1

Your title small caps

par

Amaël Le Squin Université de Sherbrooke

Thèse présentée au Département de biologie en vue
de l'obtention du grade de docteur ès sciences (Ph.D.)

faculté des sciences
université de sherbrooke

Sherbrooke, Québec, Canada, juillet 2020

Le 11 juillet 2020

Le jury a accepté la thèse d'Amaël Le Squin dans sa version finale

Membre du jury

Professeur Dominique Gravel
Directeur de recherche
Département de biologie
Université de Sherbrooke

Professeure Isabelle Boulangeat
Codirectrice de recherche
IRSTEA

Professeur Prénom et nom
Évaluatrice ou Évaluateur externe
Département nom
Nom de l'institution

Professeure Prénom et nom
Évaluatrice ou Évaluateur interne
Département nom
Nom de l'institution

Professeure Prénom et nom
Président-rapporteur
Département de biologie
Université de Sherbrooke

SOMMAIRE

En français ici. La typographie française s'applique avec des espaces avant et après certaines ponctuations, Ah oui ? Test : oui ! Trop cool. La césure des mots se fera aussi selon les règles françaises.

Mots-clefs : Mot clef 1, 2, …

ABSTRACT

In english here.

Mots-clefs : Keyword 1, 2, ...

REMERCIEMENTS

L’auteur exprime ici sa reconnaissance pour la direction, la coopération et l’assistance qu’il a reçue pour son travail, notamment de la part de sa directrice ou son directeur de recherche et des organismes qui ont contribué au financement de ses études. On ne peut consacrer plus d’une page aux remerciements.

TABLE DES MATIÈRES

LISTE DES TABLEAUX

CHAPITRE 1

INTRODUCTION GÉNÉRALE

Qwerty (Goudriaan, 1986; Clark, 2003), Test if punctuation is following english rules! Ah yes? Ok no space...

1.1 Sec1

Lalala

1.1.1 Sec 1.1

Lalalala (Hutchinson, 1957, and also the beatles)

CHAPITRE 2

A great chapter about biology

2.1 Introduction

A common, although rarely tested, assumption in ecology is that a species is more likely to be found where it performs the best. In other words, species probability of occurrence across its range should be positively correlated to the per capita intrinsic growth rate (McGill, 2012). This hypothesis stems from the interpretation of Hutchinsonian niche theory (Hutchinson, 1957; Maguire, 1973), which poses that species are limited to locations where the environmental conditions (*i.e.,* any property outside of the considered organisms) allow a population to persist. At the core of species distribution models, this hypothesis is used to identify the climatic variables that are constraining species ranges, and their projection in the future allows to forecast potential range shifts.

This theory, in its more concise formulation, relates the population growth rate r to the species' niche: the hypervolume in the environmental factors space is the set such that $r \geqslant 0$ (Holt, 2009; Godsoe, Jankowski, Holt, & Gravel, 2017). Formally, let $r_i(\boldsymbol{E}, \boldsymbol{R})$ be the growth rate of a focal species i when rare, namely the intrinsic growth rate for a given environment $\boldsymbol{E}$ and amount of resources $\boldsymbol{R}$. The equation

$$r_i(\boldsymbol{E}, \boldsymbol{R}) \geqslant 0,$$

specifies that the fundamental niche corresponds to the locations where $\boldsymbol{E}$ and $\boldsymbol{R}$ allow positive growth.

2.2 References

Hutchinson, G. E. (1957). Concluding Remarks. *Cold Spring Harbor Symposia on Quantitative Biology*, *22*(0), 415–427.

Maguire, B. (1973). Niche Response Structure and the Analytical Potentials of Its Relationship to the Habitat. *The American Naturalist*, *107*(954), 213–246.

Holt, R. D. (2009). Bringing the Hutchinsonian niche into the 21st century: Ecological and evolutionary perspectives. *Proceedings of the National Academy of Sciences*, *106*(Supplement_2), 19659–19665.

McGill, B. J. (2012). Trees are rarely most abundant where they grow best. *Journal of Plant Ecology*, *5*(1), 46–51.

Godsoe, W., Jankowski, J., Holt, R. D., & Gravel, D. (2017). Integrating Biogeography with Contemporary Niche Theory. *Trends in Ecology & Evolution*, *33*(7), 159–167.

CHAPITRE 3

A great chapter

(Goudriaan, 1986; Strigul, Pristinski, Purves, Dushoff, & Pacala, 2008; Lucas, 2020)

3.1 References

Goudriaan, J. (1986). Boxcartain methods for modelling of ageing, development, delays and dispersion. In J. Metz & O. Diekmann (Eds.), *The dynamics of physiologically structured populations* (pp. 453–473).

Strigul, N., Pristinski, D., Purves, D., Dushoff, J., & Pacala, S. (2008). Scaling from trees to forests : tractable macroscopic equations for forest dynamics. *Ecological Monographs*, *78*(4), 523–545.

Lucas, T. C. (2020). A translucent box: interpretable machine learning in ecology. *Ecological Monographs*, ecm.1422.

CHAPITRE 4

Examples of nomenclature commands

In this section we adapt EBT to spatial PSPMs, with the space Γ discretised such that $\Gamma = \bigcup_k \gamma_k$. The growth speed of trees is G. Actually, I changed my mind and now G stands for the Galapagos Islands.

CHAPITRE 5

DISCUSSION GÉNÉRALE ET CONCLUSION

Qwerty

5.1 Sec1

Lalala

5.1.1 Sec 1.1

Lalalala (McDowell et al., 2020)

BIBLIOGRAPHIE

Hutchinson, G. E. (1957). Concluding Remarks. *Cold Spring Harbor Symposia on Quantitative Biology*, *22*(0), 415–427.

Goudriaan, J. (1986). Boxcartain methods for modelling of ageing, development, delays and dispersion. In J. Metz & O. Diekmann (Eds.), *The dynamics of physiologically structured populations* (pp. 453–473).

Clark, J. S. (2003). Uncertainty and variability in demography and population growth: a hierarchical approach. *Ecology*, *84*(6), 1370–1381.

Purves, D. W. (2009). The demography of range boundaries versus range cores in eastern US tree species. *Proceedings. Biological sciences / The Royal Society*, *276*(1661), 1477–1484.

McDowell, N. G., Allen, C. D., Anderson-Teixeira, K., Aukema, B. H., Bond-Lamberty, B., Chini, L., … Xu, C. (2020). Pervasive shifts in forest dynamics in a changing world. *Science (New York, N.Y.) 368*(6494).

ANNEXE A

Article 1

A.1 Derivation of the net reproduction rate R_0 and some of its properties

In this appendix, we derive the net reproduction rate $R_0(x, s^*)$ for a given location x and a canopy height s^*. Finally, we prove that $R_0(x, s^*)$ is a decreasing function of s^* which allows us to make our interpretation in the results section. We suppose that the dispersal kernel $\mathcal{K}$ is a Dirac, in other words, seeds emitted from x remain in their source patch x.

A.1.1 Derivation of R_0

We use the method of characteristics in equation (**??**). This method is commonly used in transport equations, like (**??**) describing the advection of trees at a non-constant speed G along the size axis. Characteristics allow us to follow individuals through their life, *i.e.,* they represent the trajectories of individuals in the time-size plan (fig. A.1.1 for an example). Our transport equation requires an initial population at time $t = 0$ that we denote by $\phi(s)$. It is the density of trees of size s at the beginning.

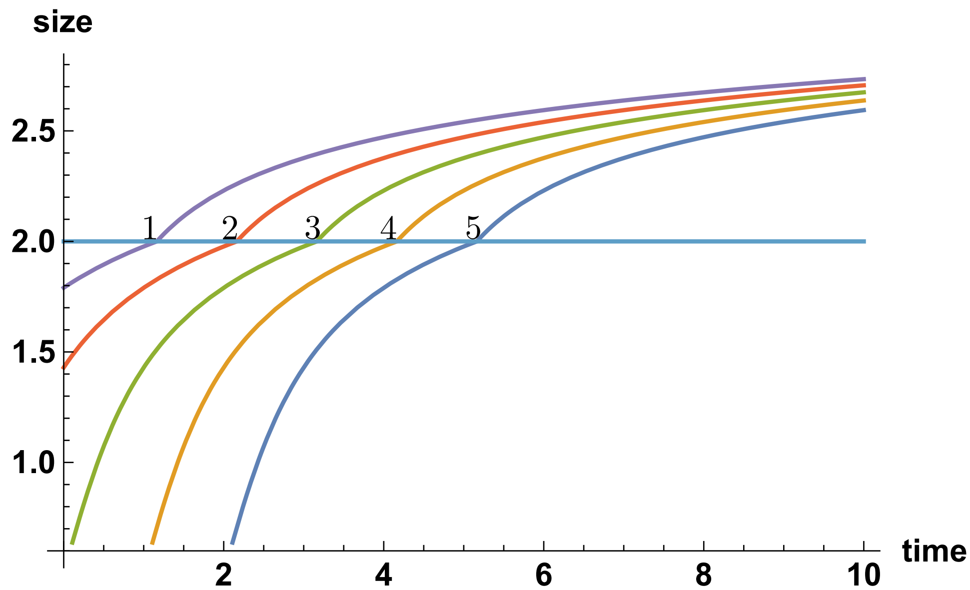

Figure A.1.1: Characteristics for a constant competition $s_c^* = 2$, a climatic constant $\xi_{x,i} = 1$, and for coefficients $\beta_0 = \ln(3)$, $\beta_1 = 1$ and $\beta_2 = -1$. These curves are parameterised by θ and allow us to follow a cohort with relative time θ

References

de Roos, A. M. (1997). A Gentle Introduction to Physiologically Structured Population Models. In S. Tuljapurkar & H. Caswell (Eds.), *Structured-population models in marine, terrestrial, and freshwater systems* (Chap. 5, pp. 119–204).

Purves, D. W., Lichstein, J. W., Strigul, N., & Pacala, S. W. (2008). Predicting and understanding forest dynamics using a simple tractable model. *Proceedings of the National Academy of Sciences of the United States of America*, *105*(44), 17018–22.

A.2 Proofs of the relations between Purves (2009) and our study

In this section, we first provide the assumptions concerning the demography in Drew W Purves (2009), and match our notations with Drew W Purves's article in the table A.1. Finally, we derive Drew W Purves (2009)'s formulæ from our R_0 equation (**??**).

Table A.1: Link between our notations and Drew W Purves (2009)'s notations. Note that Drew W Purves uses the flat-top version of the perfect-plasticity approximation, which implies the fecundity function to be proportional to the trunk area.

Meaning	**Our notation**	**Drew W Purves (2009)**
Species index	j, but mostly dropped	j
Space	x	R (not to be confound with R_0)
Time	t	τ
Threshold diameter	s^*, s_c^*	D^*
Net reprod. rate	$R_0(x, s_c^*)$	$R_{0,j,R}$
Indiv. growth rate overstorey	$G(s, s^*, x)$, $s \geqslant s^*$	$G_{L,j,R}$
Indiv. growth rate understorey	$G(s, s^*, x)$, $s < s^*$	$G_{D,j,R}$
Mortality rate overstorey	$\mu(s, s^*, x)$, $s \geqslant s^*$	$\mu_{L,j,R} = {}^{1}/_{\rho_{L,j,R}}$
Mortality rate understorey	$\mu(s, s^*, x)$, $s < s^*$	$\mu_{D,j,R} = {}^{1}/_{\rho_{D,j,R}}$
Fecundity function	$\mathcal{F}\mathscr{A}(s, s^*)$	$F_{j,R}^{\text{capita}} \pi s^2/4$

References

Purves, D. W. [Drew W.], Lichstein, J. W., Strigul, N., & Pacala, S. W. (2008). Predicting and understanding forest dynamics using a simple tractable model. *Proceedings of the National Academy of Sciences of the United States of America*, *105*(44), 17018–22.

Purves, D. W. [Drew W]. (2009). The demography of range boundaries versus range cores in eastern US tree species. *Proceedings. Biological sciences / The Royal Society*, *276*(1661), 1477–1484.

ANNEXE B

Article 2