

Six Years of Monitoring: Investigating The Impacts of Wastewater Treatment Plant Effluents on Mediterranean Pond Turtle

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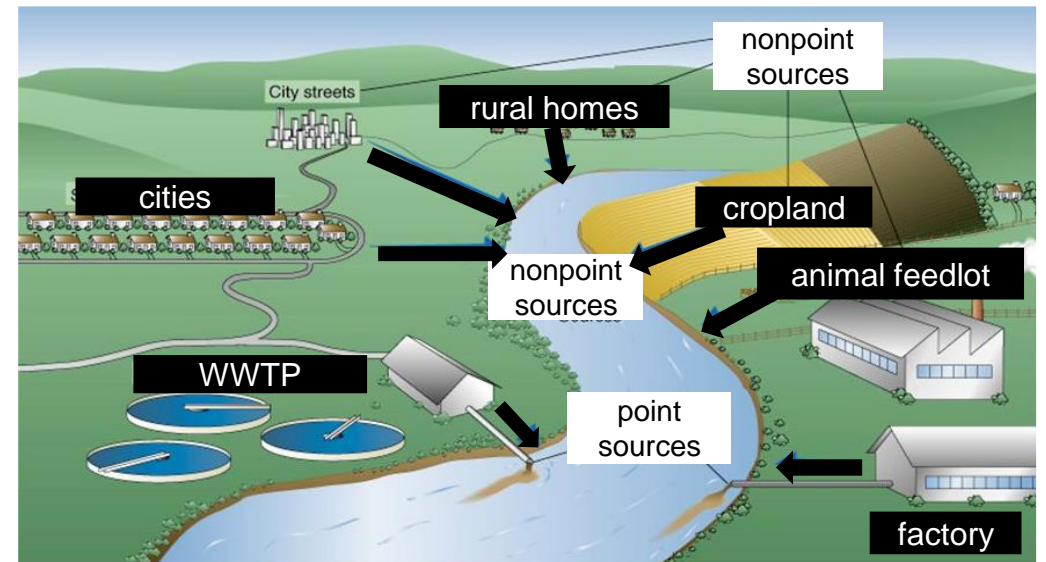
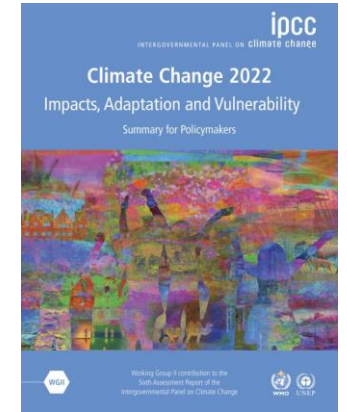
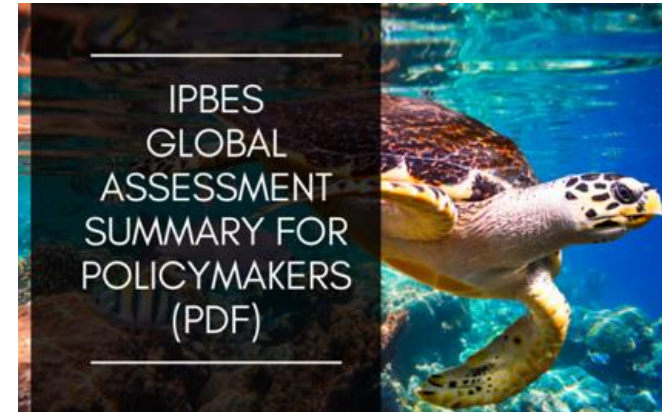
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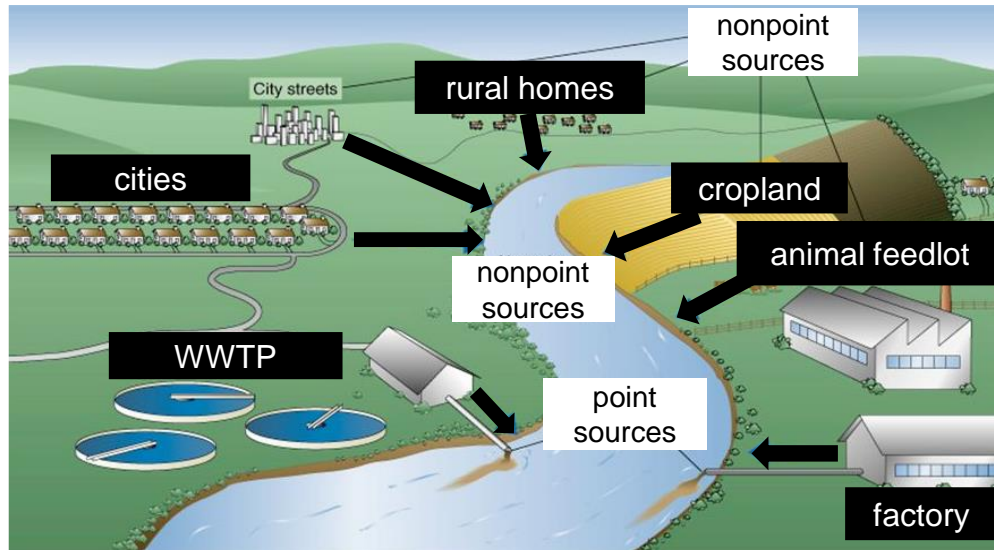
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- 6th crisis of the biodiversity *IPBES 2019*
- Reduced water disponibility *IPCC 2022*
- Increased water pollution *Wilkinson et al. 2022*
- Major threat to water biodiversity *Rahel 2002*
- 80% wastewater → untreated into water streams
- 10⁶ tons of pollutants per year *WWAP 2017*





Rainwater
(runoff + infiltration)



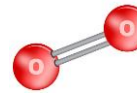
Wastewater treatment
plant (WWTP) effluents



Mineral matter

Organic matter

Pollutants



mortality
Small et al. 2014

growth
Snover et al. 2015

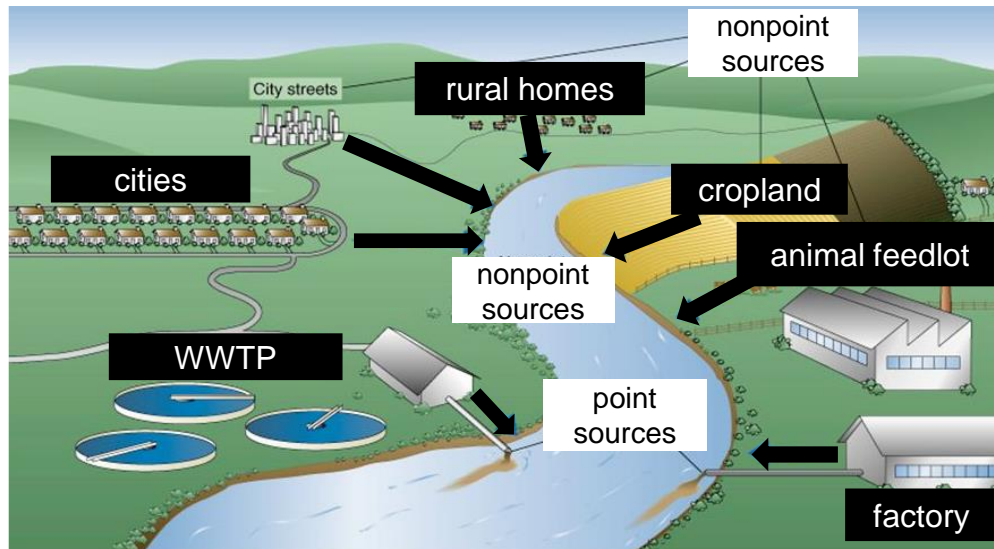
abundance
Daufresne 2004

sex-ratio
Thompson 2018

reproduction
Mazzitelli et al. 2018

physiological stress
Héritier et al. 2019





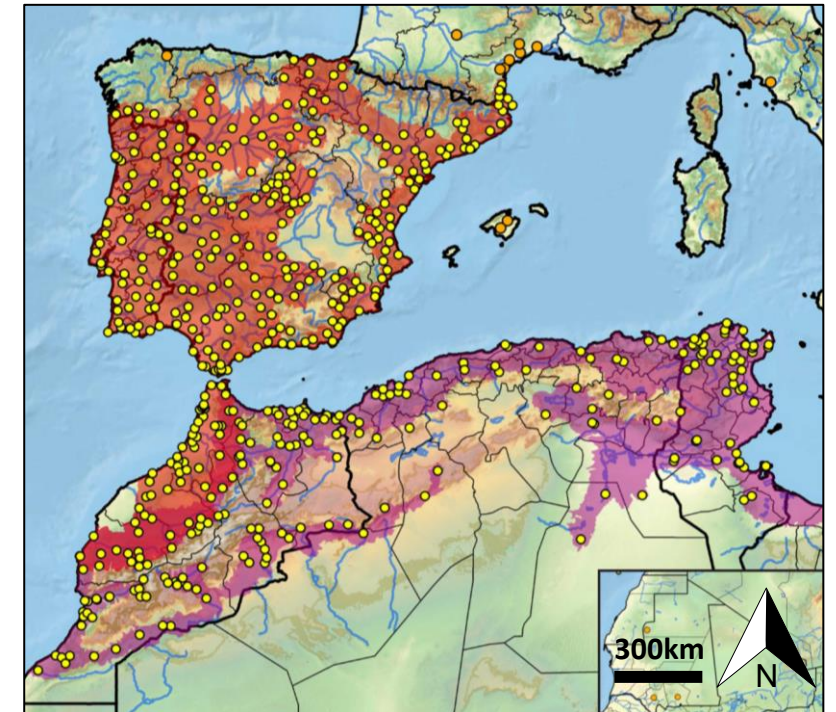
Mediterranean pond turtle
Mauremys leprosa

Freshwater turtles as sentinel species
detects differences in ambient pollution levels *Beeby 2001*

Ectotherm

Long-lived

Slow pace
of life



Bertolero & Busack 2017

Hypotheses

In an environment polluted by a WWTP, the population structure and dynamics may be determined either/or by...

H1

Resources from effluents

- ↗ survival, body condition
- ↗ transition towards WWTP

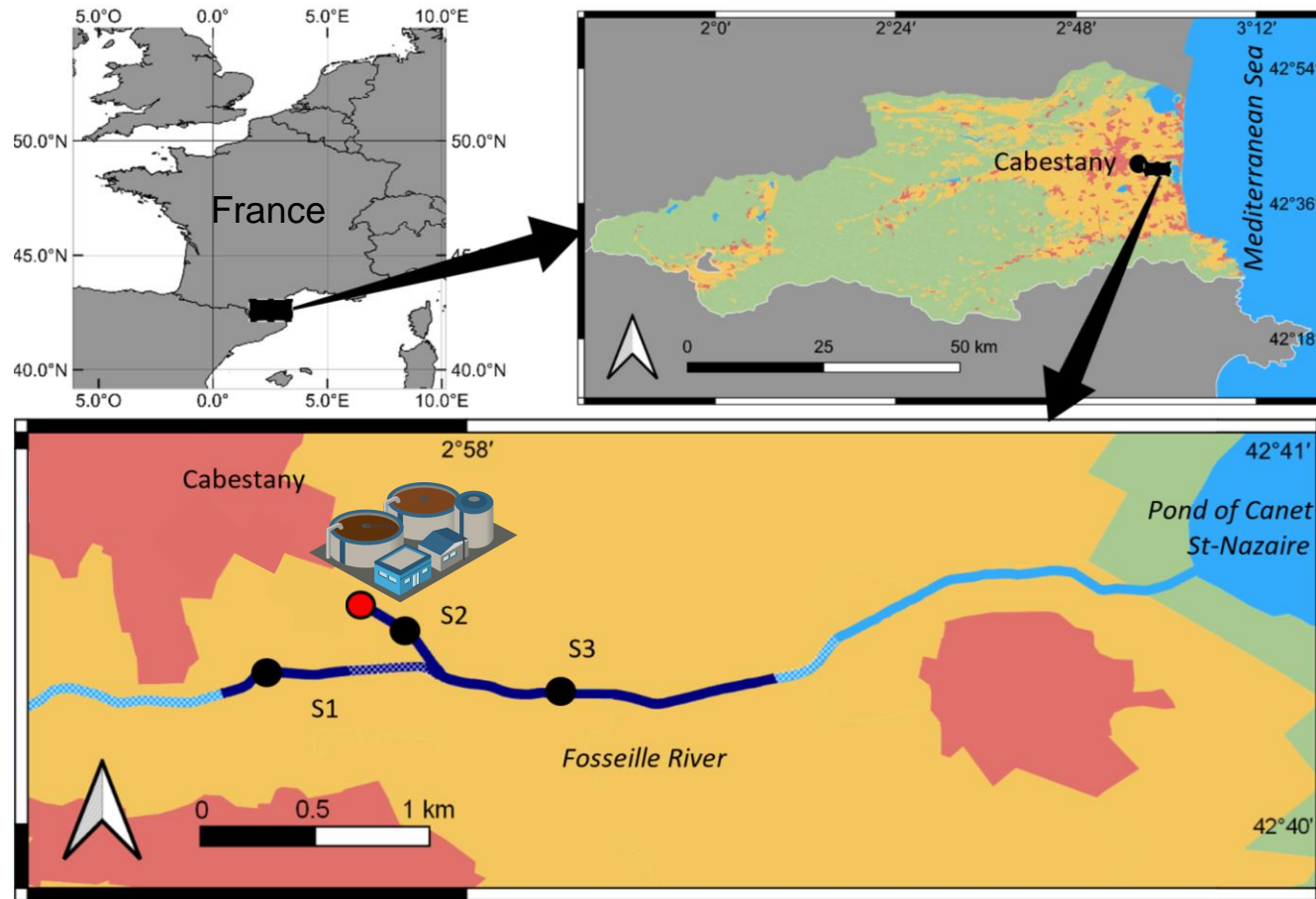


H2

Pollutants induced by effluents

- ↗ physiological stress
- ↘ survival, body condition
- ↗ dispersion away from WWTP



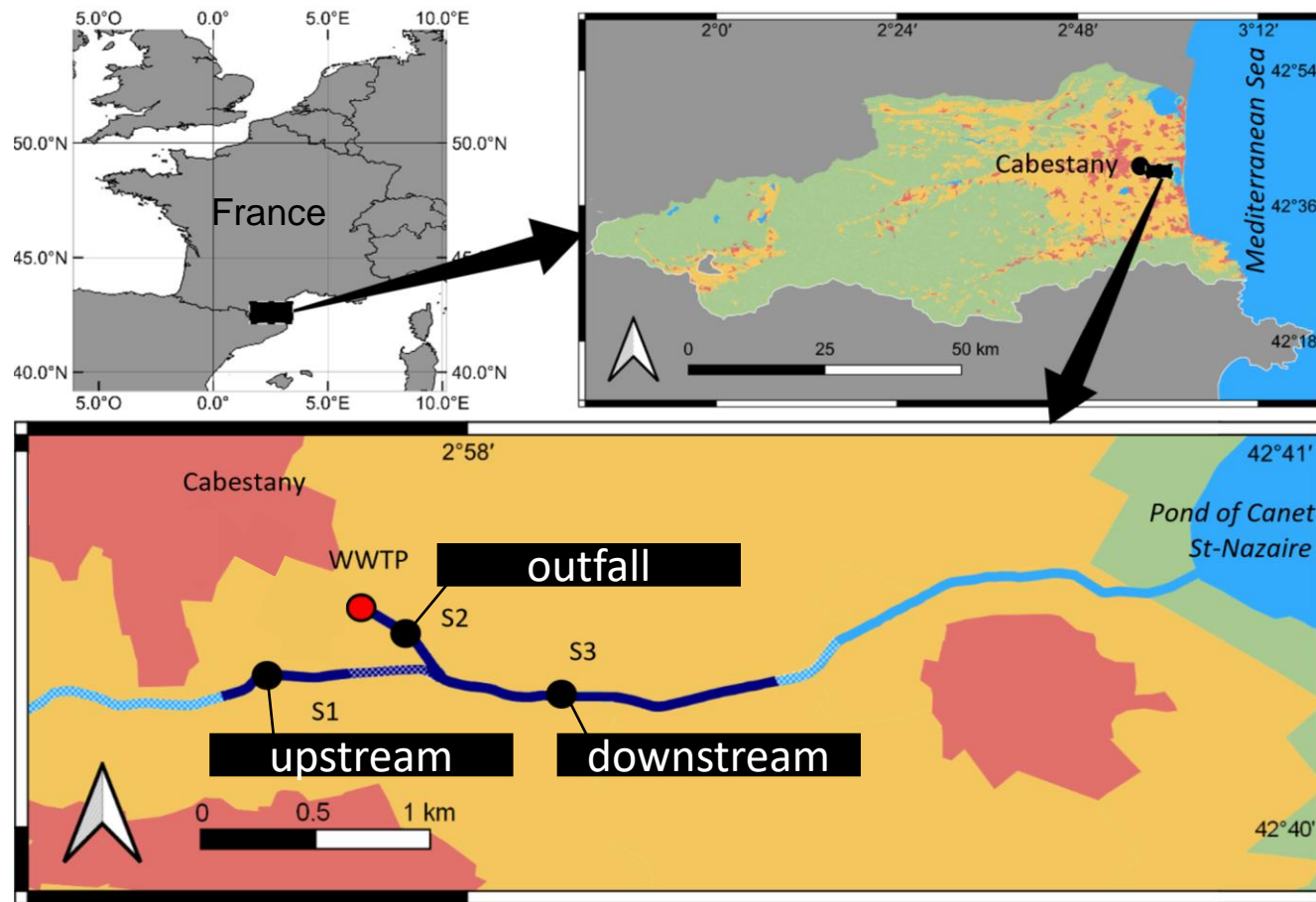


Fosseille River (Southern France, Europe)

- Peri-urban and agricultural area
- 6 km long river, connected to a WWTP
- Large Mediterranean pond turtle population



Fosseille River (Cabestany, SW France) 10/06/2022



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Water quality

- Point water samplings
- August 2018, May 2021, Sept. 2021
- Upstream – outfall – downstream WWTP



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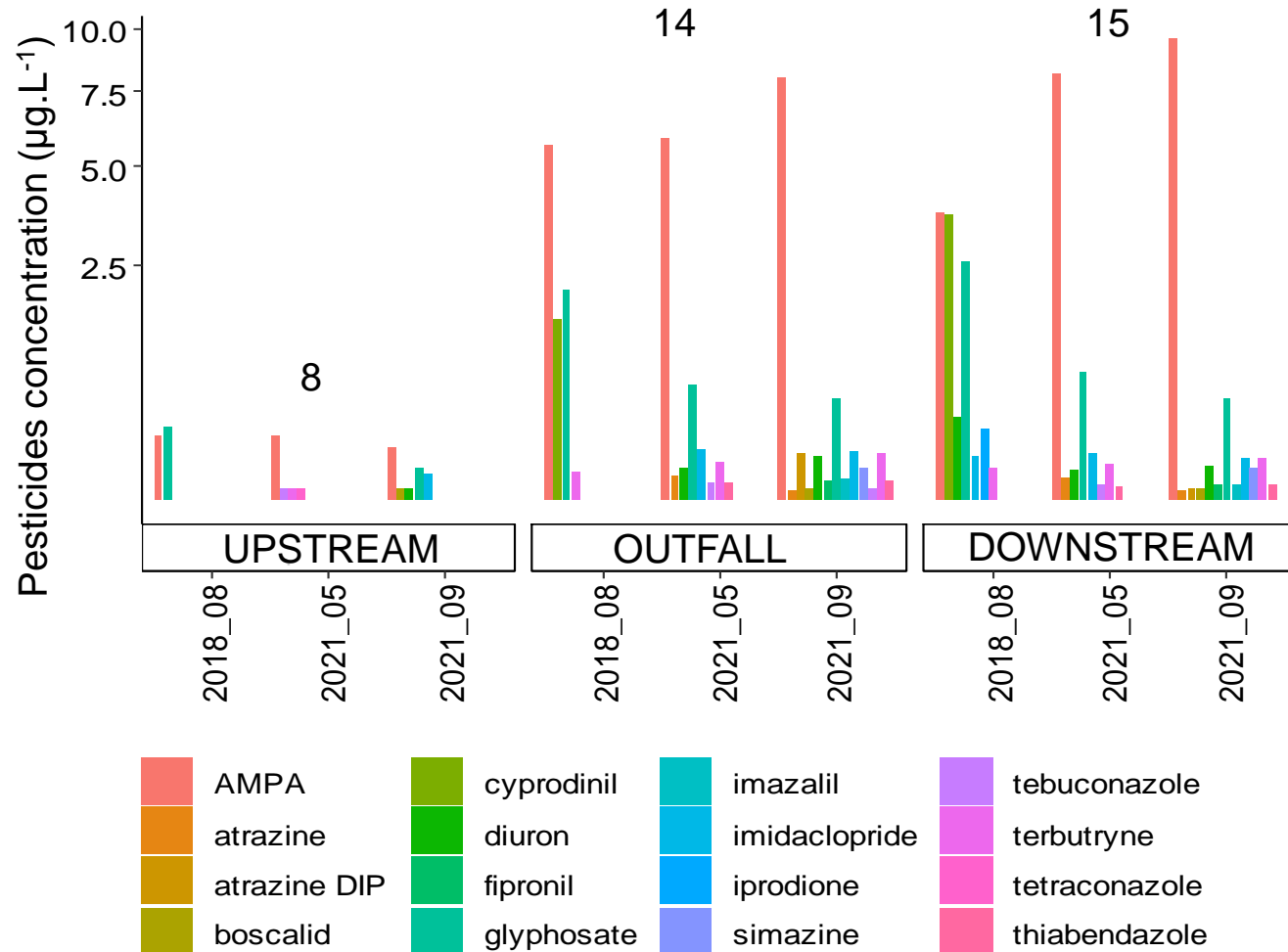
Water quality

- Point water samplings
- August 2018, May 2021, Sept. 2021
- Upstream – outfall – downstream WWTP

Turtle population monitoring

- Capture-Mark-Recapture
- 6 years between 2013 and 2021
- Robust Design & Multi-States models

Pesticides

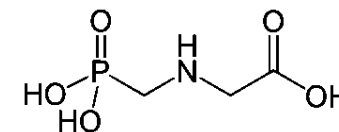


Variable	Upstream	Downstream
Pest. Diversity	low	HIGH
Pest. Concentration	low	HIGH

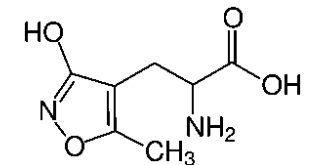
08/2018 – Wilcoxon's $W = 86$, $p = 0.05$

09/2021 – Wilcoxon's $W = 70$, $p = 0.02$

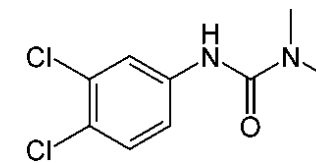
glyphosate



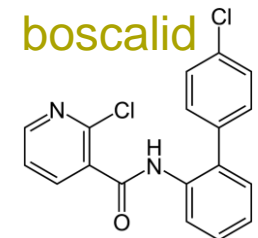
AMPA



diuron



boscalid

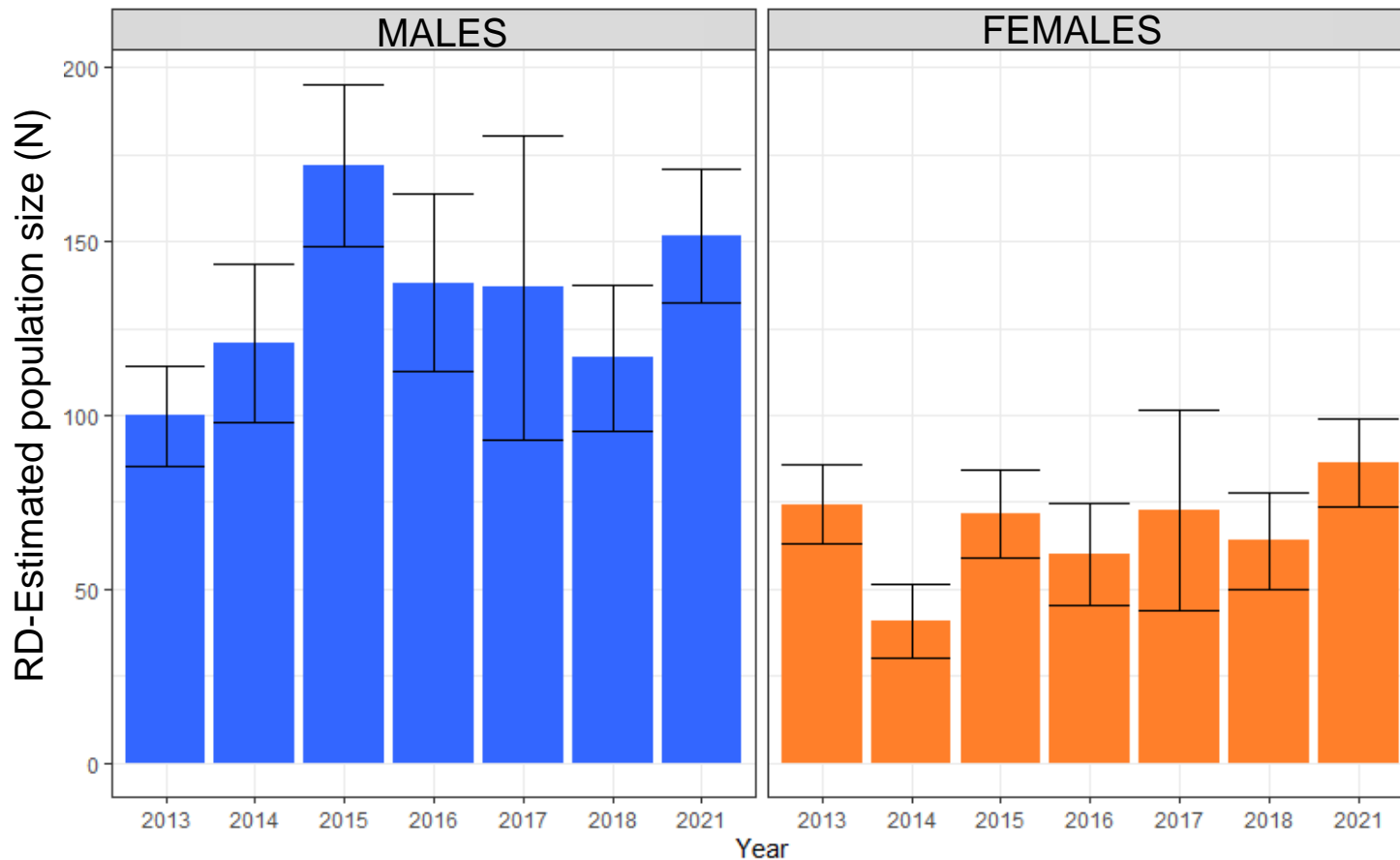


→ Effluents of the WWTP degrades the water quality of the Fosseille River

Population dynamics

Robust Design model *Pradel 1996, 2009* $N_{\text{captures}} = 786$

capture (effort x year) = 17% / survival (stable) = 88% / recruitment (year) = 14%



Variable	Upstream	Downstream
Pest. Diversity	low	HIGH
Pest. Concentration	low	HIGH
Survival (Phi)	88 % ± 2 % (stable)	
Population size (N)	202 ± 10 ids (stable)	

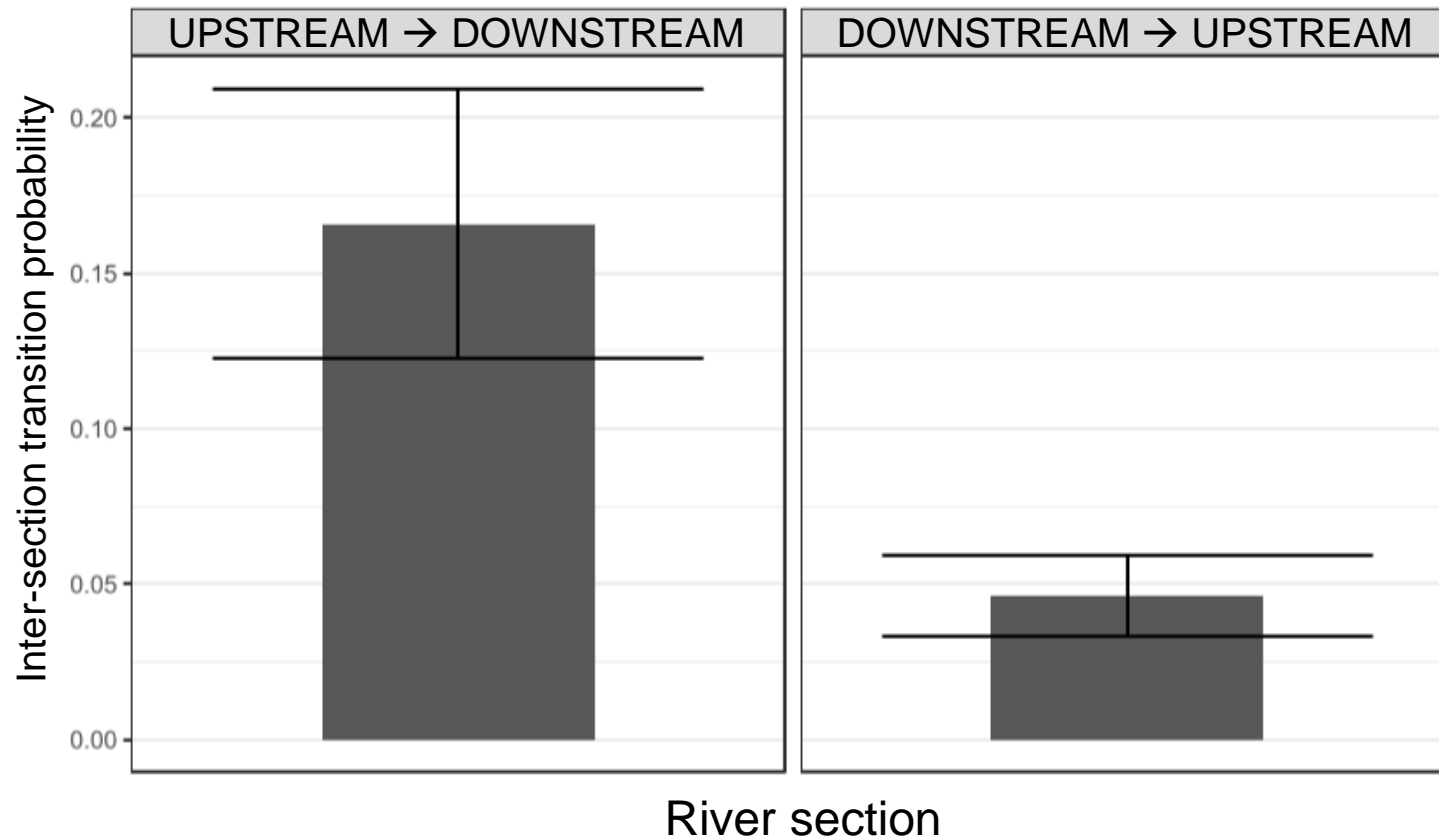
Kruskal-Wallis, $H = 0.8, p < 0.01, n = 7$

- The population of turtles is stable over the mid-term
- The sex-ratio of the population is male-biased

Population dynamics

Multi-States model *Nichols et al. 1992, 1994*

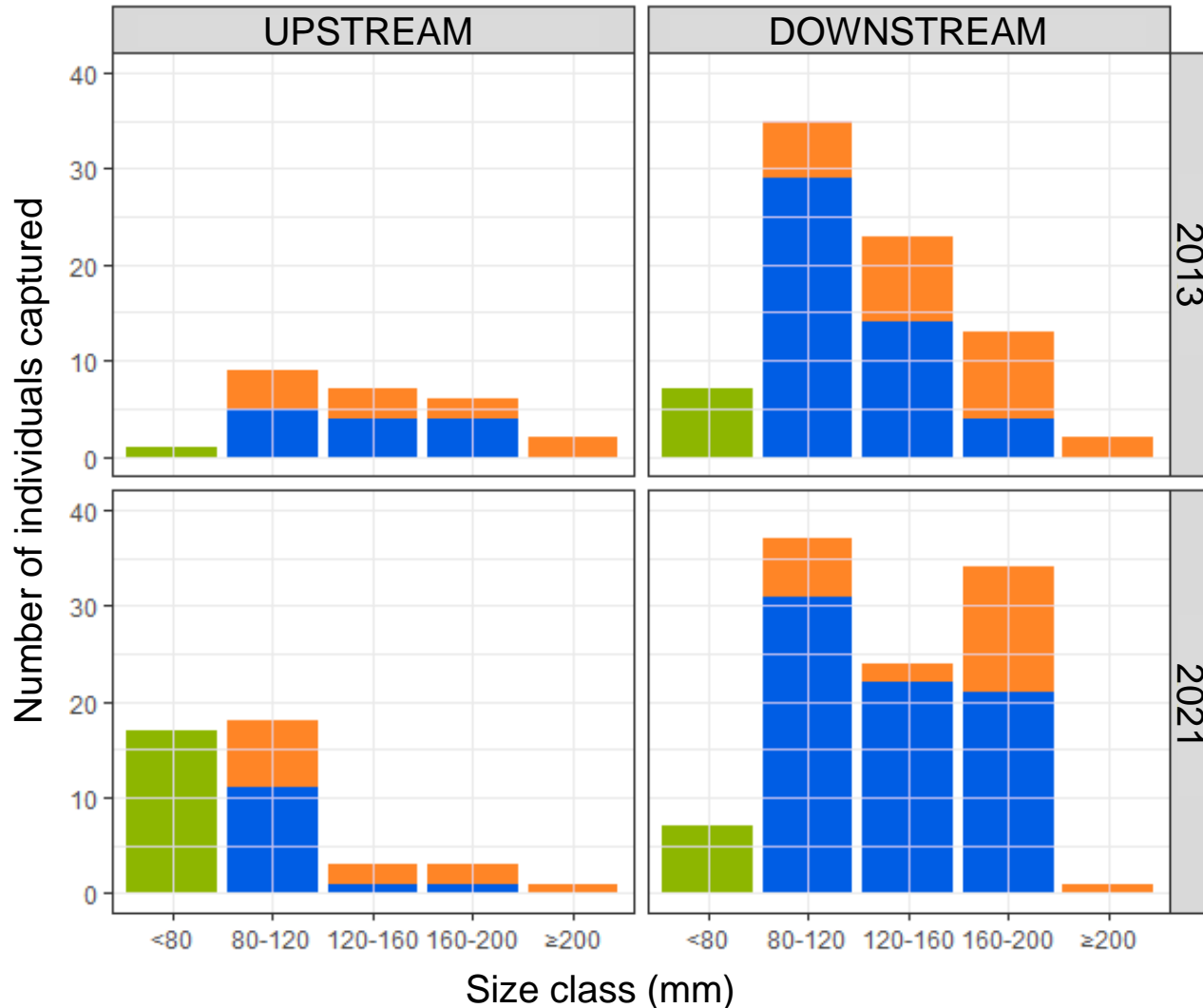
recapture (year) = 29% / survival (stable) = 90% / transition (section) = 5-17%



Variable	Upstream	Downstream
Pest. Diversity	low	HIGH
Pest. Concentration	low	HIGH
Survival (Phi)	88 % ± 2 % (stable)	
Population size (N)	202 ± 10 ids (stable)	
Transitions	5% ± 1%	17% ± 4%

→ Turtles mainly transit from upstream to downstream of the WWTP

Population structure

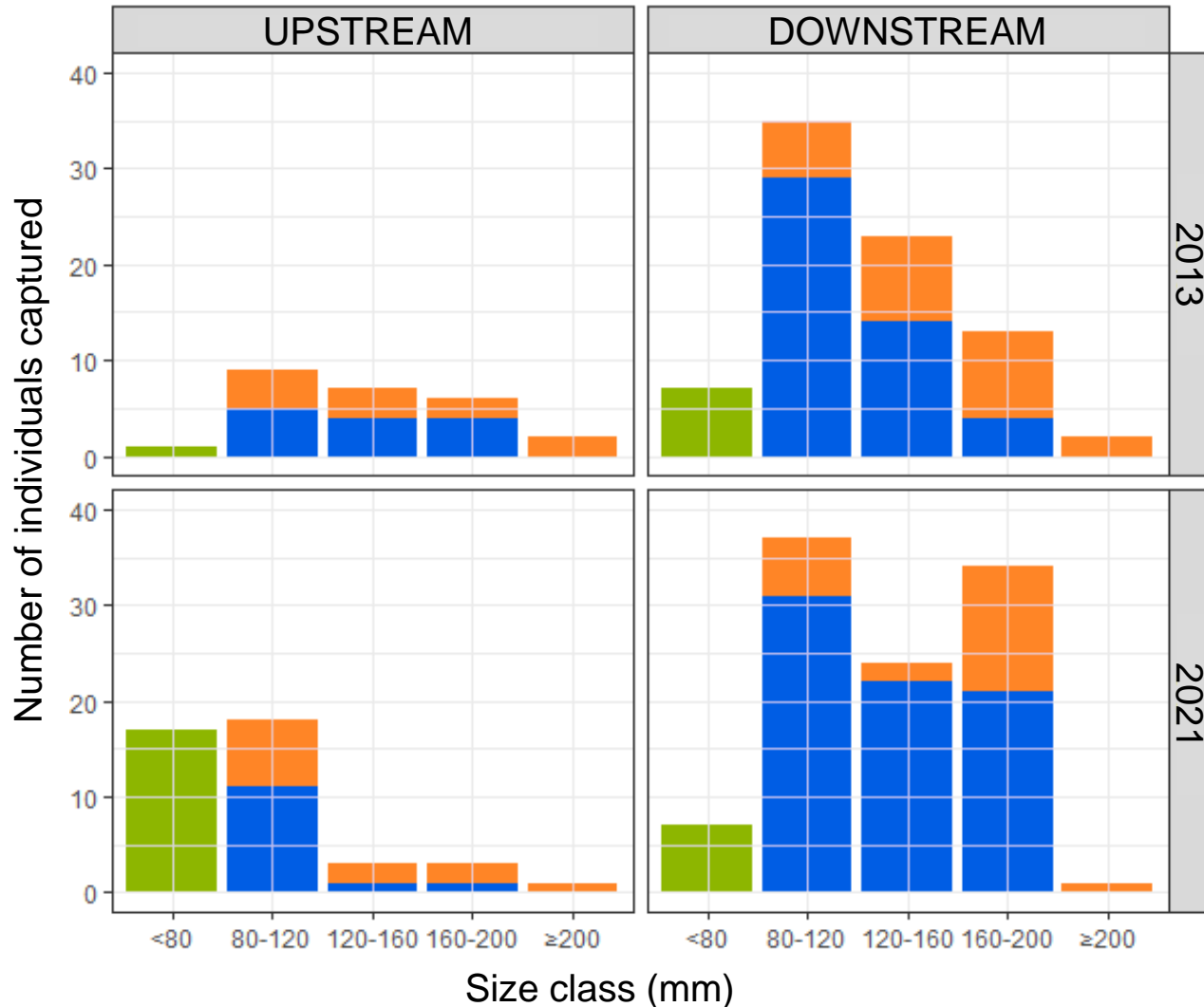


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♂-biased sex-ratio	0.48 ± 0.01	0.76 ± 0.00

Wilcoxon, $W = 28, p = 0.02, n = 7$

→ Adult sex ratio is skewed downstream of the WWTP, not upstream

Population structure



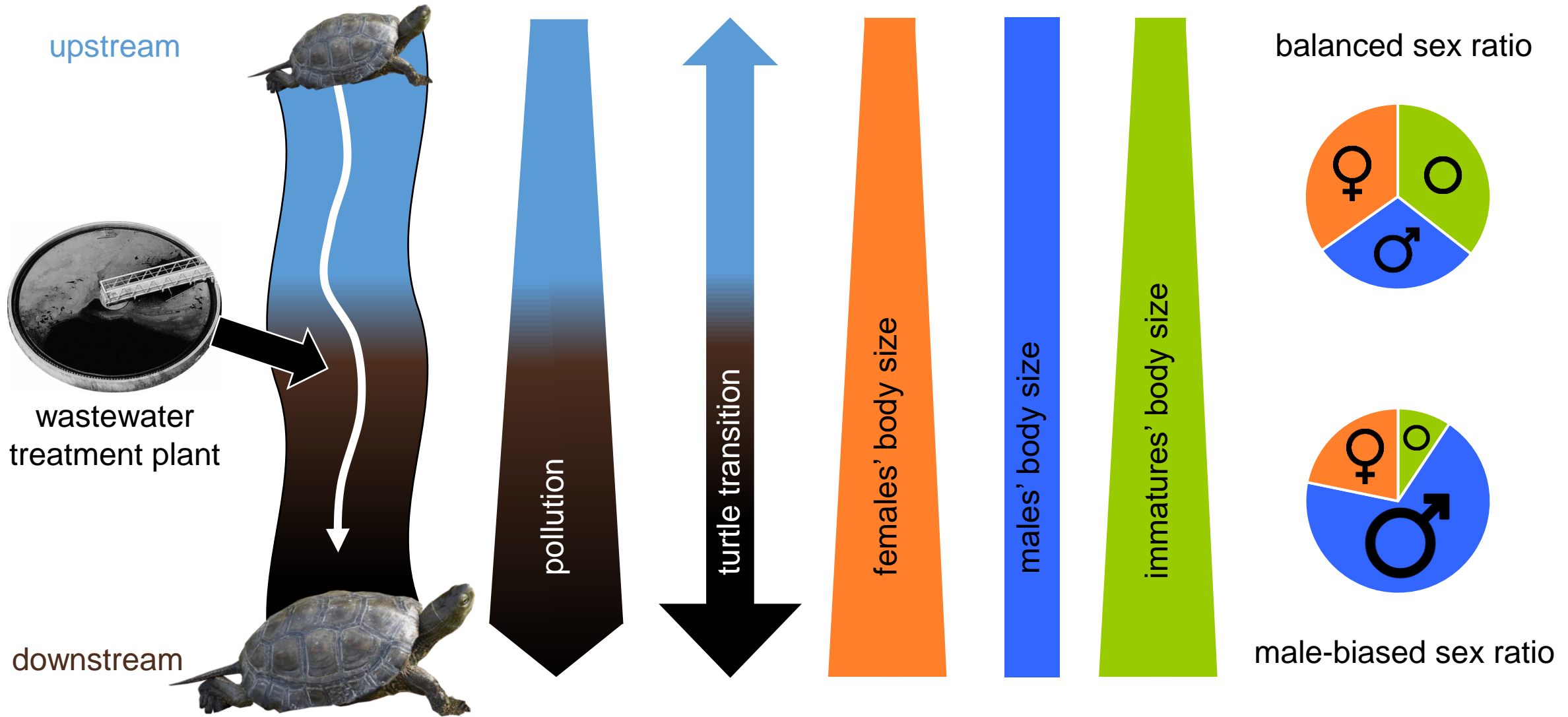
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♂-biased sex-ratio	0.48 ± 0.01	0.76 ± 0.00
Body length	-	+
Body condition	-	+

♂ *Body length* ($F = 8.86, p < 0.01$)

♀ *Body length* ($F = 8.59, p < 0.01$)
Body condition ($F = 3.89, p = 0.05$)

→ Turtles are bigger downstream than upstream of the WWTP

→ Females have a higher body condition downstream than upstream of the WWTP



H1

→ In an environment polluted by a WWTP, the structure and dynamics of the population are mainly determined by the resources induced by the effluents

21st Annual symposium on the conservation and biology of tortoises and freshwater turtles

Charleston, South Carolina – 02 August 2023



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