The River Continuum Concept

A key ecological theory by Vannote *et al.* (1980)

Presentation in Global Change Ecology of Fluvial Ecosystems

Claire, 2012

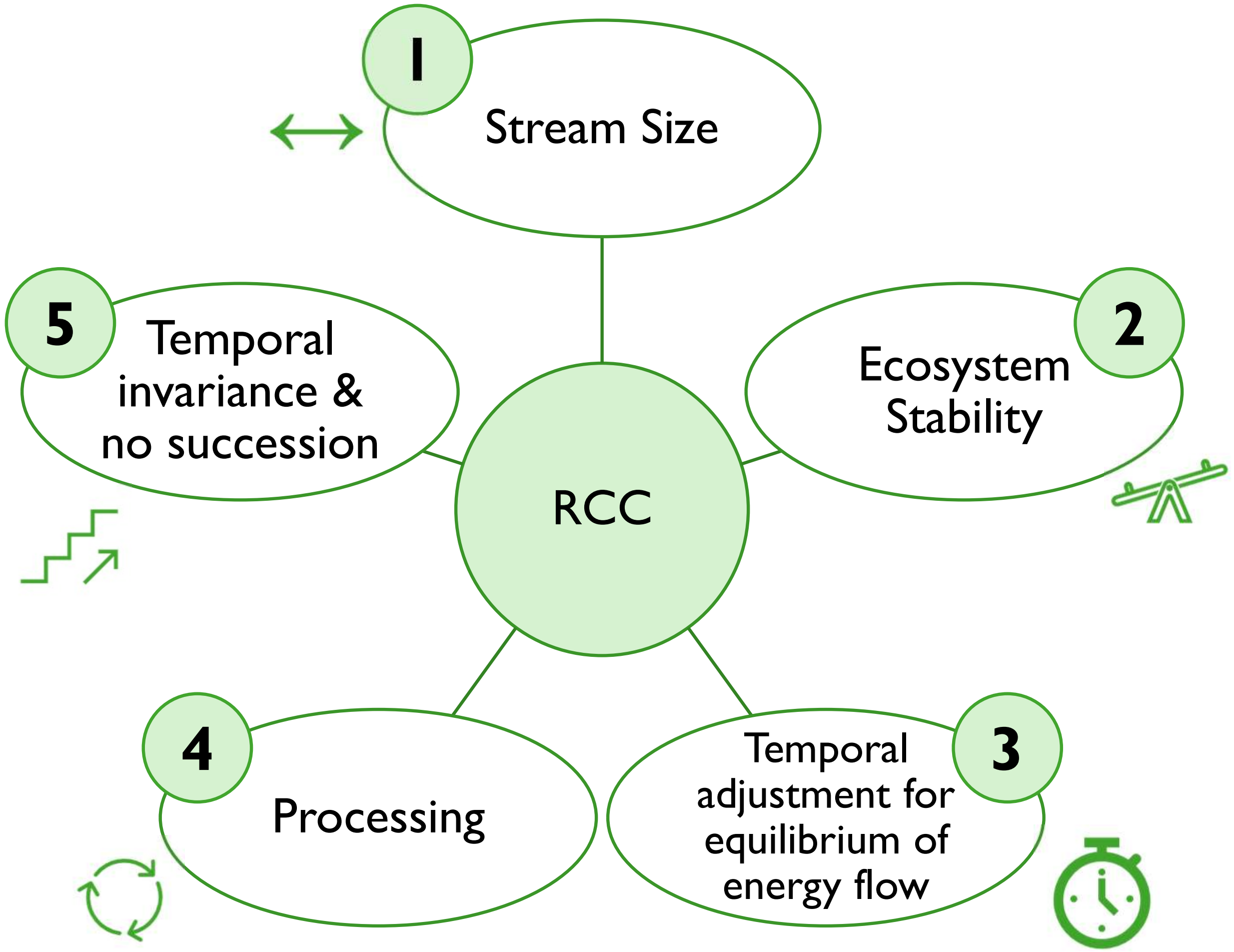
Agenda

- Introduction
- What does the RCC imply?
    1. Stream size & ecosystem structure and function
    2. River ecosystem stability
    3. Temporal adjustments for energy equilibrium
    4. Ecosystem processing
    5. Time independence & absence of succession
- Limitations & further research
- Impacts of the RCC
- Conclusion

Keyword

- **Allochthonous Inputs**:
    - Dissolved organic carbon (DOC).
    - Derived from terrestrial sources.
    - Critical in shaded, light is insufficient.
- **Autochthonous Inputs**:
    - Produced within the river.
    - Photosynthesis is required.
    - With increased light availability.
- **Gross Primary Production (GPP) :** Total amount of carbon in the river ecosystem.
- **Ecosystem Respiration (ER):** The sum of respiration through metabolism

The RCC applies to streams through 5 components



RCC

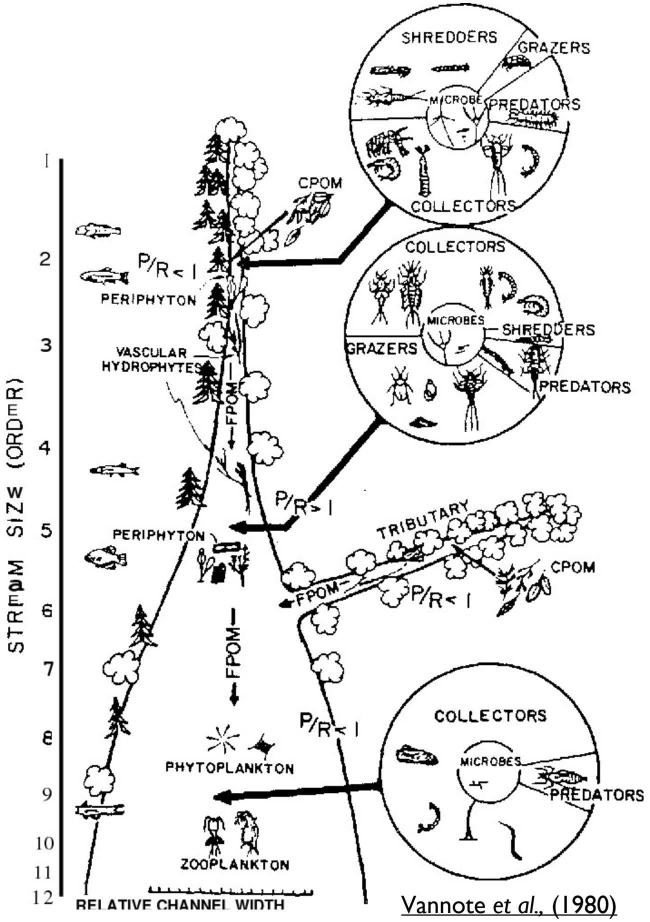
1 Stream Size

2 Ecosystem Stability

3 Temporal adjustment for equilibrium of energy flow

4 Processing

5 Temporal invariance & no succession



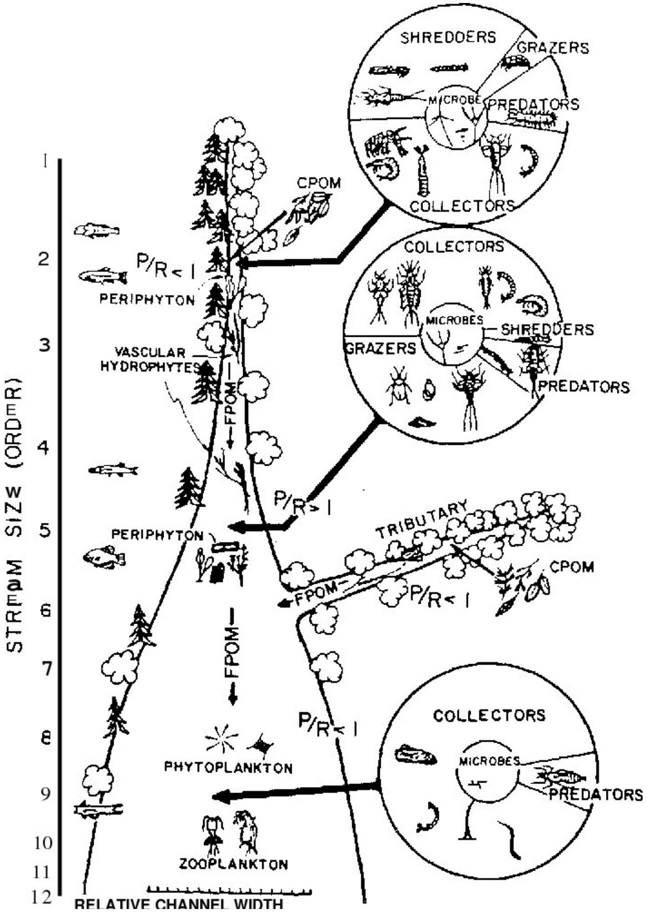
Vannote *et al.*, (1980)

Stream size & ecosystem structure and function

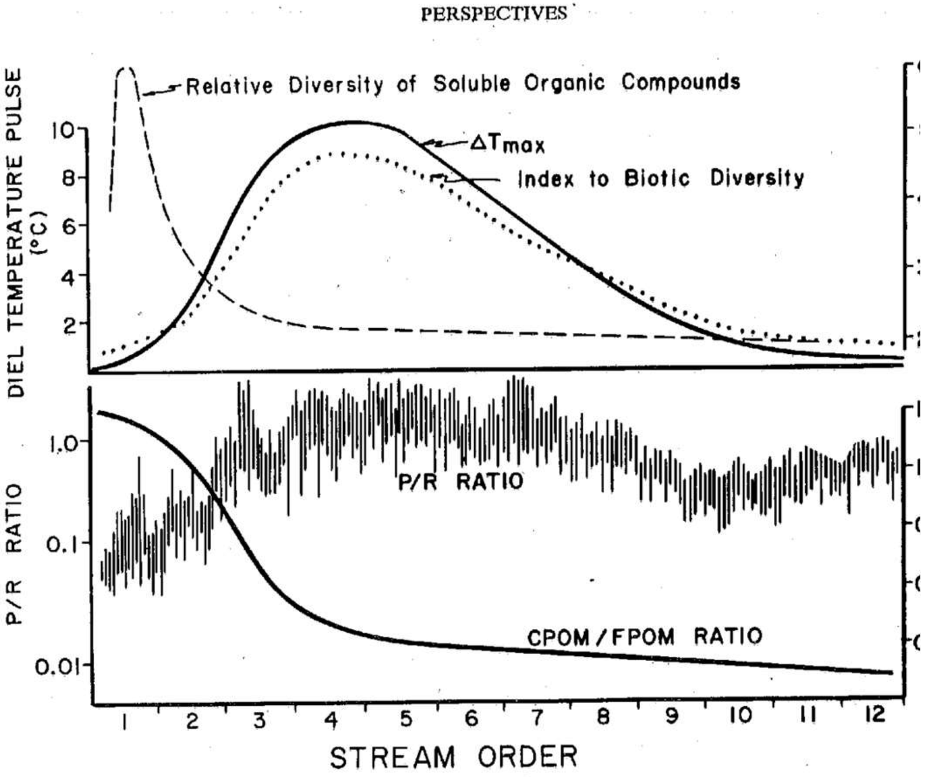
- **Headwaters (small streams):** GPP /ER < 1
- **Mid-sized Streams:** GPP ≈ ER
- **Large Rivers:** GPP/ER < 1

Invertebrate Groups & Fish Communities

  - **Small streams:** Shredders / Invertivores
  - **Middle:** Scrapers and gatherers /Piscivores
  - **Large rivers:** Filter feeders / Planktivores



River ecosystem stability

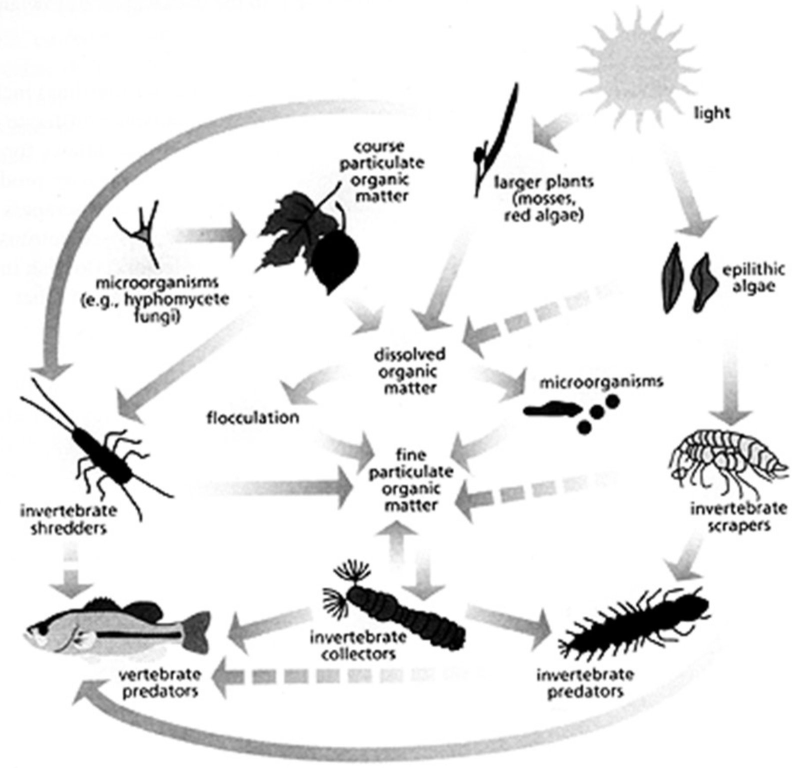


Geomorphic and Hydrologic Drivers

- Sediment deposition and erosion decides the balances
- Low diel temperature variation promotes stable biotic communities.
- Annual regime of autotrophy in mid-reach
- Heterotrophy in downstream
- Ecosystem stability achieves by dynamic balance
- Headwater streams in groundwater supply exhibit variation in ΔT Max

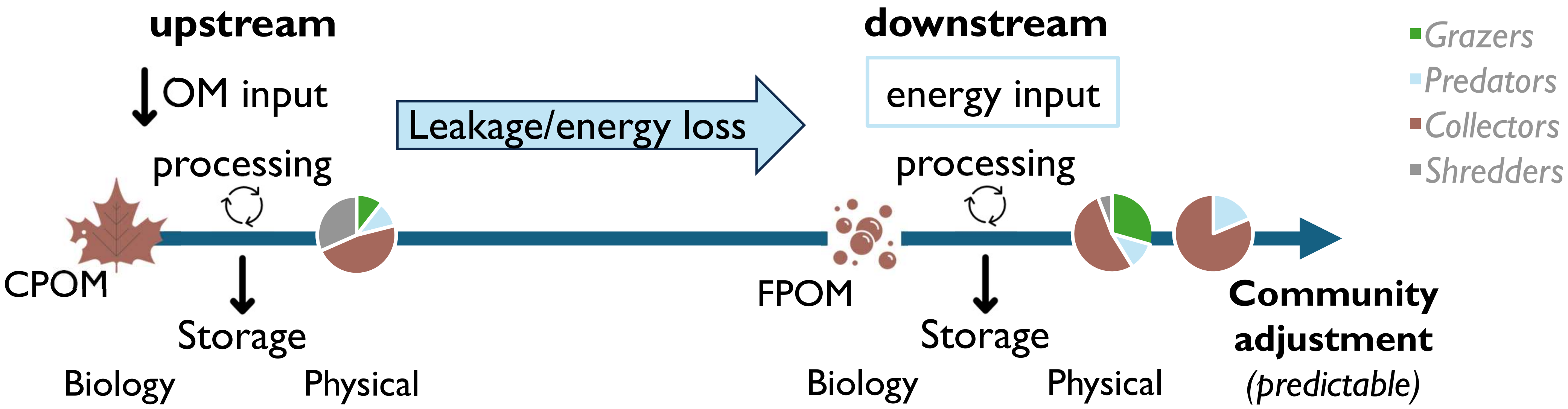
Temporal adjustments for energy equilibrium

- **Species Turnover**
  - Shifts seasonally.
  - Shredders dominate in fall.
  - Scrapers increase in spring and summer.
- **Functional Feeding Groups**
  - Macroinvertebrates and fish.
  - Collectors (filter feeders) operate consistently.



West Virginia department of environmental protection

Downstream communities are structured to process inefficiencies



upstream

↓ OM input

processing

CPOM

↓ Storage

Biology

Physical

Leakage/energy loss

downstream

energy input

processing

FPOM

↓ Storage

Biology

Physical

Community adjustment

(predictable)

🟩 *Grazers*

■ *Predators*

🟥 *Collectors*

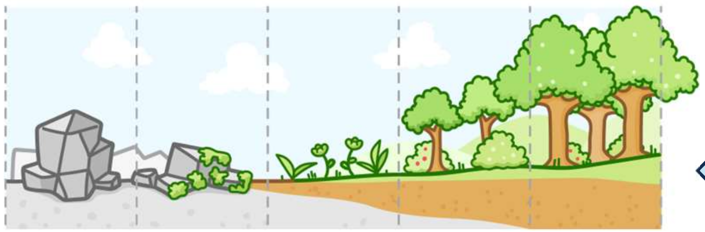
■ *Shredders*

→ higher certainty on system structure & expression of energy flow as function of:

Drivers of energy processing along stream = *f* (
seasonal variation of energy input
adjustment in species diversity
specialisation for food processing
temporal expression of functional groups
erosion−deposition−transport dynamics
)

Stream communities do not follow classical succession

Forest Succession



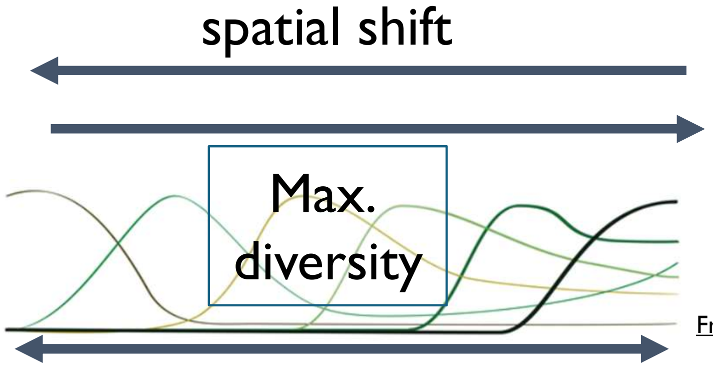
Cognito, n.d.

time

- Time-dependent
- Biological subsystem shift in time
- Isolated temporal communities
- Total absence of population at start

Streams

Claire, 2012



Frey, 2011

space

- Time-independent (dynamic equilibrium)
- Biological subsystem shift in space
- Continuous heritage of species
- All species present at all times

Species gain/loss
evolutionary timescale
- Catastrophic events
- Slow channel development

RCC Limitations sparked ecological research

Limitation	**Research suggestion**	**Advances**
Unperturbed river	human disturbance & global change	Studies on human influence
Temperate forest	different biomes	adapted for alpine, tropics…
Perennial, main stream, no flow disruption	flow regimes, stream network & floodplain	River Dis-continuum, Network Position

(Vannote et al., 1980; Dodds & Maasri, 2022; Doretto et al., 2020)

The RCC is a key ecological theory

Milestone in stream ecology

14’000 citations (google scholar)

1st continuum-oriented view on river & community function

PERSPECTIVES

The River Continuum Concept[1]

Robin L. Vannote

Stroud Water Research Center, Academy of Natural Sciences of Philadelphia, Avondale, PA 19311, USA

G. Wayne Minshall

Department of Biology, Idaho State University, Pocatello, ID 83209, USA

Kenneth W. Cummins

Department of Fisheries and Wildlife, Oregon State University, Corvallis, OR 97331, USA

James R. Sedell

Weyerhauser Corporation, Forestry Research, 505 North Pearl Street, Centralia, WA 98531, USA

and Colbert E. Cushing

Ecosystems Department, Battelle-Pacific Northwest Laboratories, Richland, WA 99352, USA

Vannote, R. L., G. W. Minshall, K. W. Cummins, J. R. Sedell, and C. E. Cushing. 1980. The river continuum concept. Can. J. Fish. Aquat. Sci. 37: 130–137.

From headwaters to mouth, the physical variables within a river system present a continuous gradient of physical conditions. This gradient should elicit a series of responses within the constituent populations resulting in a continuum of biotic adjustments and consistent patterns of loading, transport, utilization, and storage of organic matter along the length of a river. Based on the energy equilibrium theory of fluvial geomorphologists, we hypothesize that the structural and functional characteristics of stream communities are adapted to conform to the most probable position or mean state of the physical system. We reason that producer and consumer communities characteristic of a given river reach become established in harmony with the dynamic physical conditions of the channel. In natural stream systems, biological communities can be characterized as forming a temporal continuum of synchronized species replacements. This continuous replacement functions to distribute the utilization of energy inputs over time. Thus, the biological system moves towards a balance between a tendency for efficient use of energy inputs through resource partitioning (food, substrate, etc.) and an opposing tendency for a uniform rate of energy processing throughout the year. We theorize that biological communities developed in natural streams assume processing strategies involving minimum energy loss. Downstream communities are fashioned to capitalize on upstream processing inefficiencies. Both the upstream inefficiency (leakage) and the downstream adjustments seem predictable. We propose that this River Continuum Concept provides a framework for integrating predictable and observable biological features of lotic systems. Implications of the concept in the areas of structure, function, and stability of riverine ecosystems are discussed.

Key words: river continuum; stream ecosystems; ecosystem structure, function; resource partitioning; ecosystem stability; community succession; river zonation; stream geomorphology

Starting point for many ecological concepts

More precise ecological predictions

Shift descriptive → predictive stream ecology

Interdisciplinary + simple

(Dodds & Maasri, 2022; Doretto et al., 2020)

The bottom line

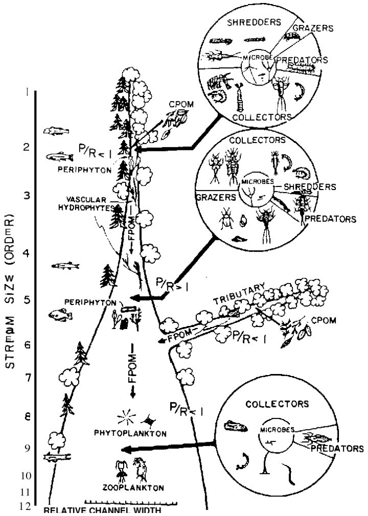
Physical continuum

driver

adjust

Biological continuum

RCC



RCC = physical + geomorphological → biological patterns

Stream community = $f\begin{pmatrix} physical\ variables \\ energy\ inputs \end{pmatrix}$ → Ecosystem processing & river metabolism

References

- Vannote, R. L., Minshall, G. W., Cummins, K. W., Sedell, J. R., & Cushing, C. E. (1980). The River Continuum Concept. *Canadian Journal of Fisheries and Aquatic Sciences*, *37*(1), 130–137. https://doi.org/10.1139/f80-017
- Dodds, W. K., & Maasri, A. (2022). The River Continuum Concept. In *Encyclopedia of Inland Waters* (pp. 237–243). Elsevier. https://doi.org/10.1016/B978-0-12-819166-8.00105-5
- Allan, J. D., Castillo, M. M., & Capps, K. A. (2021). *Stream Ecology: Structure and Function of Running Waters*. Springer International Publishing. https://doi.org/10.1007/978-3-030-61286-3
- Doretto, A., Piano, E., & Larson, C. E. (2020). The River Continuum Concept: Lessons from the past and perspectives for the future. *Canadian Journal of Fisheries and Aquatic Sciences*, *77*(11), 1853–1864. https://doi.org/10.1139/cjfas-2020-0039