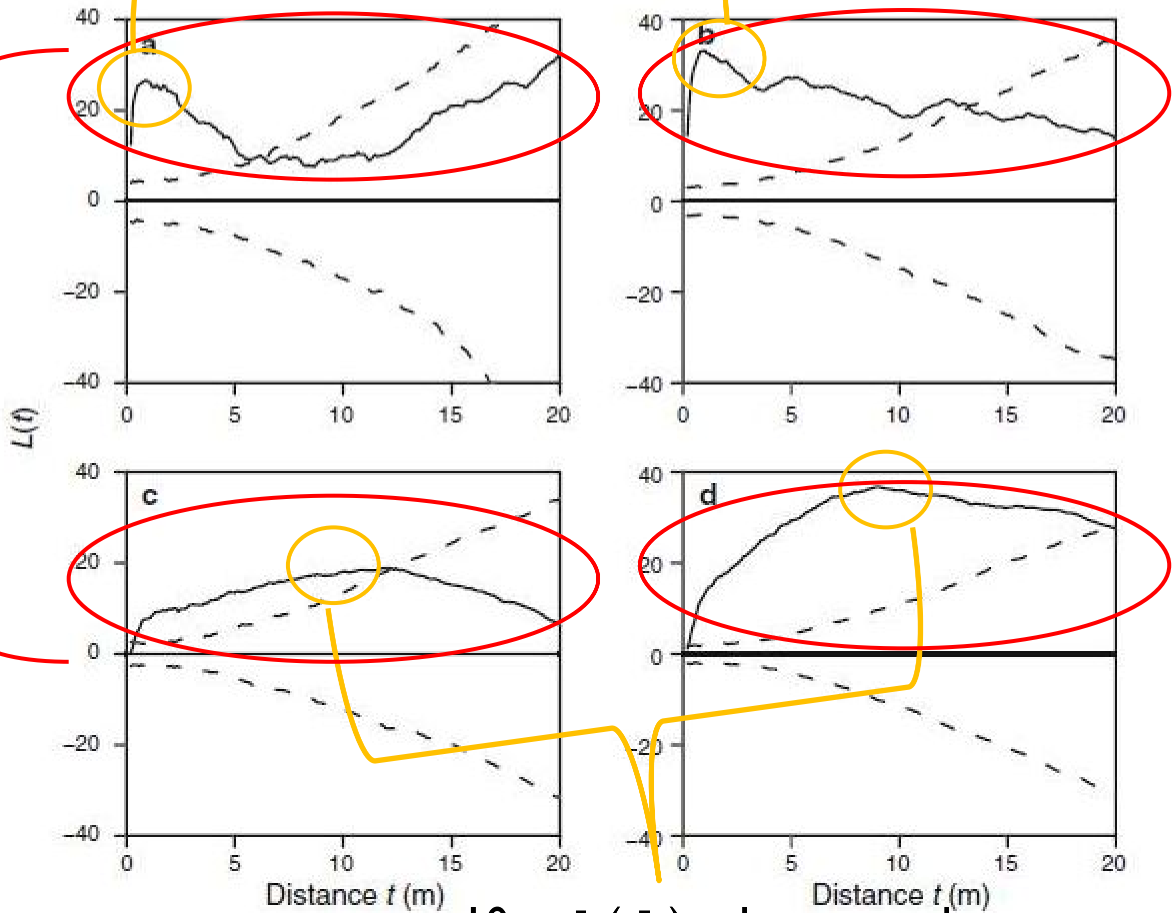
Fig. 1 Subplot-level variation in **a** stem density, **b** stand basal area, **c** mean diameter at breast height (*DBH*), and **d** the coefficient of variation (*CV*) of DBH

Results; plot-level

t=1.0m; ▪ (▪) values were largest

Fig. 2 *L*(*t*) value for trees taller than 1.3 m in a plot 1-1, **b** plot 1-2, **c** plot 2-1, and **d** plot 2-2. The *solid line* shows observed *L*(*t*) values for extant plants, *dashed lines* show 99% confidence envelopes estimated from 1,000 random distributions

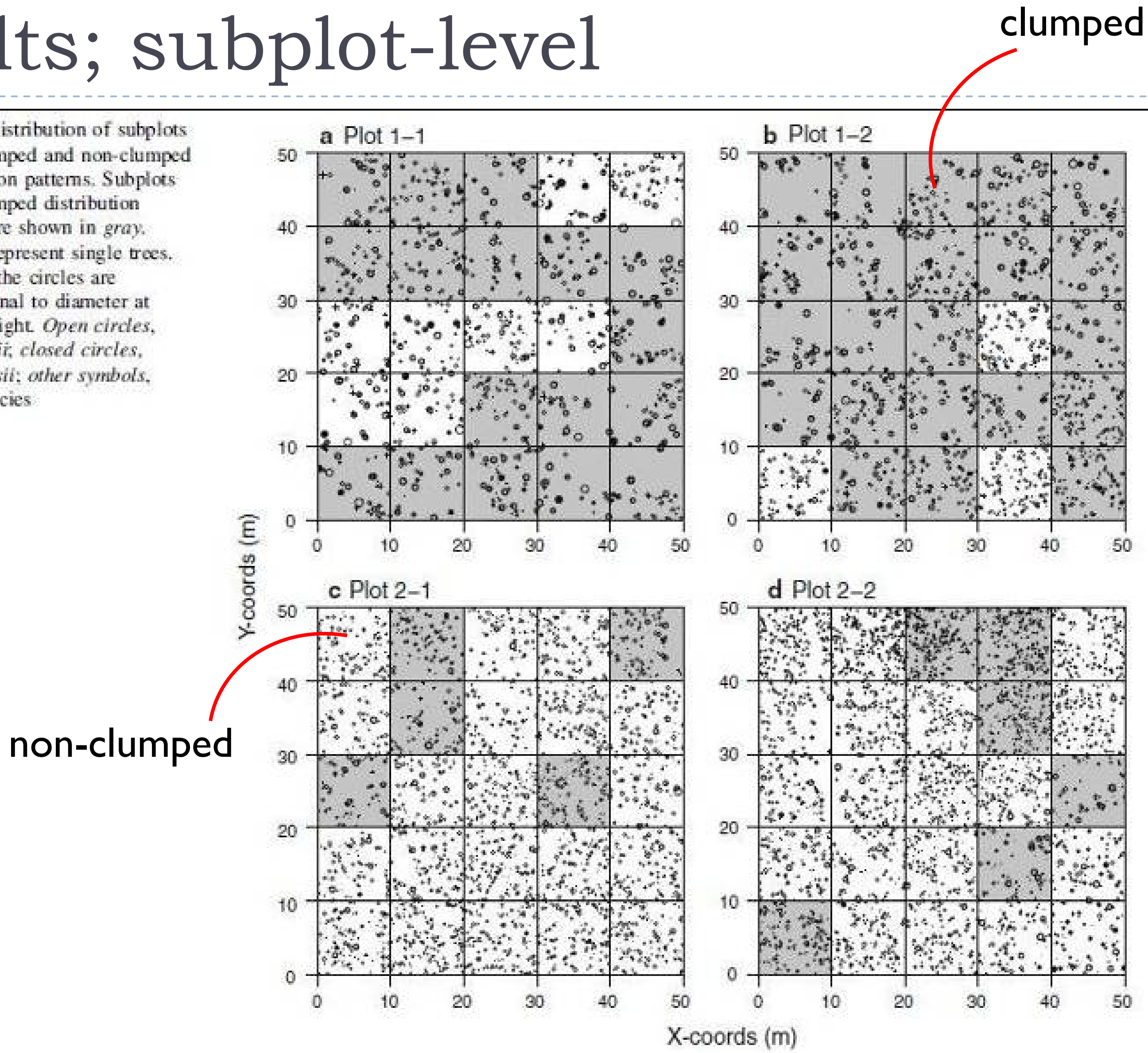
clumped



t=10m; ▪ (▪) values were largest

Results; subplot-level

Fig. 3 Distribution of subplots with clumped and non-clumped distribution patterns. Subplots with clumped distribution pattern are shown in *gray*. *Circles* represent single trees. Sizes of the circles are proportional to diameter at breast height. *Open circles*, *A. veitchii*; *closed circles*, *A. mariesii*; *other symbols*, other species

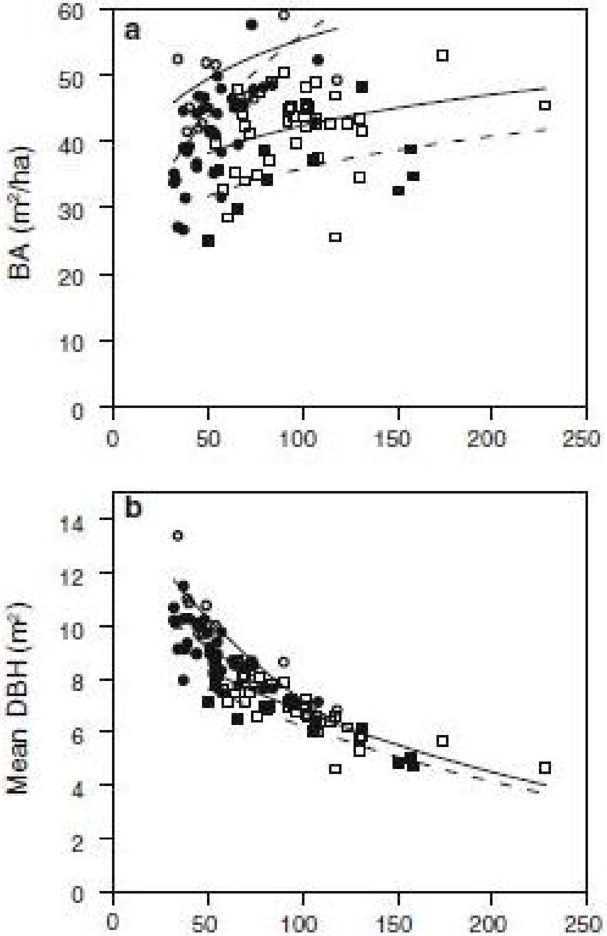


Results

- Site 1
- 樹木の空間分布のパターンは集合的であり、サブプロットレベルでの分布パターンも多くで集合的であった(That is, overall distribution pattern of the trees was clumped and the local distribution patterns were also clumped at most localities.)

- Site 2
- 樹木の空間分布のパターンは集合的であったが、サブプロットレベルでは、多くで非集合的であった(the overall distribution pattern of trees was clumped, but the local distribution patterns were not clumped in most subplots)

Results



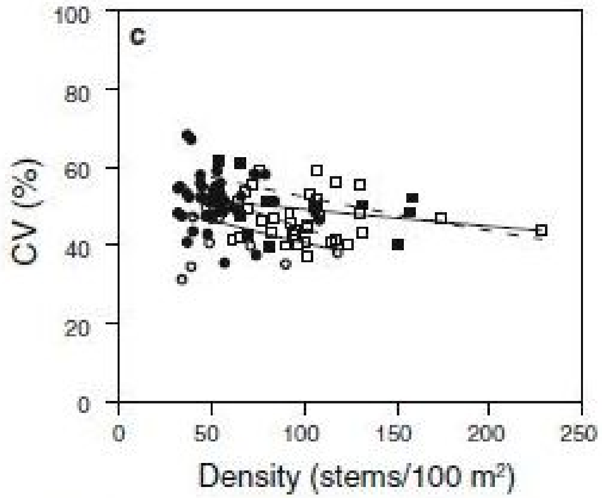


Fig. 4 Relationships between density and **a** basal area, **b** mean diameter at breast height (*DBH*), and **c** the coefficient of variation (*CV*) of DBH at Site 1 (*circles*) and Site 2 (*squares*). A *closed symbol* indicates a subplot with a clumped distribution pattern; an *open symbol* indicates a subplot with a non-clumped distribution pattern. The regression lines were estimated by generalized linear mixed model for subplots with a clumped distribution pattern (*solid lines*) and non-clumped distribution (*dashed lines*)

○: Site 1, clumped pattern
●: Site 1, non-clumped pattern
□: Site 2, clumped pattern
■: Site 2, non-clumped pattern

Discussion

- 種構成は単純なのに、林分構造は多様であった

  (Although the species composition in the study site forests was very simple, there were large variations in the forest structure within the plots)

- 単一の大規模攪乱を受けた亜高山帯シラビソーオオシラビソ林分でも、空間的不均質性がうまれる

  (this shows that great spatial heterogeneity can arise even within a area that experienced a single large disturbance in the subalpine *Abies* forest)

Discussion

胸高断面積のばらつき
(variation in basal areas)

↓

光環境の違い
(heterogeneous light conditions)

∴胸高断面積∝樹冠閉鎖
(basal area) (canopy closure)

(Mitchell and Popovich 1997; Hale 2001)

林床植生の個体数、動態
(the abundance and dynamics of understory plants)

胸高直径のばらつき
(variation in the mean and CVs of DBH)

||

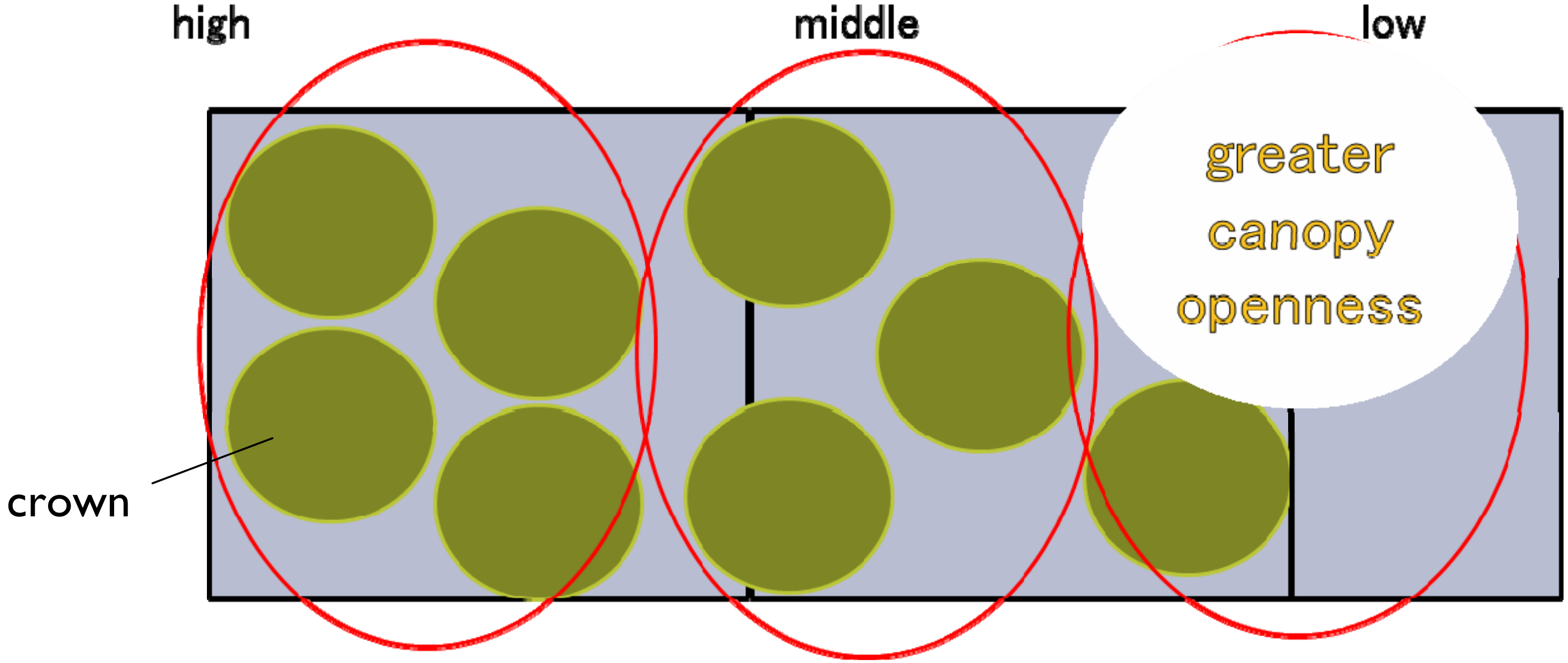
樹木のサイズのばらつき
(spatial heterogeneity of tree sizes)

樹木の枯死・生産性はサイズに依存する(S.N. Suzuki, unpublished results)
(the mortality and fecundity of these trees depends strongly on tree size)

↓

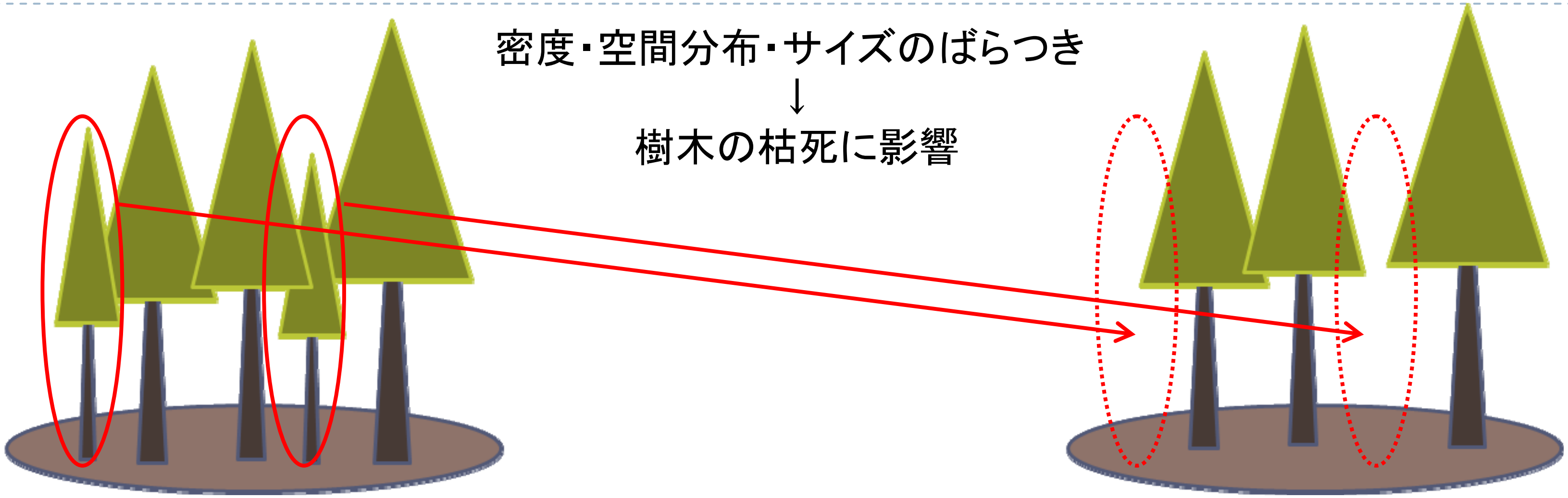
樹木の個体群の空間パターン
(the spatial pattern of tree demographics)

Discussion ~Effects of local spatial pattern on the local stand structure~



樹木の分布パターンが集合的であった場合
⇒低密度の場所の方が、高密度の場所より、樹冠が閉塞するのが遅い
(If the distribution pattern of trees is clumped, the canopy closes later in low-density areas than in high-density areas)

Discussion ~Effects of local spatial pattern on the local stand structure~



高密度により樹木が枯死した場合

✓空間分布はより規則的に近づく
(Kenkel 1988; Kenkel et al. 1997; Suzuki et al. 2008)

✓一方で、サイズのばらつきは小さくなる
(Weiner and Thomas 1986; Knox et al. 1989; Kenkel et al.1997)

(If some trees die in a density-dependent manner, then the spatial distribution pattern would be more regular after the mortality, whereas size variation would decrease)

Conclusions

- 単一大規模撹乱後のシラビソーオオシラビソ林分で、どのようにサブプロットレベルの構造が多様化するのか？(how local structures varied within an Abies forest that experienced a large stand-replacing disturbance)

プロットの初期段階の不均一性
(heterogeneity in the initial conditions of the stands)

→

密度
(stem density)

分布
(distribution)

↓

胸高断面積
(basal area)

サイズ分布
(size distributions)

↓

一回の大きな台風の襲来が森林構造の空間的不均一性に長期間の影響を与えている
(This is indicative of prolonged effects of a single large typhoon on the spatial heterogeneity of forest structure)

Conclusions

- サブプロットの空間構造の多様性は、進行中のプロセスに応じて、サブプロット間の多様性を反映している(the variation in local structure reflects variation among the local stands in response to ongoing processes)

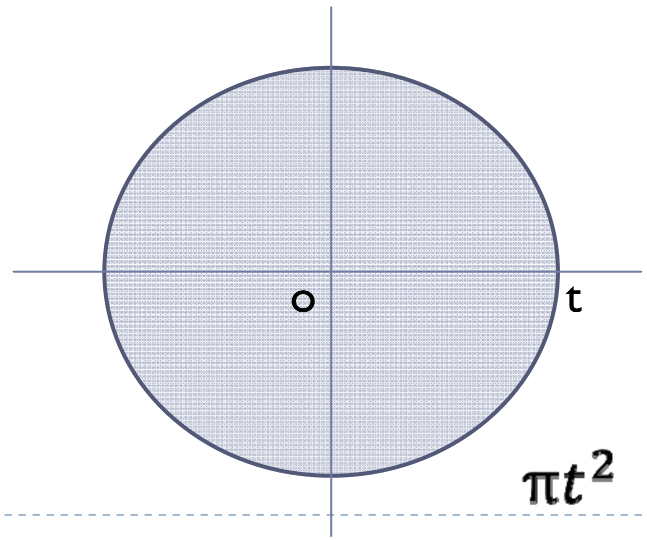
↓

- サブプロットレベルの構造を解析することによって、プロット内の森林動態の詳細な様相を知ることができる(the analysis of local structures within a plot can provide a detailed view of forest dynamics)

補足① ~RipleyのK関数法~

- K(t)は、無作為に選ばれる点から、距離tまでに分布が予測される点の数を表す。

- 完全にランダム化におかれた状態では
- $L(t) = \sqrt{K(t)/\pi} - t,\ K(t) = \pi t^2$ で表される。
- $\Rightarrow L(t) = 0$



補足② ~Monte Carlo Test~

- 空間完全ランダム性(csr)での100回のシミュレーション
- ⇒空間完全ランダム性を棄却するorしない

STATISTICS FOR SPATIAL DATA (p. 617)
NOEL A. C. CRESSIE

補足③

Discussion ~Spatial distribution patterns at the plot level and subplot level~

Plot level

- ✓ 個々のパッチ(Patches of individual)
- ✓ パッチの大きさの推定(Estimation of the patch scales)
- ✓ セーフサイトの不均質性による集合分布パターン(the clumped distribution pattern that results from heterogeneous distribution of safe site)

⇕

Subplot level

- ✓ サブプロットレベルでの分布パターンによる空間の多様性(Spatial variation in local distribution patterns)⇒プロットレベルでわからないもの
- ✓ モザイク状のパッチを生み出す複数攪乱によって形成された森林(the clumped distribution pattern that results from heterogeneous distribution of safe site)