Méthodes d'analyse des données de biodiversité

et indicateurs de biodiversité

Quelques approches de l'équipe Biodiversité d'Irstea Nogent

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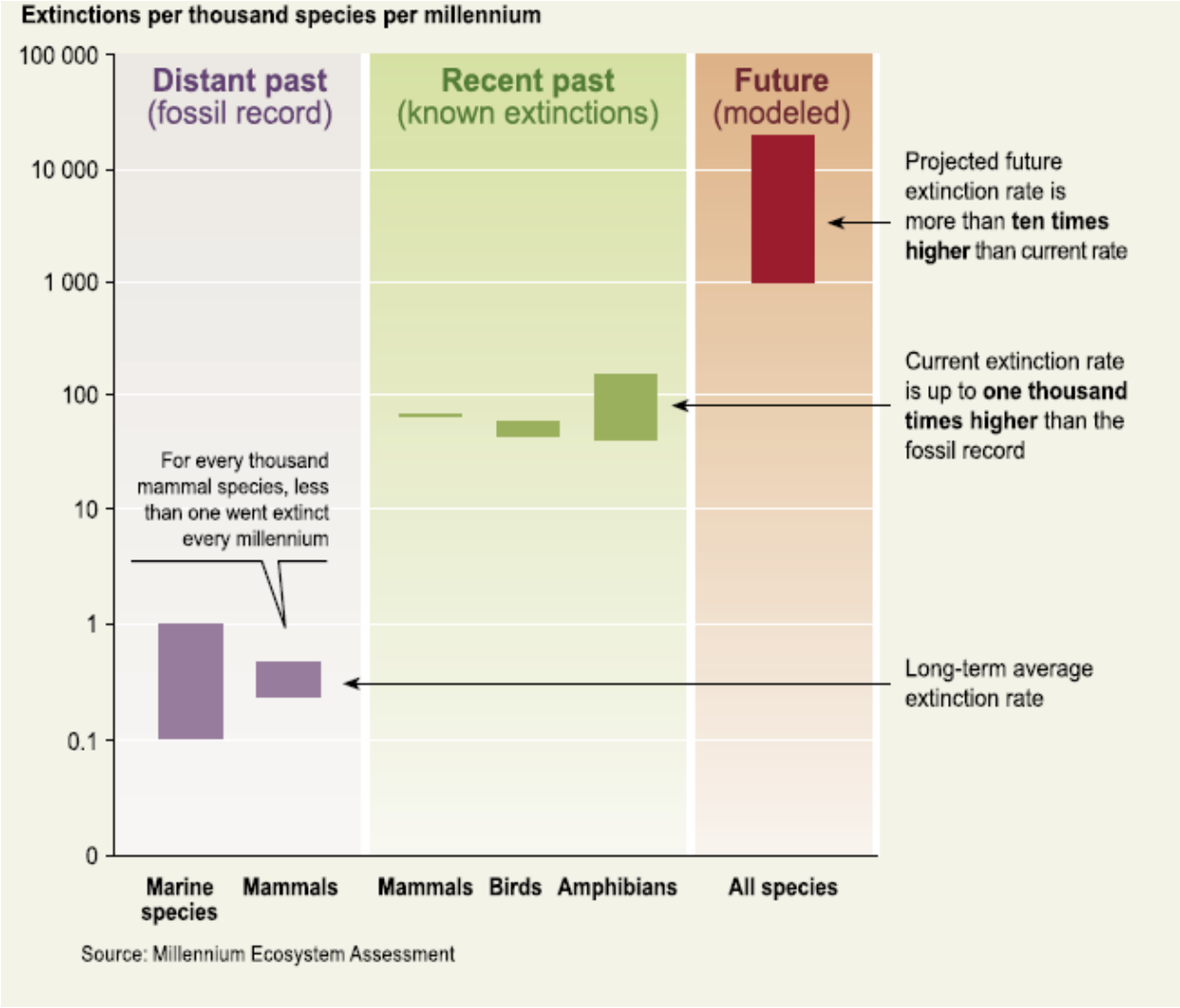
Contexte

* Engagement des sociétés contemporaines à enrayer la crise d’extinction d’espèces et d’érosion de la biodiversité (e.g. Convention internationale sur la biodiversité).

Le taux d'extinction actuel des espèces comme anormalement élevé



Contexte

* Des efforts pour produire, résumer et diffuser des **connaissances** et des **outils** servant à évaluer :

  – **l'Etat de la biodiversité**

  – les **Pressions** pesant sur la biodiversité et **Réponses** prises par la société

  ↳ ici: **gestion forestière et biodiversité interspécifique**

Les modèles statistiques paramétriques (MSP) : un outil de choix …

* Pour relier Pressions, Etats et Réponses, modéliser

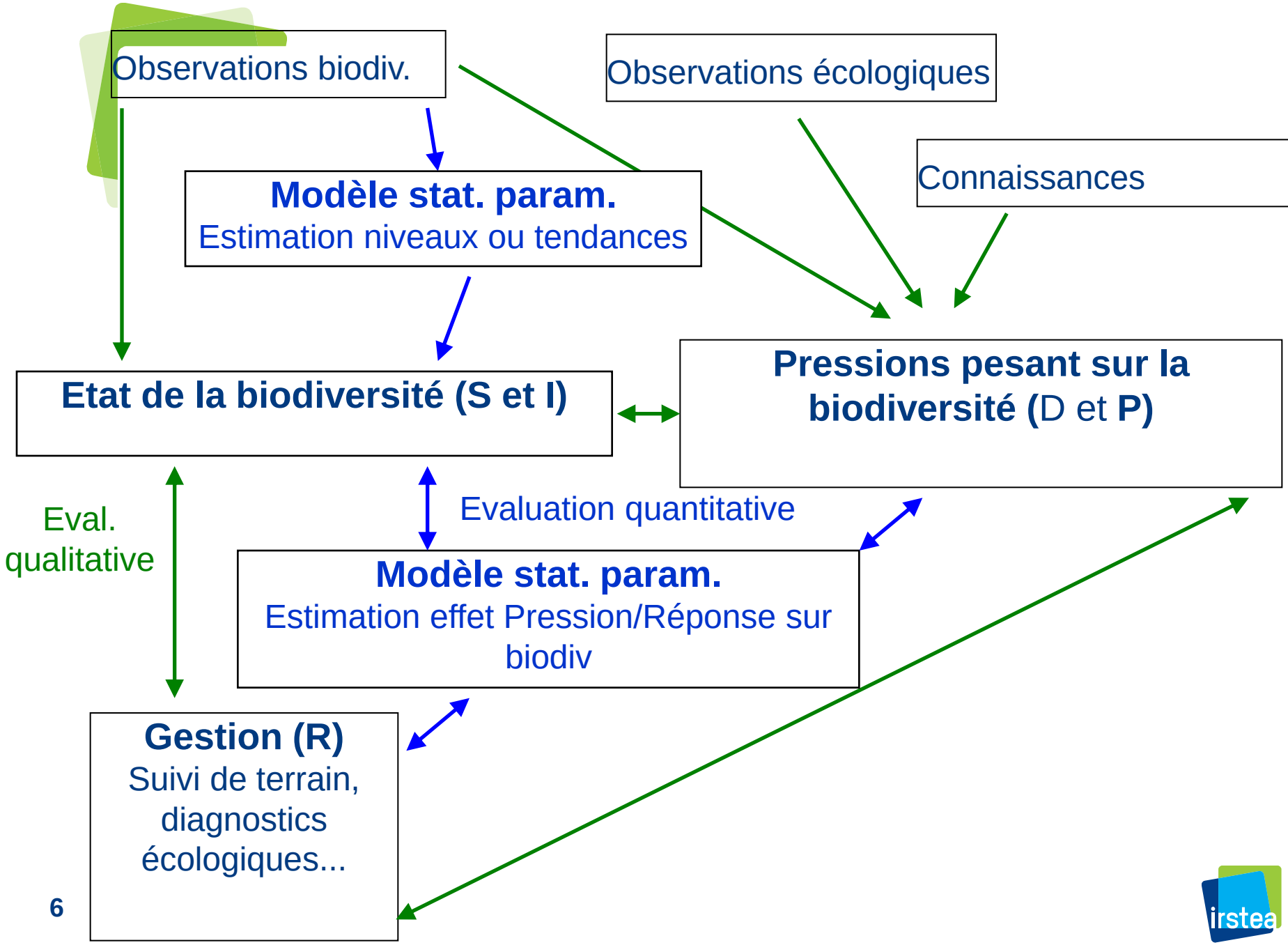
– l'abondance ou la présence d'**espèces** (herbacées, insectes…)

ou – l'abondance ou la richesse **de groupes d'espèces**

en fonction de

– variables temporelles, spatiales

– variables liées à la gestion forestière (ex: composition en essences…) ou à des politiques (Natura 2000, trame…)


Observations biodiv.
Observations écologiques
Connaissances
Modèle stat. param.
Estimation niveaux ou tendances
Etat de la biodiversité (S et I)
Pressions pesant sur la biodiversité (D et P)
Eval. qualitative
Evaluation quantitative
Modèle stat. param.
Estimation effet Pression/Réponse sur biodiv
Gestion (R)
Suivi de terrain, diagnostics écologiques...

Grands axes utilisation des MSP

1 – Relations indicateurs de Pression/Réponse et Etats de biodiversité

Barbier, S., Chevalier, R., Loussot, P., Bergès, L., & Gosselin, F. (2009) Improving biodiversity indicators of sustainable forest management: tree genus abundance rather than tree genus richness and dominance for understory vegetation in French lowland oak hornbeam forests. *Forest Ecology and Management*, **258**, pp. S176-S186.

Bouget, C., Nusillard, B., Pineau, X., & Ricou, C., Charles (2012) Effect of deadwood position on saproxylic beetles in temperate forests and conservation interest of oak snags. *INSECT CONSERVATION AND DIVERSITY*, **5**, pp. 264-278.

Bouget, C., Larrieu, L., Nusillard, B., & Parmain, G. (2013) In search of the best local habitat drivers for saproxylic beetle diversity in temperate deciduous forests. *Biodiversity and Conservation*, **22**, pp. 2111-2130.

Brin, A., Bouget, C., Brustel, H., & Jactel, H. (2011) Diameter of downed woody debris does matter for saproxylic beetle assemblages in temperate oak and pine forests. *Journal of Insect Conservation*, **15**, pp. 653-669.

Toigo, M., Paillet, Y., Noblecourt, T., Soldati, F., Gosselin, F., & Dauffy-Richard, E. (2013) Does forest management abandonment matter more than habitat characteristics for ground beetles?. *Biological Conservation* , **157**, pp. 215-224.

Bouget, C., Larrieu, L., & Brin, A. (2014) Key features for saproxylic beetle diversity derived from rapid habitat assessment in temperate forests. *Ecological Indicators*, **36**, pp. 656-664.

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Zilliox, C. & Gosselin, F. (2014) Tree species diversity and abundance as indicators of understory diversity in French mountain forests: Variations of the relationship in geographical and ecological space. *Forest Ecology and Management*, **321**, pp. 105-116.

Bouvet, A., Paillet, Y., Archaux, F., Tillon, L., Denis, P., Gilg, O., & Gosselin, F. (2016) Effects of forest structure, management and landscape on bird and bat communities. *Environmental Conservation*, **43**, pp. 148-160.

Grands axes utilisation des MSP

2 – Variations indicateurs

Vuidot, A., Paillet, Y., Archaux, F., & Gosselin, F. (2011) Influence of tree characteristics and forest management on tree microhabitats in France. *Biological Conservation*, **144**, pp. 441-450.

Regnery, B., Paillet, Y., Couvet, D., & Kerbiriou, C. (2013) Which factors influence the occurrence and density of tree microhabitats in Mediterranean oak forests?. *FOREST ECOLOGY AND MANAGEMENT*, **295**, pp. 118-125.

Larrieu, L., Cabanettes, A., Gonin, P., Lachat, T., Paillet, Winter, Bouget, C., & Deconchat, M. (2014) Deadwood and tree microhabitat dynamics in unharvested temperate mountain mixed forests: A life-cycle approach to biodiversity monitoring. *Forest Ecology and Management*, **334**, pp. 163-173.

Redon, M., S. Luque, Gosselin F. & T. Cordonnier. (2014). Is generalisation of uneven-aged management in mountain forests the key to improve biodiversity conservation within forest landscape mosaics? *Annals of Forest Science*. 71, 751-760.

Paillet, Y., Pernot, C., Boulanger, V., Debaive, N., Fuhr, M., Gilg, O., and Gosselin, F. (2015) Quantifying the recovery of old-growth attributes in forest reserves: A first reference for France. *Forest Ecology and Management* **346**:51-64. doi:10.1016/j.foreco.2015.02.037.

Paillet, Y., Archaux, F., Boulanger, V., Debaive, N., Fuhr, M., Gosselin, F., & Guilbert, E. (2017) Snags and large trees drive higher tree microhabitat densities in strict forest reserves. *Forest Ecology and Management*.

Grands axes utilisation des MSP

3 – Relevés biodiversité (effets observateurs, temps…)

Paillet, Y., Coutadeur, P., Vuidot, A., Archaux, F. & Gosselin, F. (2015) Strong observer effects on tree microhabitats inventories : a case study in a French lowland forest. *Ecological Indicators*, 49:14-23.

Archaux F., Gosselin F., Bergès L. et Chevalier R., 2006, Effects of sampling time, quadrat richness and observer on exhaustiveness of plant censuses, *Journal of Vegetation Science*, 17, p. 299-306.

Archaux, F., Camaret, S., Dupouey, J.-L. , Ulrich, E., Corcket, E., Bourjot, L., Brêthes, A., Chevalier, R., Dobremez, J.-F. , Dumas, Y., Dumé, G., Forêt, M., Forgeard, F., Lebret Gallet, M., Picard, J.-F. , Richard, F., Savoie, J., Seytre, L., & Timbal (2009) Can we reliably estimate species richness with large plots? an assessment through calibration training. *Plant Ecology*, **203**, pp. 303-315.

Archaux, F., Henry, P.Y., & Gimenez, O. (2012) When can we ignore the problem of imperfect detection in comparative studies?. *Methods in Ecology and Evolution*, **3**, pp. 188-194.

(…)

Choix d'utilisation des MSP

1 – Magnitude des relations

Barbier, S., Chevalier, R., Loussot, P., Bergès, L., & Gosselin, F. (2009) Improving biodiversity indicators of sustainable forest management: tree genus abundance rather than tree genus richness and dominance for understory vegetation in French lowland oak hornbeam forests. *Forest Ecology and Management*, **258**, pp. S176-S186.

Zilliox, C. & Gosselin, F. 2014. Tree species diversity and abundance as indicators of understory diversity in French mountain forests: Variations of the relationship in geographical and ecological space. *Forest Ecology and Management*, 321, 105-116.

Wei, L, A. Villemey, F. Hulin, I. Bilger, Y. Dumas, R. Chevalier, F. Archaux & F. Gosselin (2015). Plant diversity on skid trails in oak high forests: a matter of disturbance, micro-environmental conditions or forest age? *Forest Ecology and Management*. 338:20-31.

Wei, L., F. Hulin, R. Chevalier, F. Archaux and F. Gosselin (2016). Is plant diversity on tractor trails more influenced by disturbance than by soil characteristics? *Forest Ecology & Management*, **379**:173-184

Wei, L., Chevalier, R., Archaux, F. & Gosselin, F. (2015) Influence of stand attributes and skid trail area on stand-scale ground flora diversity. *Canadian Journal of Forest Research*. **45**:1816-1826.

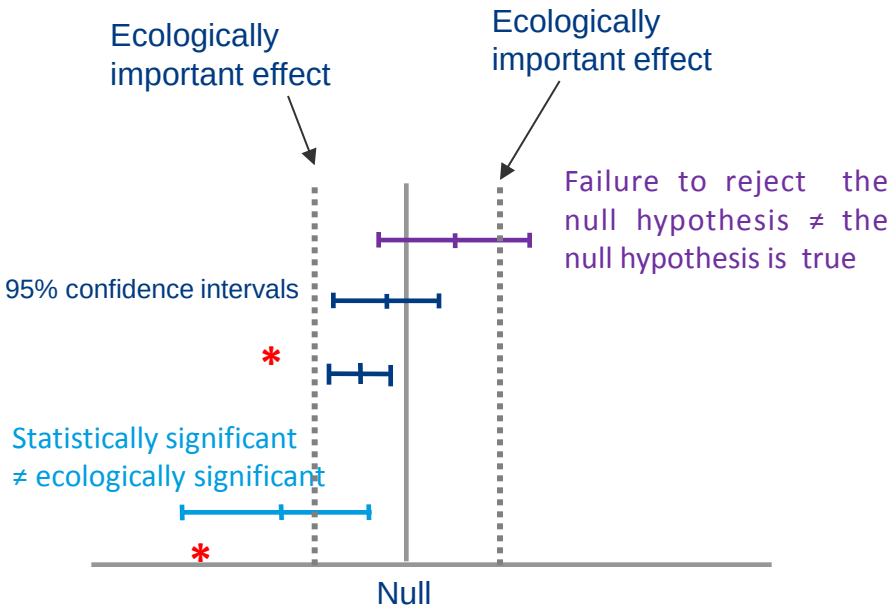
2- Integrated modelling/state space models

Picard, M., Papaïx, J., Gosselin, F., Picot, D., Bideau, E., & Baltzinger, C. (2015) Temporal dynamics of seed excretion by wild ungulates: Implications for plant dispersal. *Ecology and Evolution*, **5**, pp. 2621-2632.

Campagne, C.S., Roche, P., Gosselin, F., Tschanz, L., & Tatoni, T. (2017) Expert based Ecosystem Services capacity matrices: dealing with variability of scoring. *Revised version submitted*.

Negligibility analysis

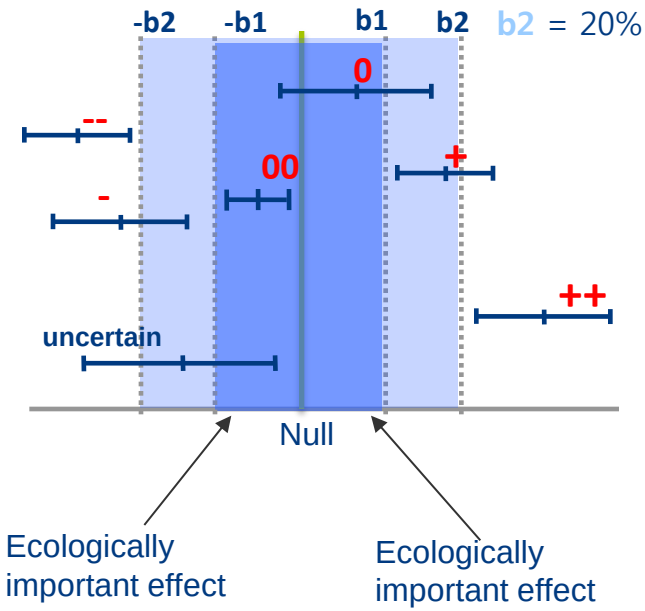
To know whether a given variation of an explanatory variable implies a negligible
or
non-negligible variation of the mean of species richness with 95% probability.



Statistical significance test

weak (b1) negligibility intervals
Strong (b2) negligibility intervals (0 < b1 < b2)

For species richness
b1 = 10% (weak change)
b2 = 20% (strong change)



Wei (2014)

Correspondance entre négligeabilité et significativité de l'effet de 7 indicateurs

	Effet non-significatif	Effet significatif
Effet négligeable	**18**	**1**
Pas assez d'info.	**15**	**2**
Effet non-négligeable	**-**	**6**

Barbier et al. (2009), *For. Ecol. Manage.*

Exemple

Relation entre le couvert du sapin et la richesse spécifique de groupes écologiques *(associés à la lumière)* des plantes vasculaires **dépend fortement des conditions écologiques** *(ici: pente et orientation)*

log du multiplicateur de la RS moyenne avec +15% de couvert de sapin

	Herbacées			Ligneuses	
	HL☼	IL☼/✹	LL✹	HL☼	IL☼/✹
Terrains plats	-0.142 [-0.206; -0.0806] 0**	0.0275 [-0.0165; 0.0719] 00	0.0933 [0.0381; 0.145] 0**	-0.0282 [-0.0581; 0.000448] 00	-0.0556 [-0.116; 0.00857] 0
Orientation E/W	-0.249 [-0.395; -0.103] -**	-0.0117 [-0.113; 0.079] 00	0.158 [0.0489; 0.268] **	0.047 [-0.0138; 0.117] 0	-0.0458 [-0.193; 0.109] 0
Orientation S	0.04 [-0.24; 0.321]	0.206 [0.0124; 0.386] *	0.42 [0.197; 0.658] ++**	0.163 [0.0281; 0.296] *	0.2 [-0.105; 0.526]
Orientation N	-0.538 [-0.707; -0.368] --**	-0.229 [-0.353; -0.11] -**	-0.104 [-0.253; 0.0317]	-0.0687 [-0.155; 0.0165] 0	-0.291 [-0.482; -0.101] -

HL: high light; IL: intermediate light; LL: low light

Zilliox & Gosselin (2014) *FEM*

Développements/tests méthodes des MSP

1 – Distributions de probabilité

↳ distributions de comptage sous-dispersées

Definition and units	Mean	Variance
Species Richness of Forest Bryophytes	10.1	3.4
Species Richness of Forest Herbs	4.0	4.7
Species Richness of Peri-Forest Herbs	3.0	8.1
Species Richness of Non-Forest Herbs	2.1	7.2
Species Richness of Forest Woody species	4.7	3.1
Species Richness of Peri-Forest Woody species	4.6	3.9

Barbier et al. (2009) Forest Ecol. Manage.

Distributions de comptage sous-dispersées

- Littérature: très peu de distributions de comptage sous-dispersées compatibles avec une utilisation en régression. Une exception: la *Comway-Maxwell-Poisson corrigée* (CMP2, Huang 2017, Statistical Model.)

  ☒ Limites CMP2: très lourde numériquement, trop lourde en Bayésien.

- Développement de *nouvelles distributions*, plus légères numériquement.

  ⇨ Test en cours pas simulation

Barbier et al. (2009) Forest Ecol. Manage.,

Gosselin (2011) HDR, Gosselin et al. (In Prep.)

Développements/tests méthodes des MSP

1 – Distributions de probabilité

↳ distributions pour données d'abondance en classes

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Analyzing plant cover class data quantitatively: Customized zero-inflated cumulative beta distributions show promising results

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ABSTRACT

Although parametric statistical methods have several advantages over ordination methods, understory plant cover class data are traditionally more often analyzed with ordination techniques than with parametric ones. Among the latter, only the cumulative logit model can take into account all the peculiarities of cover data: bounded between 0 and 100%, asymmetric classes, high proportion of zeroes. However, results provided by the cumulative logit model are difficult to interpret. We tested ten Bayesian models based on a zero-inflated cumulative beta probability distribution which is bounded, can assume various shapes and accounts for zeroes. Some of these models also make results easier to interpret by allowing the user to directly estimate the mean and variance of data underlying cover class observations, much as in generalized linear models (GLMs). We applied our new models and the cumulative logit model to real data, then compared their performance using the Deviance Information Criterion (DIC) and sampled posterior *p*-values.

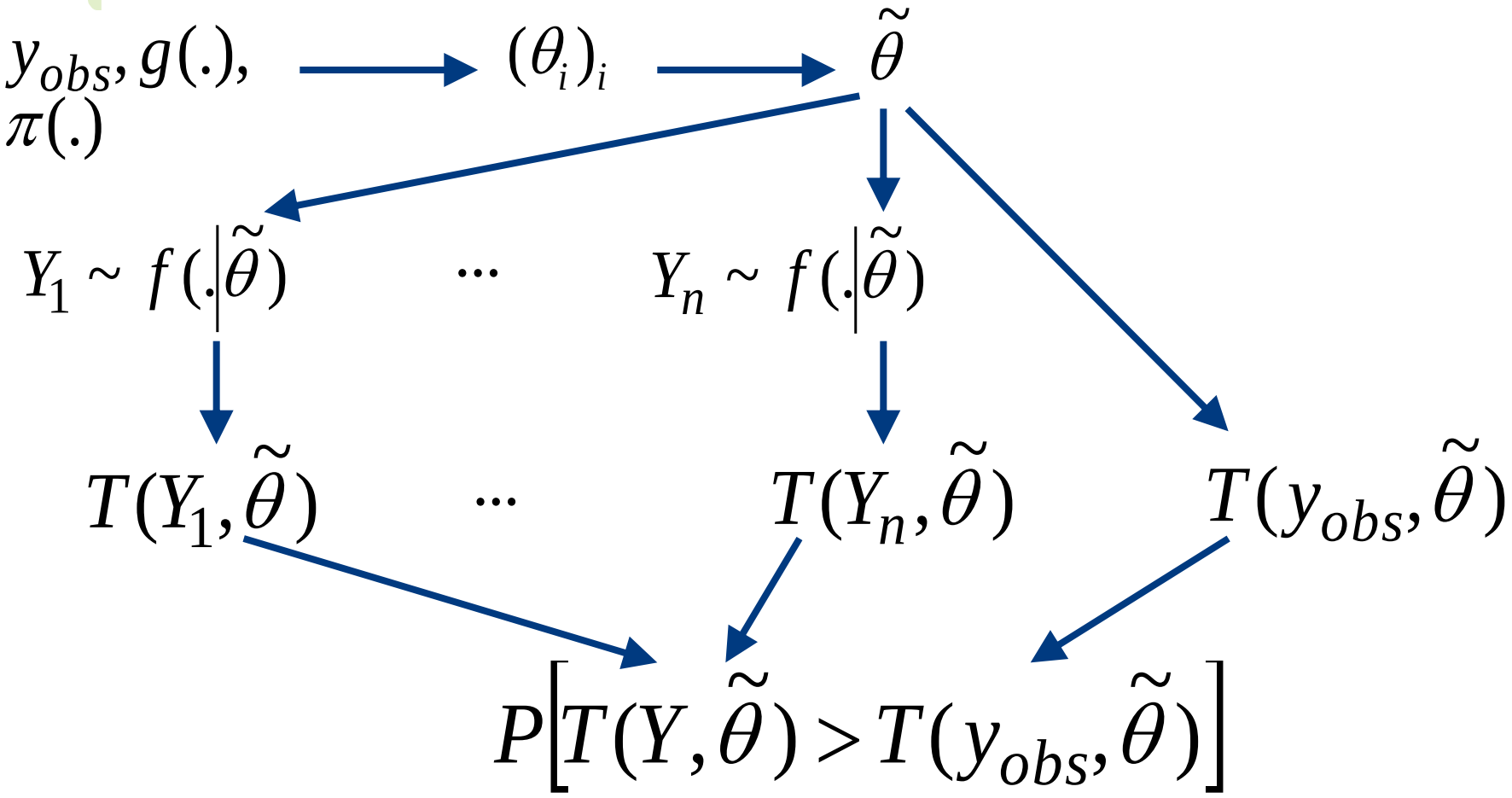
Four of the Bayesian beta models performed better (lower DIC), as well or rarely worse (depending on species) than the cumulative logit model and showed an ease of interpretation similar to that of GLMs. They therefore provide promising alternatives to existing parametric methods for modeling plant cover class data.

Développements/tests méthodes des MSP

2 – Outils pour jauger la qualité d'ajustement

- Critique des modèles dans le cadre des « internal goodness-of-fit p-values »
- Pas d'outil général dont la valeur est facilement interprétable (distribution de référence non connue sauf sur des cas particuliers) (Robins et al. 2000 JASA)
- Proposition d'une nouvelle méthode à distribution de référence connue asymptotiquement (Gosselin 2011 Plos One)

La « sampled posterior p-value » (Gosselin, 2011)



Résultats de simulation

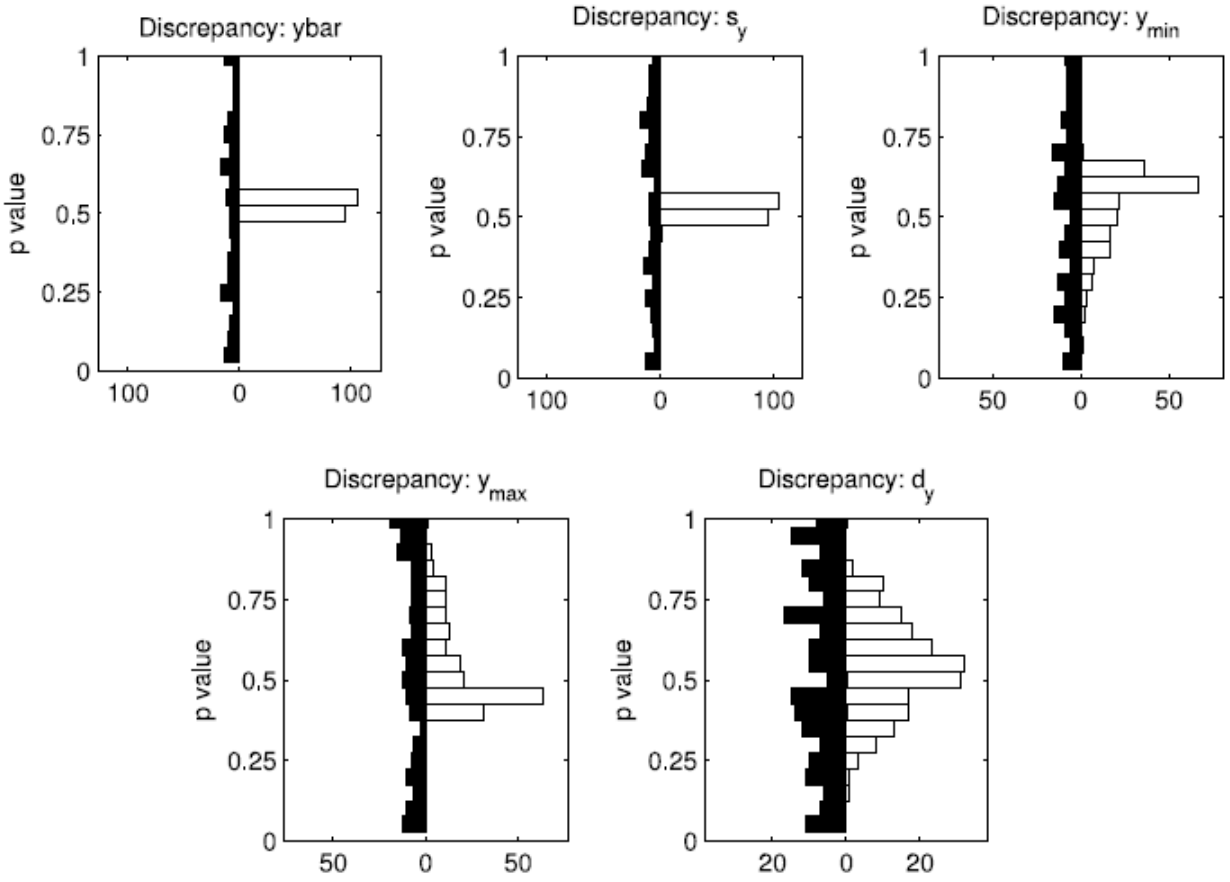
* Exemple issu de Zhang (2014) *Comput. Stat. Data Anal*.

* Mêmes modèles hiérarchiques double-gaussiens que Sinharay & Stern (2003)

* Diagnostique des données observées (avec différentes fonctions de discrépance)

* Autres exemples dans Gosselin (2011)

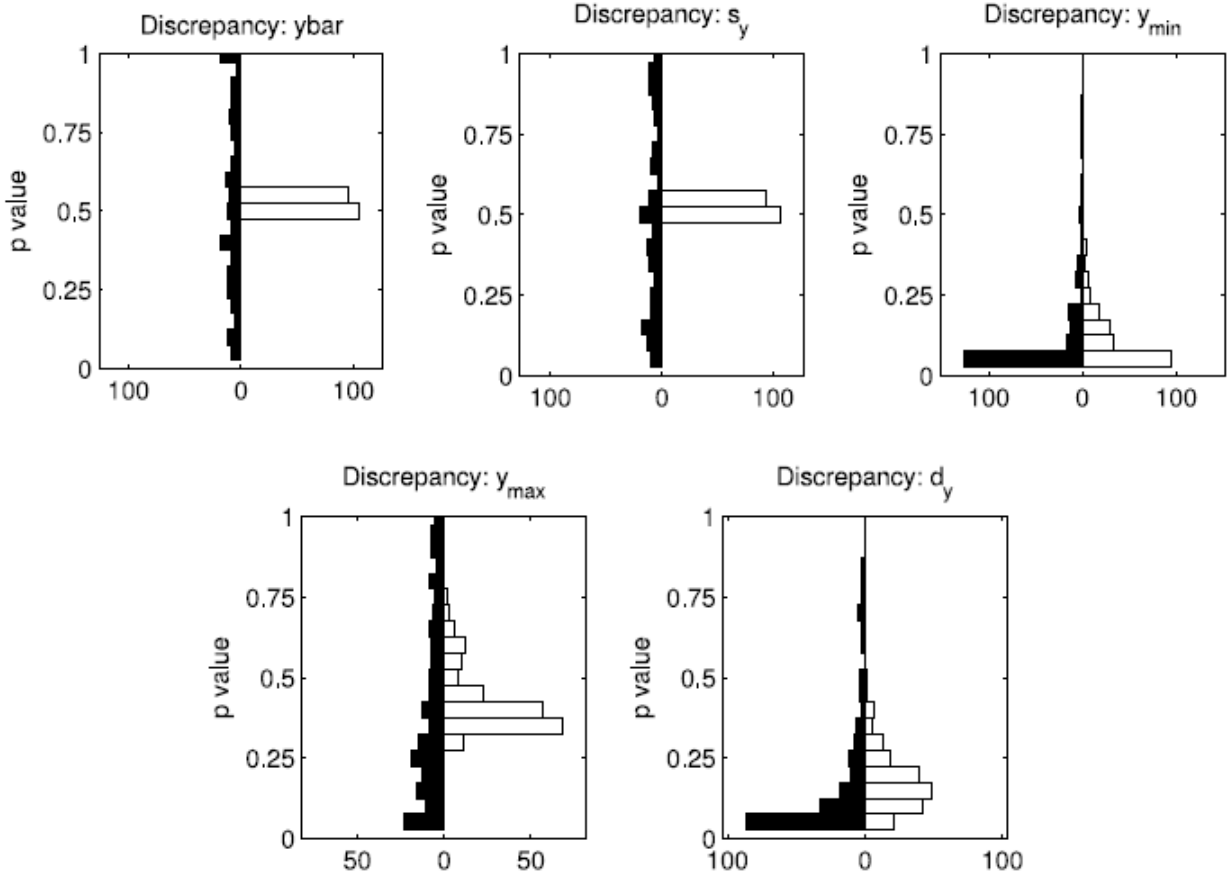
Bonne vraisemblance



Sampled posterior → spp ppp ← Posterior predictive

Zhang (2014) *CSDA*

Mauvaise vraisemblance



Sampled posterior → spp ppp ← Posterior predictive

Zhang (2014) *CSDA*

Développements/tests méthodes des MSP

3 – Amélioration/test/critiques de méthodes

Ecography 37: 476–489, 2014
doi: 10.1111/j.1600-0587.2013.00279.x

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Comparison of regression methods for spatially-autocorrelated count data on regularly- and irregularly-spaced locations

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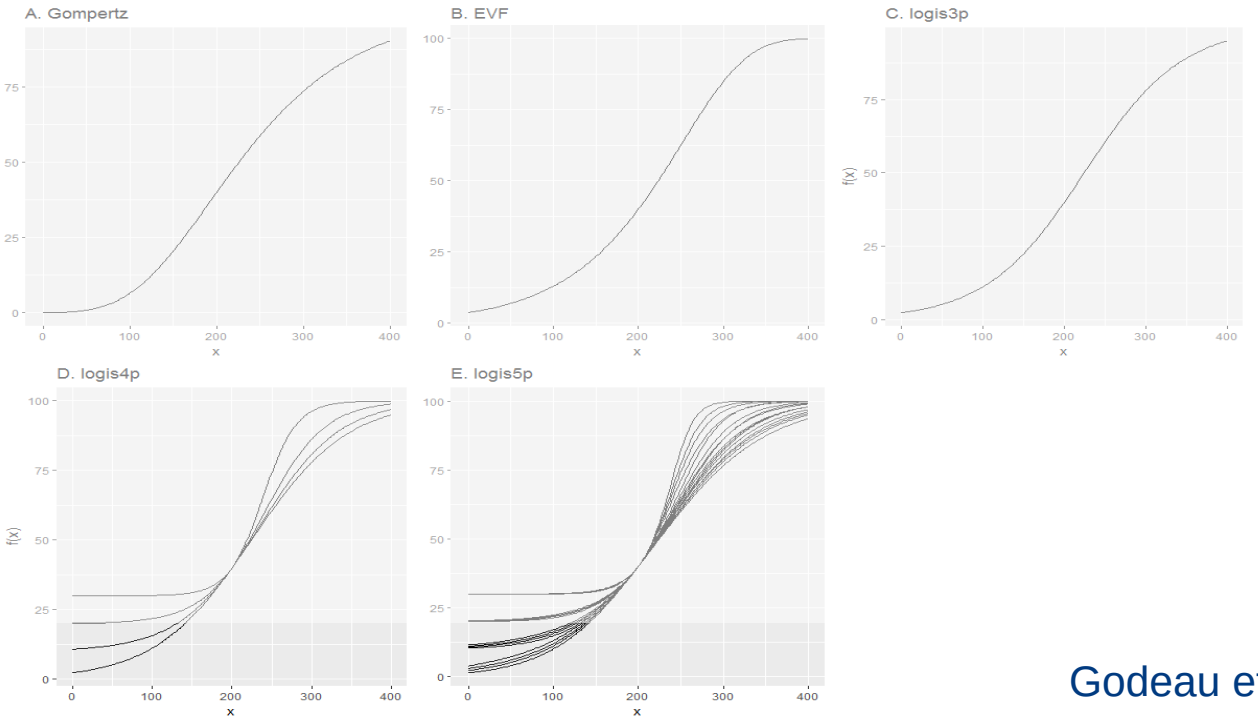
Perspectives (MSP)

1 – Relations non-linéaires

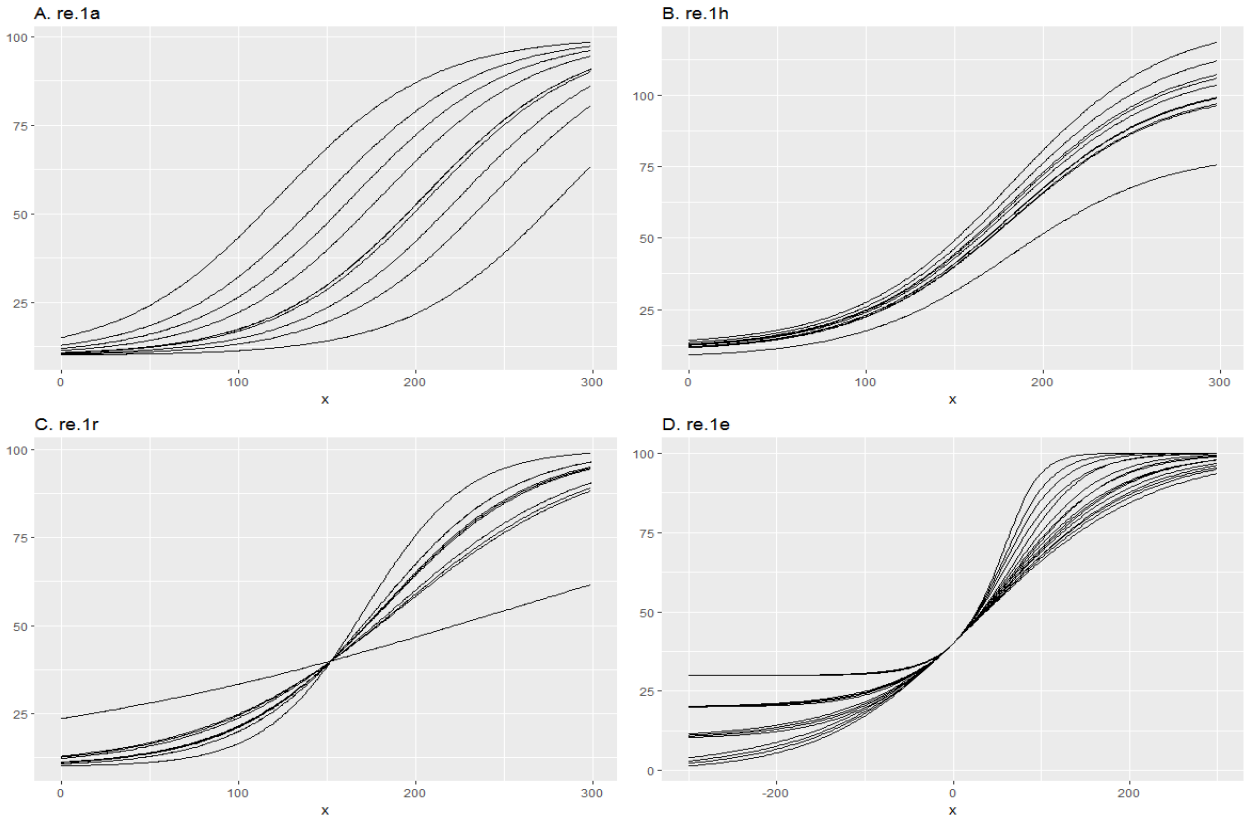
But: Enrichir la gamme des possibles (formes sigmoides…)



Godeau et al. (In Prep.)

Relations non-linéaires

But: Permettre/estimer des variations spatiales non-linéaires



Godeau et al.
(In Prep.)

Relations non-linéaires

Avec des impacts en termes de **GOF** et sur l'estimation de la **magnitude des relations**

*Effet d'ajouter 9,8 m3/ha de **volume de gros bois mort** (plus de 47,5 cm de diamètre) sur la moyenne de…*

	… Richesse spécifique des champignons lignicoles menacés	**… Richesse spécifique des bryophytes forestières**
Avec une forme linéaire généralisée	x 1,12 [1,05;1,2]	x 1,05 [1,03; 1,07]
Avec une forme "seuil" (sigmoide discontinue)	x 4,62 [2,1; 11,7]	x 1,82 [1,54; 2,15]

from Gosselin et al. (2017) Rendez-vous techniques ONF

Perspectives (MSP)

2 – Joint species modelling

But: modéliser la biodiversité de manière hiérarchique en partageant de l'information entre espèces

Suite thèse E. Dauffy-Richard (2004)
Thèse Ugoline Godeau (2016-2019)
Projet ANR NGBM puis Gambas (2nde phase 2017 & 2018)

Difficultés numériques probables si on veut garder des MSP souples (Bayésien: trop lent; Fréquentiste (TMB): instable)

Perspectives (MSP et au-delà)

3 – Métriques de biodiversité

But: aller plus loin que les métriques classiques (Richesse, Diversité, Equitabilité, Trait moyen…) en intégrant davantage l'abondance absolue

Lié à:

Gosselin, F. 2001. Lorenz partial order: the best known logical framework to define evenness indices. *Community Ecology* **2**(2):197-207**.**

Gosselin, F. (2012) Improving Approaches to the Analysis of Functional and Taxonomic Biotic Homogenization: beyond Mean Specialization. *Journal of Ecology*, **100**, pp. 1289-1295.

Gosselin, F. (2016) Putting floristic thermophilization in forests into a conservation biology perspective: beyond mean trait approaches. *Annals of Forest Science*. **73**:215-218

Un grand merci pour votre invitation et votre attention.

Des questions?