Dynamics and Persistence of populations in riparian corridors

Dynamique et persistance des populations dans le corridor rivulaire

Van Looy Kris, Piffady Jérémy

Irstea, Milieux aquatiques, écologie et pollutions (UR MALY) - Site web
3 bis quai Chauveau - CP 220, F-69336 Lyon - France
Kris.van-looy@irstea.fr, Jeremy.piffady@irstea.fr

RÉSUMÉ

La connectivité des corridors fluviaux est fortement touchée par les altérations physiques. La persistance des populations d'espèces rivulaires vient à risque alors. L'association de la quantité et la qualité de l'habitat avec la dynamique du paysage et de la résistance aux perturbations anthropiques est encore mal comprise dans le cadre du processus de survie et de la colonisation des espèces, mais essentielles pour prioriser les actions de conservation et de restauration. Nous présentons une approche de modélisation qui met en évidence la connectivité dans le contexte spatial et temporel pour identifier les corridors vitaux et des priorités de conservation dans la Loire et ses principaux affluents. Un cadre de modélisation dynamique de la métapopulation est appliqué pour intégrer la dynamique fluviale et la connectivité du corridor. La dynamique naturelle du cours d'eau peut être confrontée à des altérations physiques dans cette modélisation et traduite dans la persistance de la population. L'altération des régimes de crues et de flux en général est censée être primordiale à la dynamique des populations dans les écosystèmes rivulaires. Pourtant, on sait peu des seuils critiques d'altération. Nous avons appliqué la modélisation de métapopulation pour deux espèces d'arbre. D'un côté, une espèce avec une dispersion limitée, l'Orme lisse; et une espèce limitée par le recrutement, le Peuplier noir. Identifier la persistance des métapopulations pour les deux essences sur les grandes rivières dans le bassin de la Loire souligne l'influence de la connectivité aux risques d'extinction et permets d'identifier les corridors prioritaires en ce qui concerne la qualité de l'habitat et de la connectivité.

ABSTRACT

Connectivity of river corridors is highly impacted by physical alterations posing risks to population persistence and restoration. The association of habitat quality and quantity with the landscape dynamics and resilience to human-induced disturbances is still poorly understood in the context of species survival and colonization processes, but essential to prioritize conservation and restoration actions. We present a modelling approach that elucidates network connectivity in spatial and temporal context to identify vital corridors and conservation priorities in the Loire river and its major tributaries. A dynamic population modelling framework is applied to integrate river landscape dynamics and network connectivity. Natural dynamics of the river landscape can be confronted with physical alterations in such models and translated in population persistence. Alteration of flooding and flow regimes is believed to be critical to population dynamics in river ecosystems. Still, little is known of critical levels of alteration both spatially and temporally. We applied metapopulation modelling approaches for a dispersal-limited tree species, white elm; and a recruitment-limited tree species, black poplar. Identifying metapopulation persistence for the two tree species over the larger rivers in the basin highlights crucial connections and network structure influence to extinction risks in relation to habitat quality and connectivity.

MOTS CLES

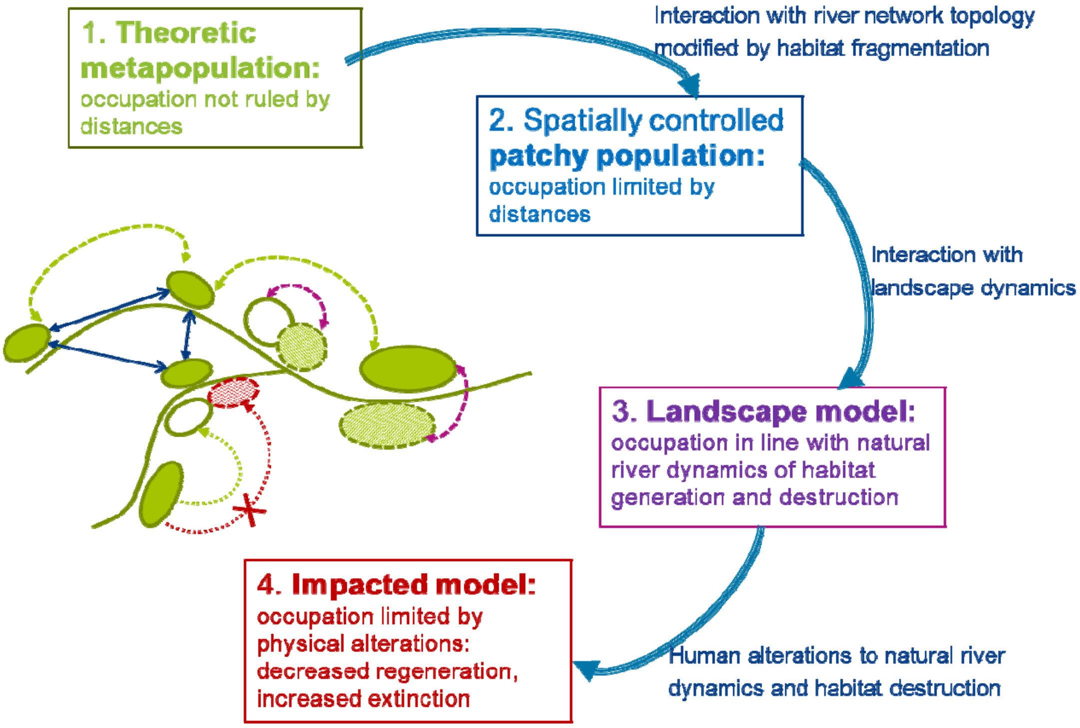
Flow alteration, fragmentation, hydromorphology, metapopulation models, resilience

1 METAPOPULATION MODELLING FRAMEWORK

Connectivity of river corridors is highly impacted by physical alterations posing risks to population persistence and restoration. The association of habitat quality and quantity with the landscape dynamics and resilience to human-induced disturbances is still poorly understood in the context of species survival and colonization processes, but essential to prioritize conservation and restoration actions. We present a modelling approach that elucidates these aspects of network connectivity in spatial and temporal context to identify vital corridors and conservation priorities in the Loire river and its major tributaries. A dynamic population modelling framework is used to bring population dynamics in relation to river landscape dynamics and network connectivity. Natural dynamics (resilience) of the river landscape can be confronted with physical alterations in such models and measured in population persistence. Disconnection and alteration of flooding and flow regimes is believed to be critical to population dynamics in river ecosystems. Still, little is known of critical levels of alteration both spatially as temporally, or the role of the river landscape resilience in this.

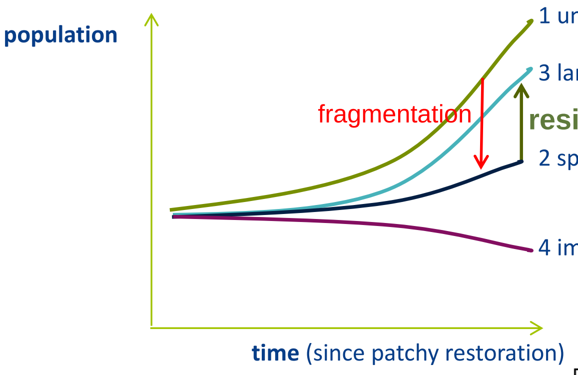
We applied metapopulation modelling approaches to population dynamics for a dispersal-limited tree species, white elm; and a recruitment-limited tree species, black poplar. The links with landscape dynamics are explicit in metapopulation models as they integrate the spatio-temporal dynamics of habitats and populations in river networks. Identifying metapopulation persistence for the two tree species over the larger rivers in the basin highlights crucial connections and network structure influence to extinction risks in relation to habitat quality and connectivity.

We construct contrasting metapopulation scenarios starting from the two model species, and three model types: connectivity-ruled or seed-rain model, landscape dynamics model (integrating habitat creation and destruction additionally) or stable habitat model, alterations model versus undisturbed.



The models grow in complexity to answer the questions 1) what role river network connectivity plays, 2) what role river dynamics play and 3) what role alterations play.

The first step is to integrate connectivity in the metapopulation model. Therefore, with inclusion of a connectivity factor, the model must additionally be adjusted to whether or not extinction or colonization depends on occupancy patterns. The simplest model assumes that colonization and extinction are constant. More specifically, this means that the number of occupied patches does not affect the number of colonization events in the metapopulation, which is the signature of external colonization. We hereafter refer to this as the propagule rain model.



1 unconstrained growth

2 spatially controlled

3 landscape dynamics

4 impacted river

1 intrinsic growth

with a carrying capacity K $K = 1 - \frac{e}{c}$

and growth rate $r = c - e$.

with c: regeneration rate and e: extinction risk

2 connectivity colonisation rate $c_i = c \times IIC_i$

extinction rate: $e_i = e / (IIC_i + 1)$

3 landscape dynamics

patch occupation P: $1 - (D + e / G + c)$

G: habitat generation, D habitat destruction

4 impacted river

c_n = c (probability physical alteration)

Black poplar regeneration rate: c: 0,8
(high seed rain/dispersal by wind, water)
extinction rate e: 0.5 (high turnover)

White elm: c: 0.2 , e: 0.1

2 MODEL PARAMETERS

As to carrying capacity for our dispersal limited species (Ulmus laevis), apart from the alteration risk factor, we suppose all habitat in optimal condition and equilibrium with all patches occupied (local abundance = carrying capacity). As to population dynamics, local carrying capacity temporal change (colonization rates) will be lower for this species due to lower regenerative and productive strategies. For the recruitment limited species (Populus nigra) the carrying capacity needs corrections both for alteration risk and for connectivity. In our metapopulation model, patch area is used as an estimate of the local population carrying capacity (Ovaskainen & Hanski 2004)). This way, here we can use river segment's riparian forest area as a surrogate for local carrying capacity. Patches in the network nodes differ between the species models: Ulmus floodplain forest patches, Populus riparian forest patches (higher dynamics). Extinction rates between 0.50 and 0.29, and colonization rates between 0.14 and 0.53 were recorded for an annual species of dynamic river banks, with annual habitat generation dynamics (Honnay *et al.* 2009). For our forest species and their habitat, we look for habitat generation periodicities of 10 years (channel forming discharge) as modeling time step.

We are able to distinguish in the model between the traditional spatial aspects (areas and distances, connectivity and fragmentation) and the landscape (river) dynamics and its alterations.

BIBLIOGRAPHIE

Honnay, O., Jacquemyn, H., Van Looy, K., Vandepitte, K. and Breyne, P. (2009). Temporal and spatial genetic variation in a metapopulation of the annual Erysimum cheiranthoides on stony river banks. *Journal of Ecology*, 97, 131-141.

Ovaskainen, O. and Hanski, I. (2004). From individual behavior to metapopulation dynamics: Unifying the patchy population and classic metapopulation models. *American Naturalist*, 164, 364-377.