



MetaEcoServ

Le concept de métaécosystème pour comprendre la distribution des services écosystémiques dans les hydrosystèmes

Consortium Biosefair 2021-2024

Co-animé par A. Jeliaskov (HYCAR), T. Datry (RiverLy) & A. Truchy (SLU / RiverLy)

Concept de métaécosystème

Ecology Letters, (2003) 6: 673–679

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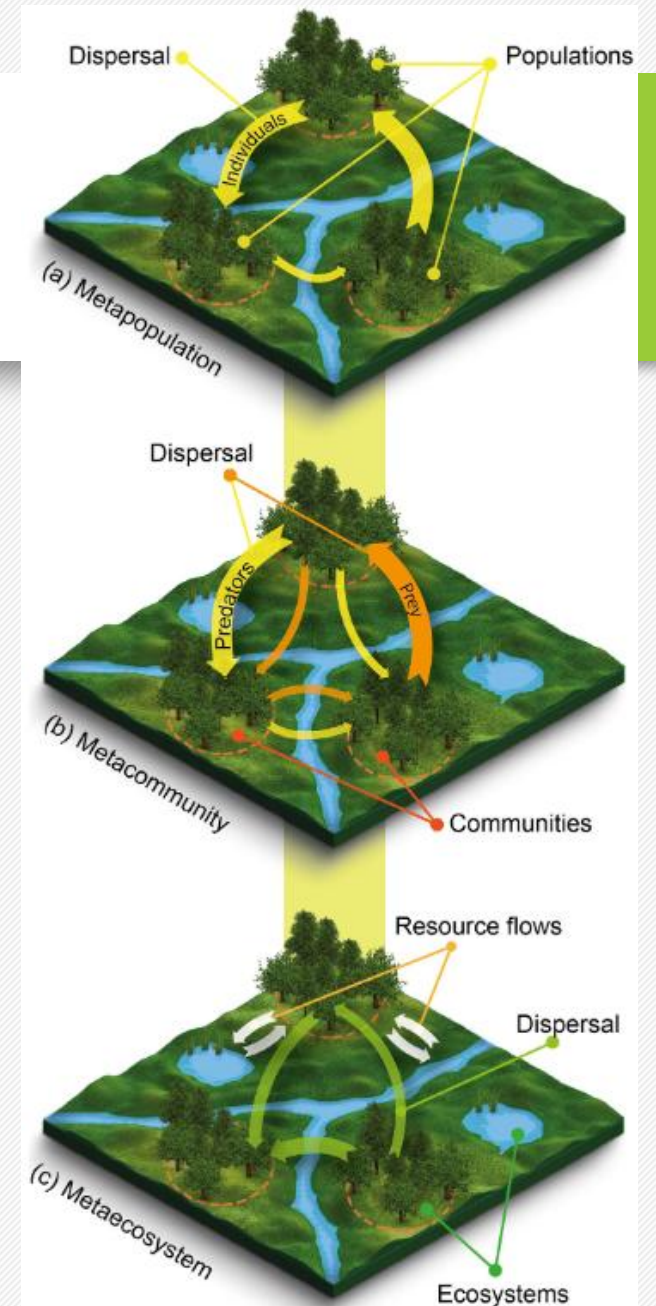
IDEAS AND PERSPECTIVES

Meta-ecosystems: a theoretical framework for a spatial ecosystem ecology

Abstract

This contribution proposes the meta-ecosystem concept as a natural extension of the metapopulation and metacommunity concepts. A meta-ecosystem is defined as a set of ecosystems connected by spatial flows of energy, materials and organisms across ecosystem boundaries. This concept provides a powerful theoretical tool to understand the emergent properties that arise from spatial coupling of local ecosystems, such as global source–sink constraints, diversity–productivity patterns, stabilization of ecosystem processes and indirect interactions at landscape or regional scales. The meta-ecosystem perspective thereby has the potential to integrate the perspectives of community and landscape ecology, to provide novel fundamental insights into the dynamics and functioning of ecosystems from local to global scales, and to increase our ability to predict the consequences of land-use changes on biodiversity and the provision of ecosystem services to human societies.

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Essays and Perspectives

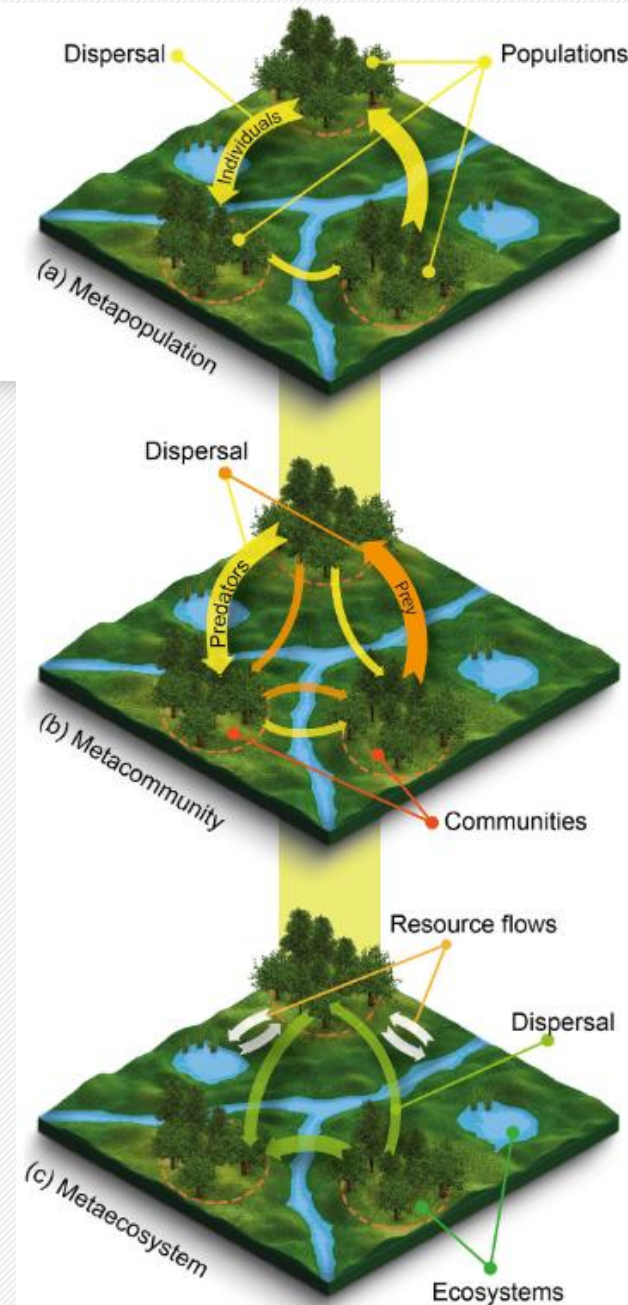
Towards an applied metaecology^{*,**}

Luis Schiesari^{a,*}, Miguel G. Matias^b, Paulo Inácio Prado^c, Mathew A. Leibold^d, Cecile H. Albert^e,
 Jennifer G. Howeth^f, Shawn J. Leroux^g, Renata Pardini^c, Tadeu Siqueira^h, Pedro H.S. Brancalionⁱ,
 Mar Cabeza^j, Renato Mendes Coutinho^k, José Alexandre Felizola Diniz-Filho^l, Bertrand Fournier^m,
 Daniel J.G. Lahr^c, Thomas M. Lewinsohnⁿ, Ayana Martins^o, Carla Morsello^a, Pedro R. Peres-Neto^m,
 Valério D. Pillar^p, Diego P. Vázquez^q

3 caractéristiques importantes pour appliquer le concept de métaécosystème :

- La structure spatiale de l'environnement (hétérogénéité)
- La connectivité (flux de transfert)
- Les mécanismes locaux (émergence de propriétés à plus large échelle)

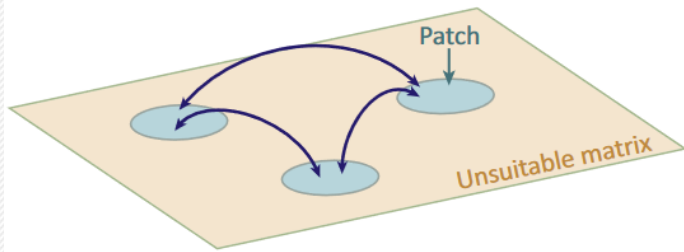
← 3 exemples de cas d'étude où l'application du concept s'est avérée utile pour une espèce ou un (dis)service donné



De la mutiplicité des métaécosystèmes...



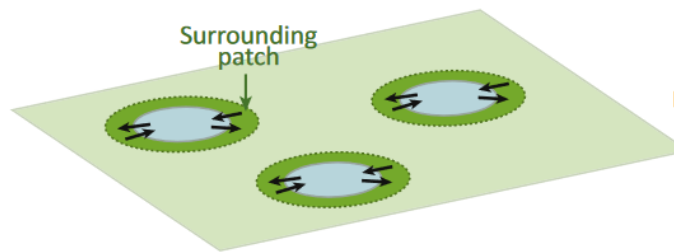
(A) Dispersal-based meta-ecosystem



Metacommunity-like dynamics
similar ecosystems
same species

Examples:
networks of
ponds, lakes,
or islands

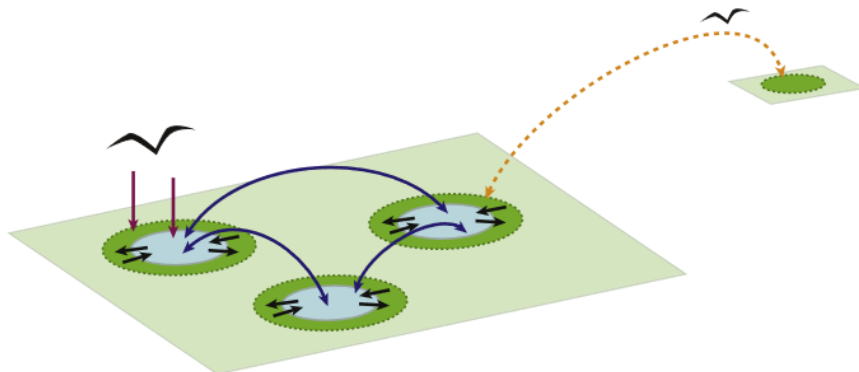
(B) Resource-flow based meta-ecosystem



Resource exchanges dynamics
dissimilar ecosystems
different species or stages

Examples:
couplings at
freshwater-riparian,
ocean-coastal,
benthic-pelagic
interfaces

(C) Spatial scale integration

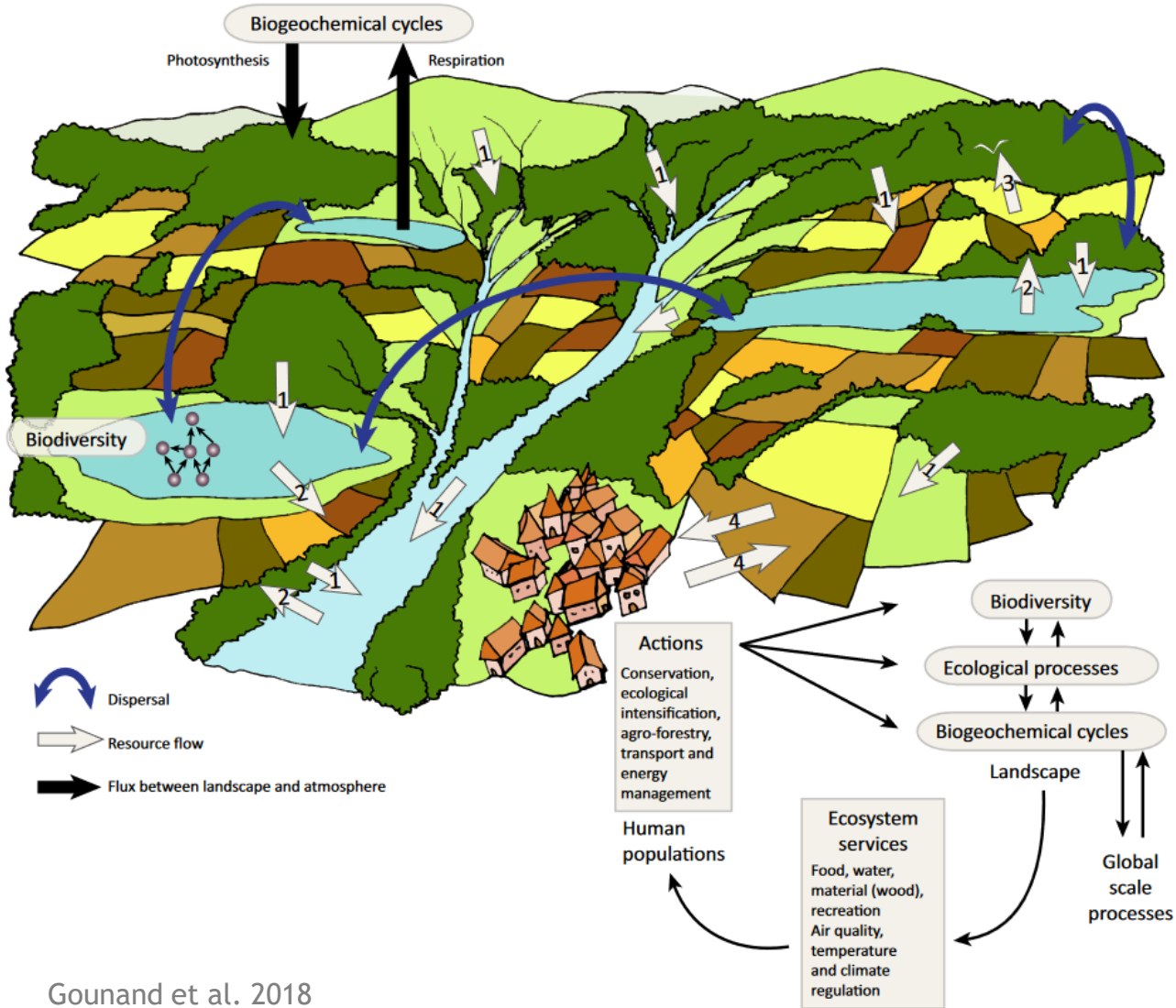


- Dispersal
- Resource flows
- Foraging
- Seasonal migration

Meta-Ecosystems 2.0: Rooting the Theory into the Field

Isabelle Gounand,^{1,2,*} Eric Harvey,^{1,2} Chelsea J. Little,^{1,2} and Florian Altermatt^{1,2}

... aux services écosystémiques



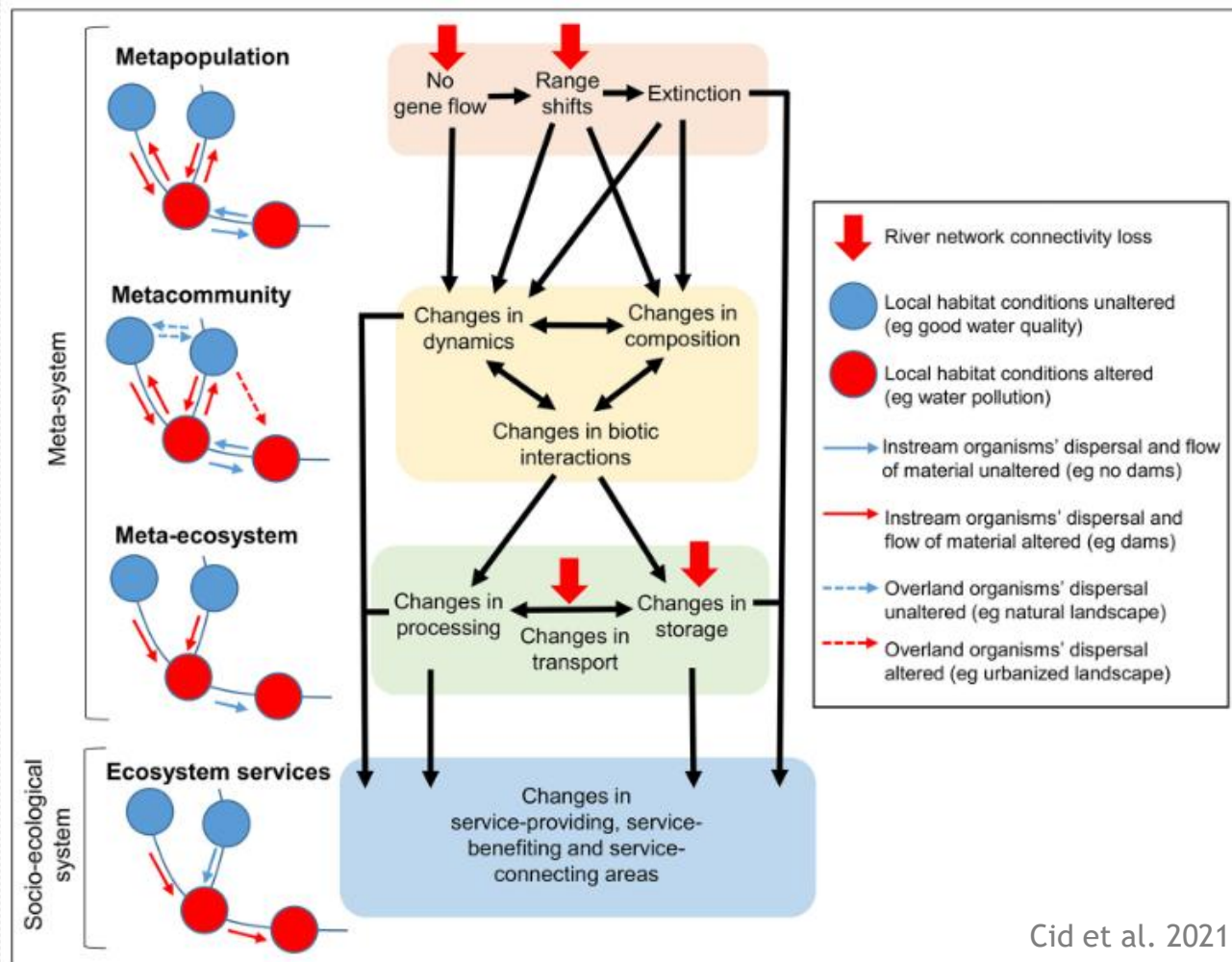
Gounand et al. 2018

Meta-Ecosystems 2.0: Rooting the Theory into the Field

Isabelle Gounand,^{1,2,*} Eric Harvey,^{1,2} Chelsea J. Little,^{1,2} and Florian Altermatt^{1,2}

From meta-system theory to the sustainable management of rivers in the Anthropocene

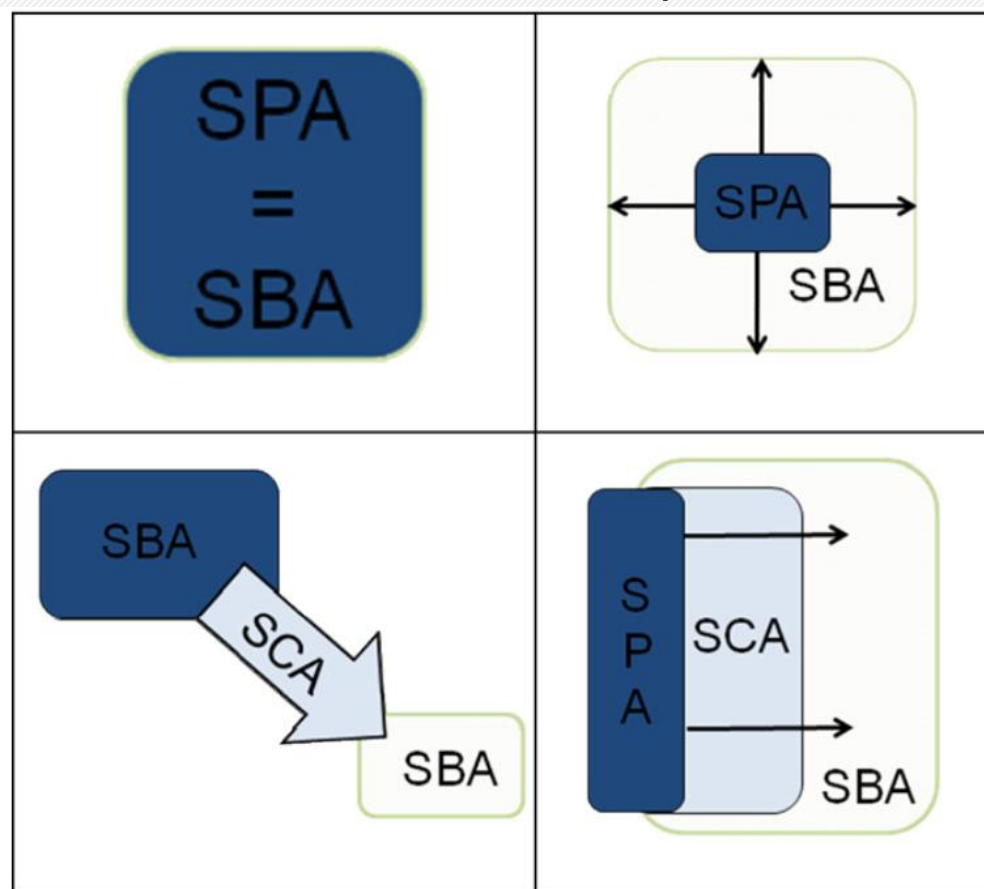
Núria Cid^{1*}, Tibor Erős², Jani Heino³, Gabriel Singer⁴, Sonja C Jähnig^{5,6}, Miguel Cañedo-Argüelles^{7,8}, Núria Bonada^{7,9}, Romain Sarremejane¹, Heikki Mykrä³, Leonard Sandin¹⁰, Riikka Paloniemi¹¹, Liisa Varumo¹¹, and Thibault Datry¹



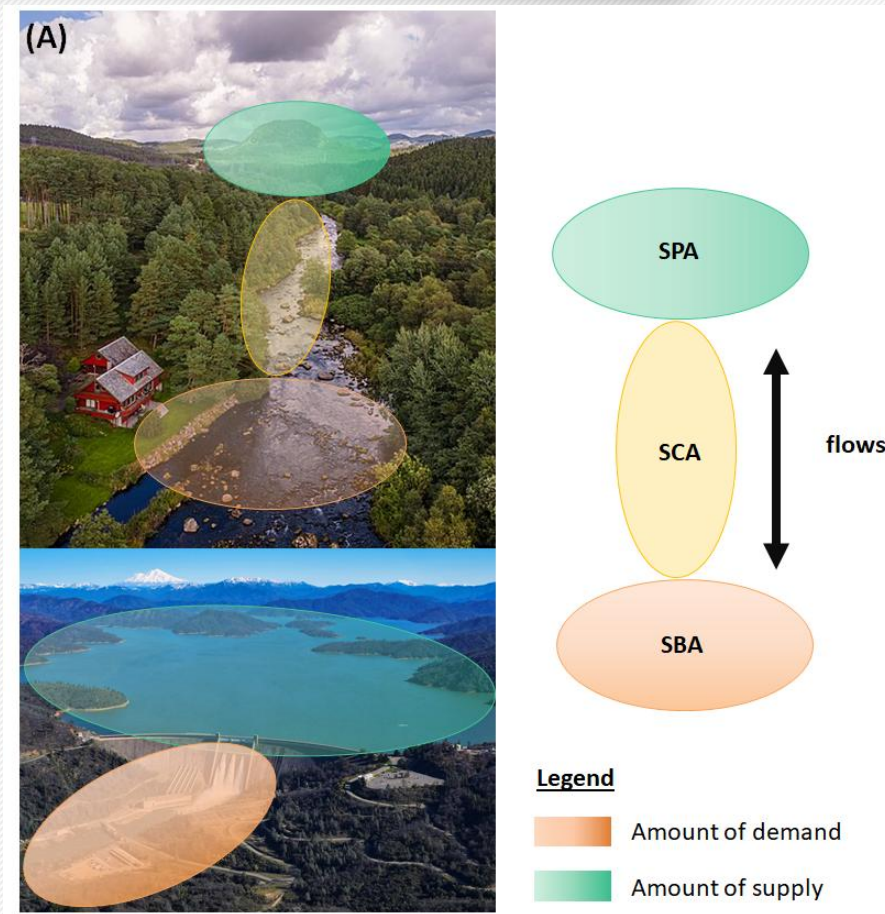
Spatial indicators for the assessment of ecosystem services: Providing, benefiting and connecting areas and landscape metrics

Ralf-Uwe Syrbe*, Ulrich Walz

service provision chain



Syrbe & Walz 2012 after Fischer et al. 2009



Truchy et al. 2025

Compléments de connaissances à apporter

- Focus sur les hydrosystèmes en général
- Liens explicites et empiriques entre processus méta et dynamiques des ES
- Dynamiques spatio-temporelles des ES
- Exemples concrets d'application sur hydrosystèmes
- Agenda de recherche : futures questions à investiguer

Integrating metaecosystem framework with ecosystem service dynamics in sociohydrocosystems

Amélie Truchy ^{1,2,*}, David Eme ¹, Franck Jabot ³, Fabrice Vinatier ⁴, Aurélien Jamoneau ⁵, Eric J. Petit ⁶, Bertrand Villeneuve ⁵, Laure Carassou ⁵, Thibault Datry ^{1,†} and Alienor Jeliaskov ^{7,†}

Article d'opinion

Introduction

The spatiotemporal template of socio-hydrocosystems as meta-ecosystems

Coupling the meta-ecosystem framework and the ecosystem service chain to understand ES maintenance and delivery in SHS

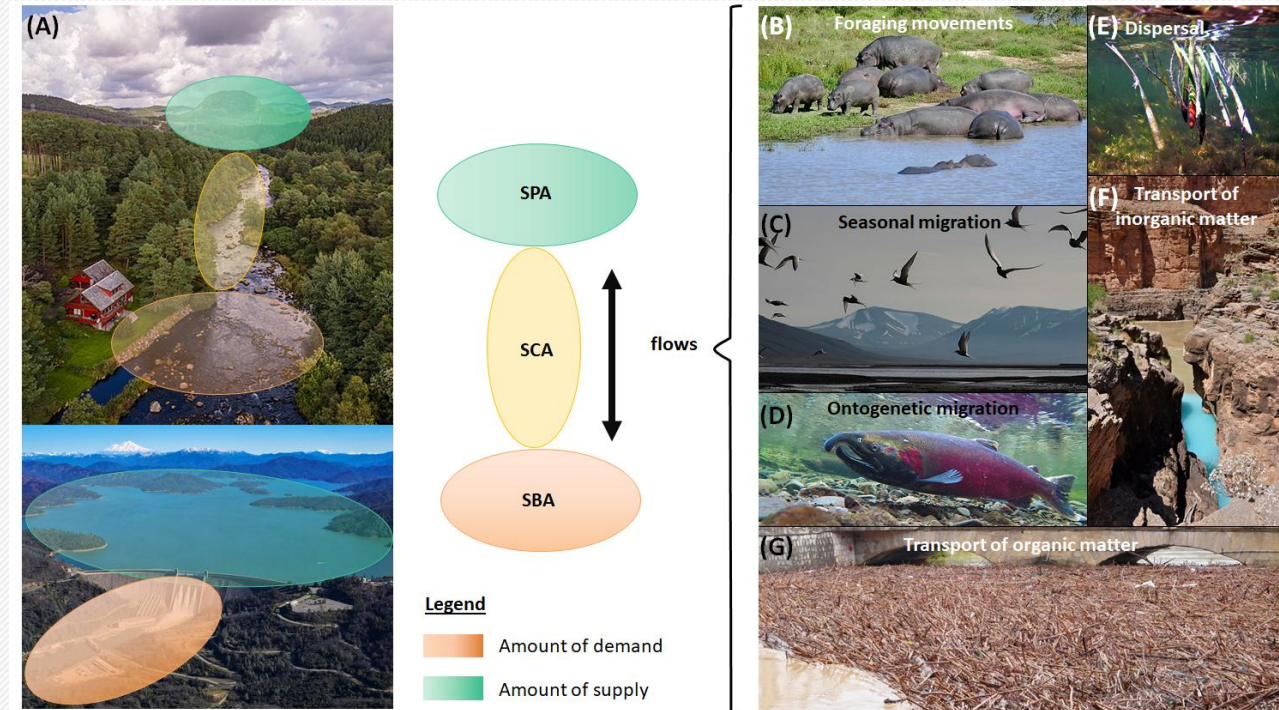
1. ES driven by organisms' movement (disp, migr, forag, etc.)
2. ES driven by flows of energy and matter

Implications of an ES meta-ecosystem approach for socio-hydrocosystem management (→ 3 exemples de gestion centrés sur les socio-HS)

1. Tidal connectivity restoration & large-scale benefits to nekton communities
2. NBS for mitigating water pollution
3. Pacific Salmon return & ES portfolios

Future research directions for developing a metasytem approach for ES management

1. Conceptual challenges
2. Methodological and technical challenges
3. Epistemological challenges



Integrating metaecosystem framework with ecosystem service dynamics in sociohydrocosystems

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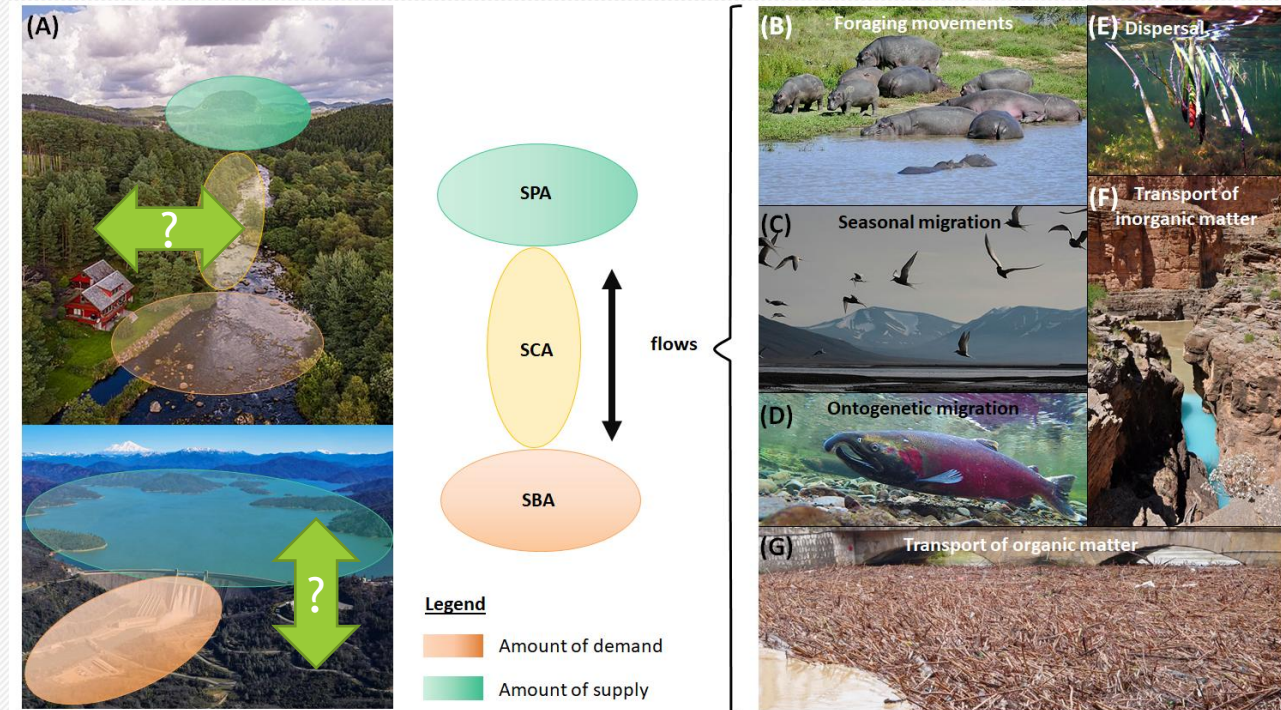
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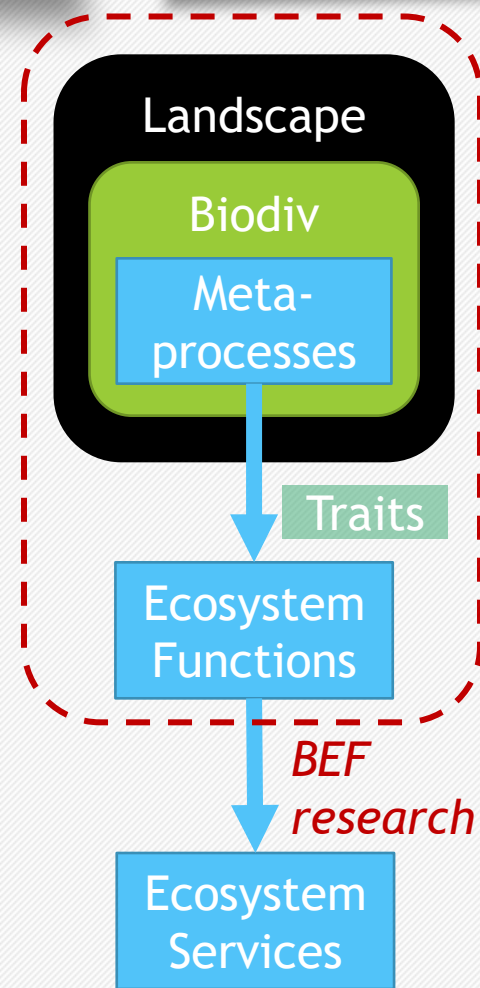
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What next?

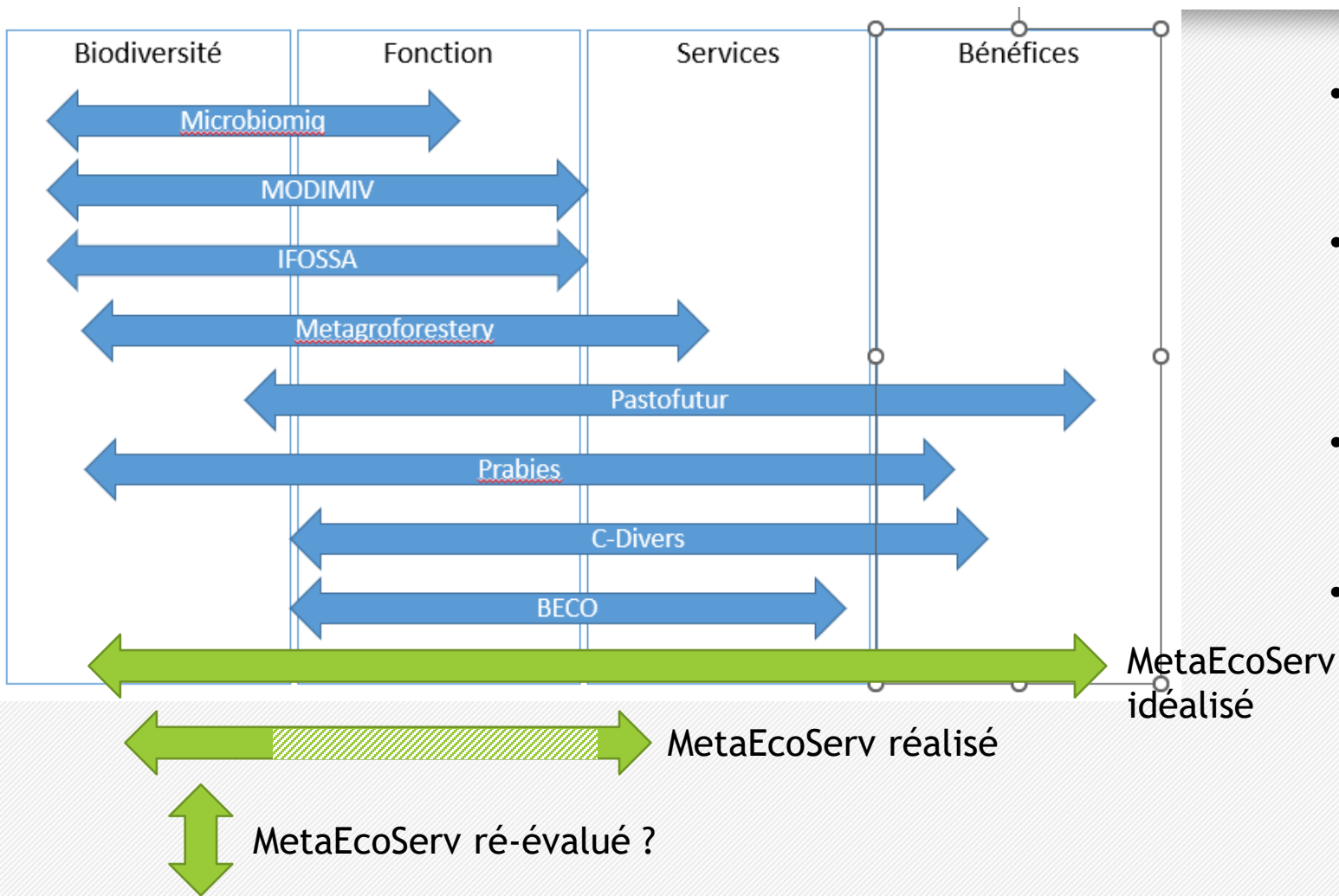


Perspectives de recherche

- Resolve causal chain linking meta-ecosystem processes with services
- Predict abrupt changes in ecological systems and ES driven by a complex interplay between long trends and short extreme events (eg. drought, flood, pest emergence...) in **multi-stressors context**
- Consolidate the conceptual foundations of the **bundle view of meta-ecosystem services** and better understand the complex relationships between multiple ES
- Perform **data collection** on spatial and temporal ecological fluxes and on their impacts on ES, especially at ecosystem interfaces (ecotones)
- Develop versatile **modeling methods to upscale** monitored fluxes at the appropriate scale for ES diagnosis
- Quantify the relative **contribution of different meta-ecosystem processes** in the distribution of given ES



Retour sur la notion ES



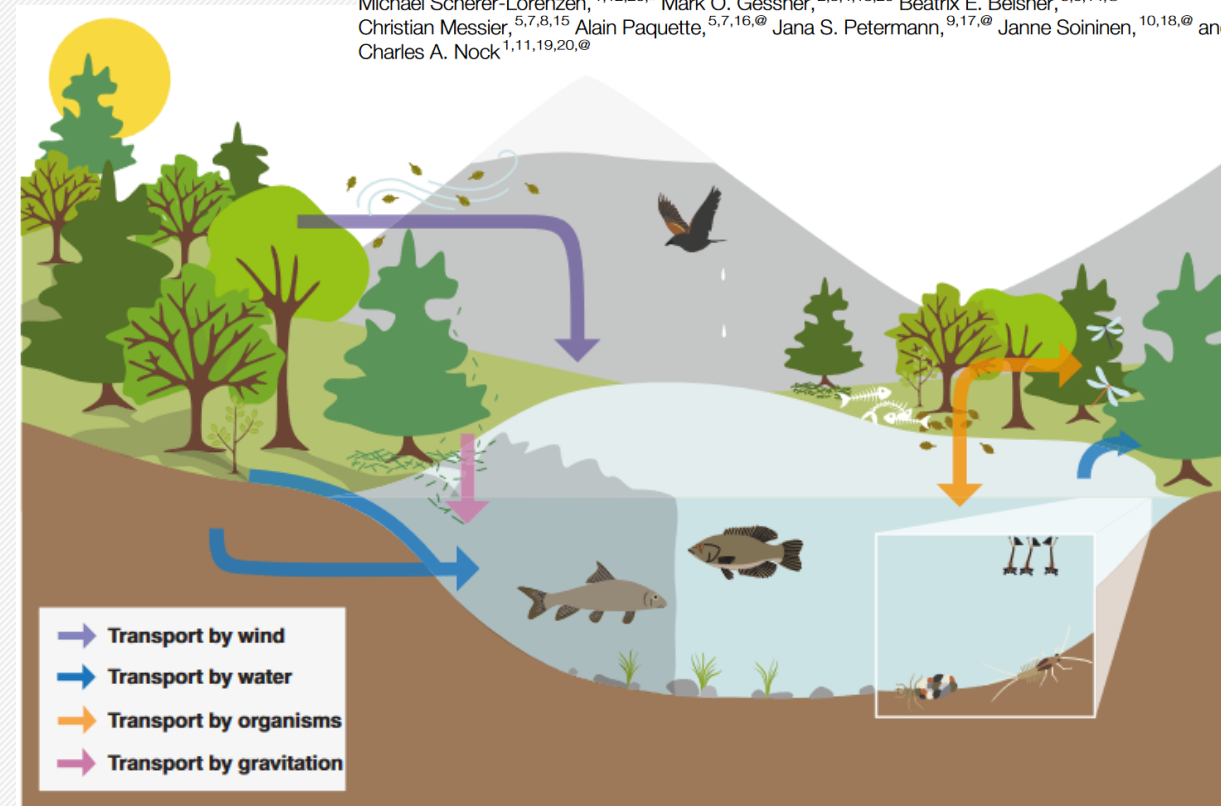
- Nos objets d'étude appartiennent souvent à la « boîte noire » des services de support difficiles à délimiter et quantifier.
- 'Court-circuitage' des fonctions pour tenter d'aller directement aux services → conceptuellement possible mais dans la pratique empirique, difficile.
- Au-delà de la biodiversité, les **processus** écologiques sont notre entrée principale → shift conceptuel bénéfique ?
- Difficulté de traduire les services en bénéfices quantitatifs car consortium exclusivement écologique → besoin des regards et compétences SHS.

Proposition de projet : Metaecosystem & Interfaces

Question générale : Quel-est le rôle des interfaces terre-aqua, de leurs propriétés, et de leur diversité dans le fonctionnement métaécosystémique des bassins versants ?
(dynamiques de diversité, flux, fonctions, etc.)
→ A tester empiriquement à large échelle, sur une diversité représentative d'interfaces

Pathways for cross-boundary effects of biodiversity on ecosystem functioning

Michael Scherer-Lorenzen,^{1,12,20,*} Mark O. Gessner,^{2,3,4,13,20} Beatrix E. Beisner,^{5,6,14,@} Christian Messier,^{5,7,8,15} Alain Paquette,^{5,7,16,@} Jana S. Petermann,^{9,17,@} Janne Soininen,^{10,18,@} and Charles A. Nock^{1,11,19,20,@}



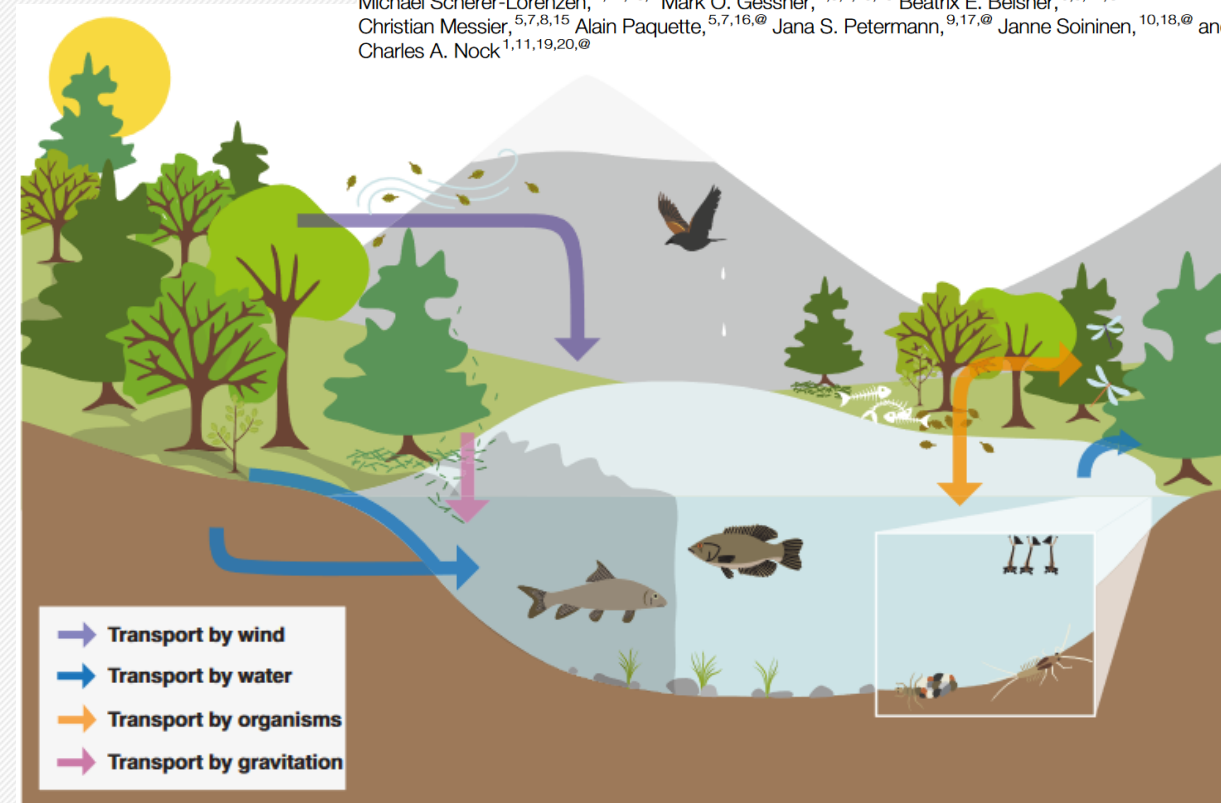
Proposition de projet : Metaecosystem & Interfaces

Hypothèse : Diversité des interfaces terre-aqua module les **fonctions écologiques** rendues par les milieux parce qu'elle augmente leur connectivité, et donc leur fonctionnement en métaécosystèmes

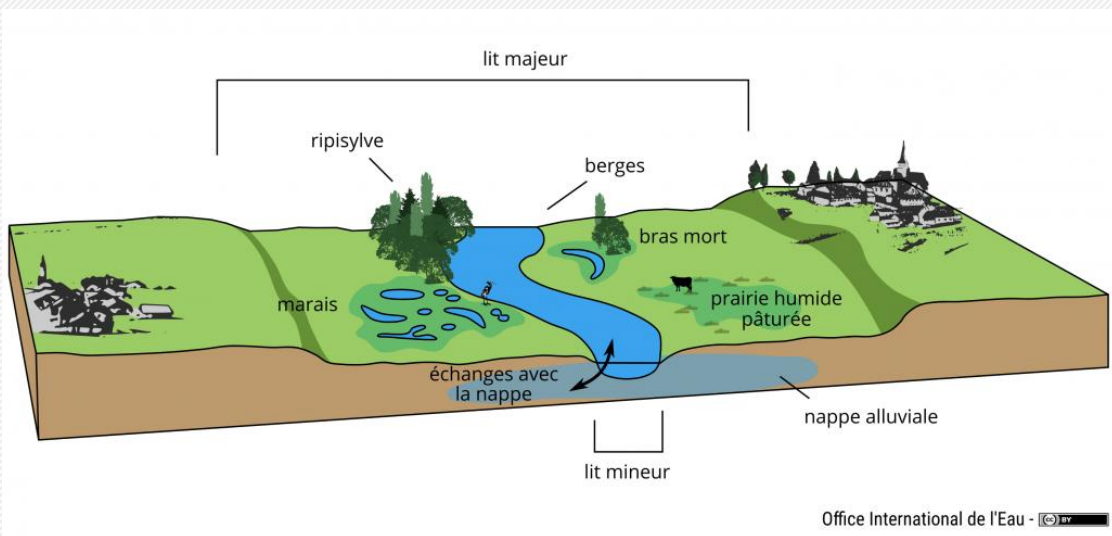
Décomposition
Production primaire
Détoxification
Emergence ?

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Metaecosystem & Interfaces



WP5. TAls as a transdisciplinary object:
compromises and recommendations?

WP1. Data collection: sampling strategy / field work (for WP2) and data synthesis (for WP3)

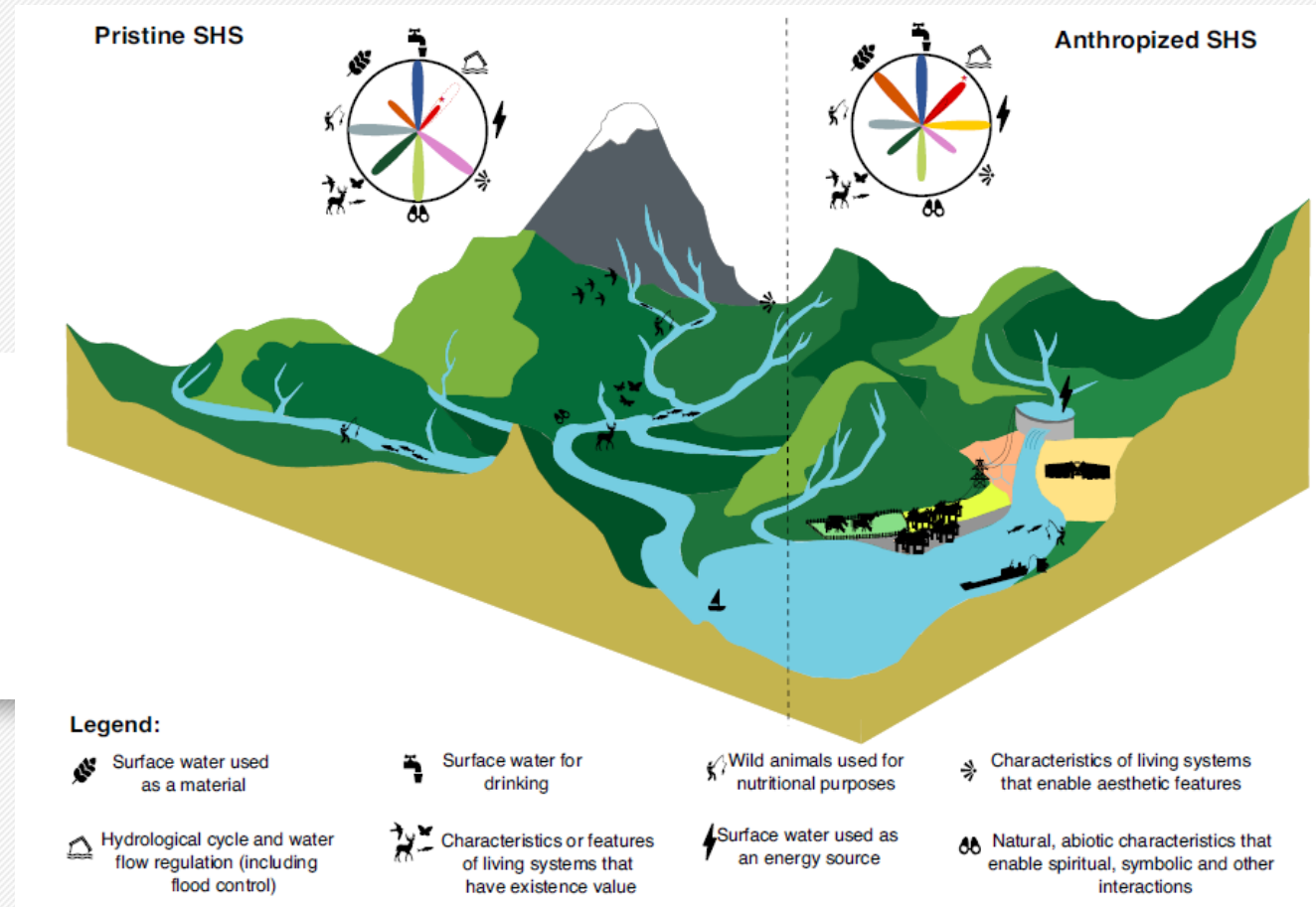
WP2. Local-scale approach: Understand the role of TAl in metaecosystem processes and BEF relationships (and ES)

WP3. Watershed-scale approach: Test the effects of TAl diversity / properties on biodiversity and functions (and ES) in restored ecosystems

WP4. Cross-scale integration modelling & management scenarios

Ouvert à discussions & collaborations !

Merci au métaprogramme Biosefair



Et merci pour votre attention !

Annexes

WP5. TAIs as a transdisciplinary object:
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WP4. Cross-scale integration modelling & management scenarios

For WP2: Census the dozen of local field sites (INRAE partners+others), select some sites in contrasted hydrosystems and uses
For WP3: Compile datasets among partners from restored wetlands (COSAR, etc.) and complement with measured functions

On local, finely and longly monitored case studies:

- Reflect on and find “common currency” between terrestrial and water ecosystems → “metaecosystem functions”
- On TAI transects, measure these metaecosystem functions, in both water and ground
- Analyse BEF links & feedback loop
- Analyse the importance of TAI permeability and properties in the functions
- Analyse the time lag and interseasonal effects

On overall watersheds, geomatic analyses of TAI related to restored hydrosystems (e.g. SYRAH data in France, UNECE data in Europe):

- Analyse correlations between TAI diversity, beta diversity of communities (alpha, beta), and ecological functions measured (or proxies estimated) in the system Before vs. After restoration
- Focus on a particular biotic flux to refine the investigation of the relationships between metacommunity processes and functions (testing hypotheses on their shape, cf. Naeem et al. etc.)

- Develop mechanistic models to represent TAI, local-scale processes, transfers between scales
- Use the model to predict the resulting functions at the watershed scale
- Use the model to validate the correlative analysis of WP3
- Assess the best scale of integration for each function
- (Develop an additional module in the model to predict the consequences in terms of ES distribution)
- Prospective work: Test management strategies