Hacking Ecology

a primer for data-driven ecology in the Anthropocene

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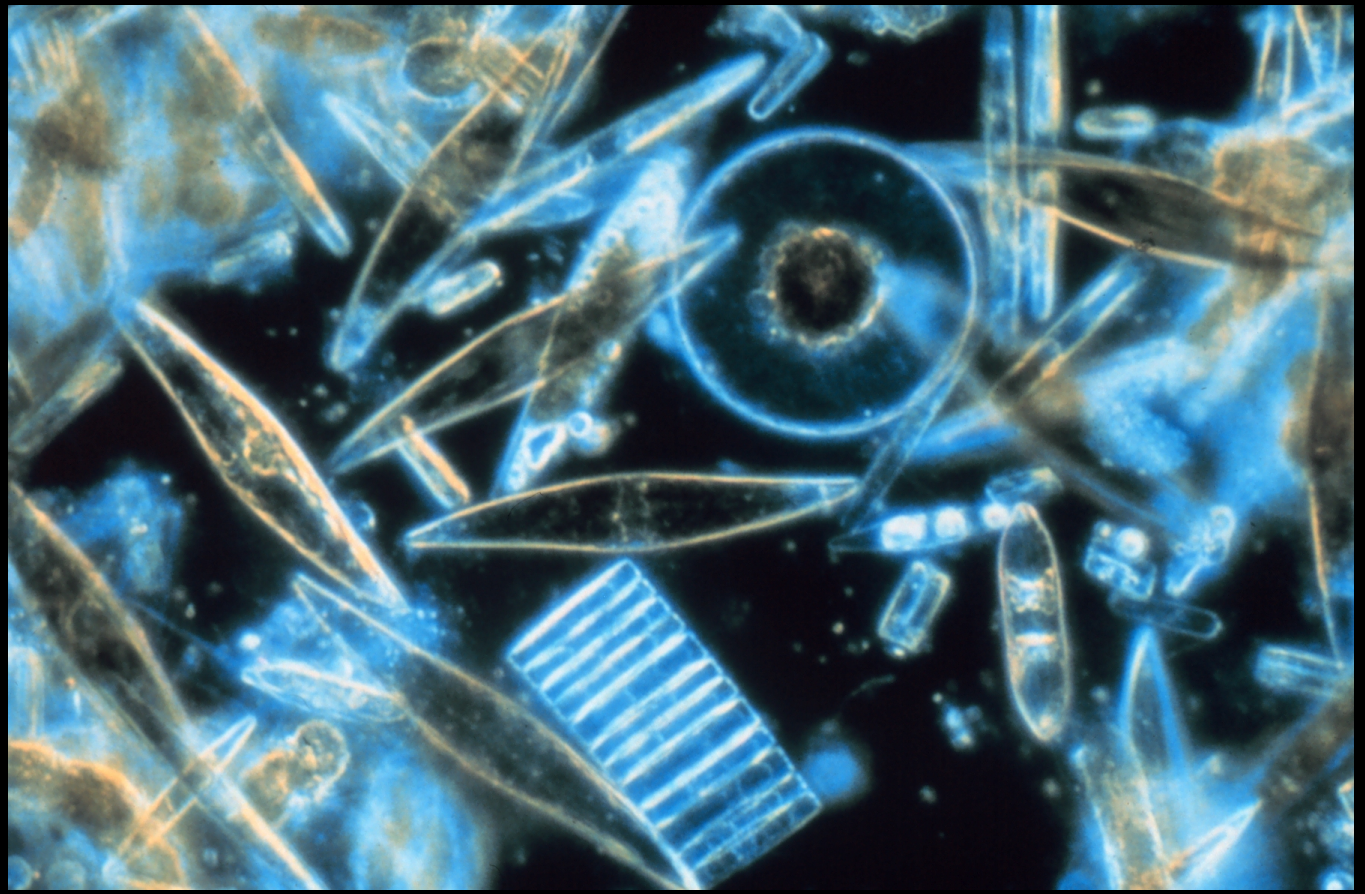
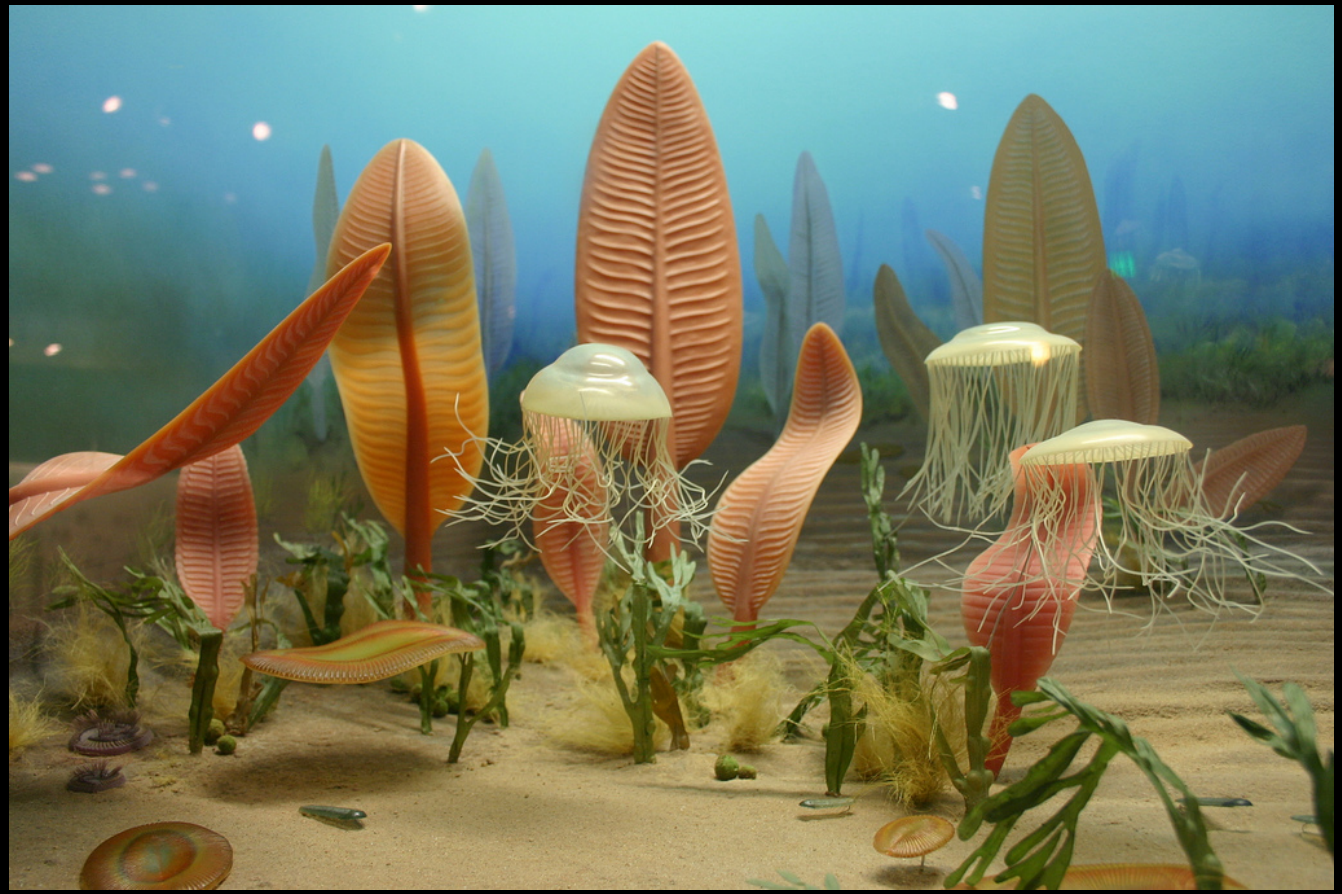
In the Beginning...

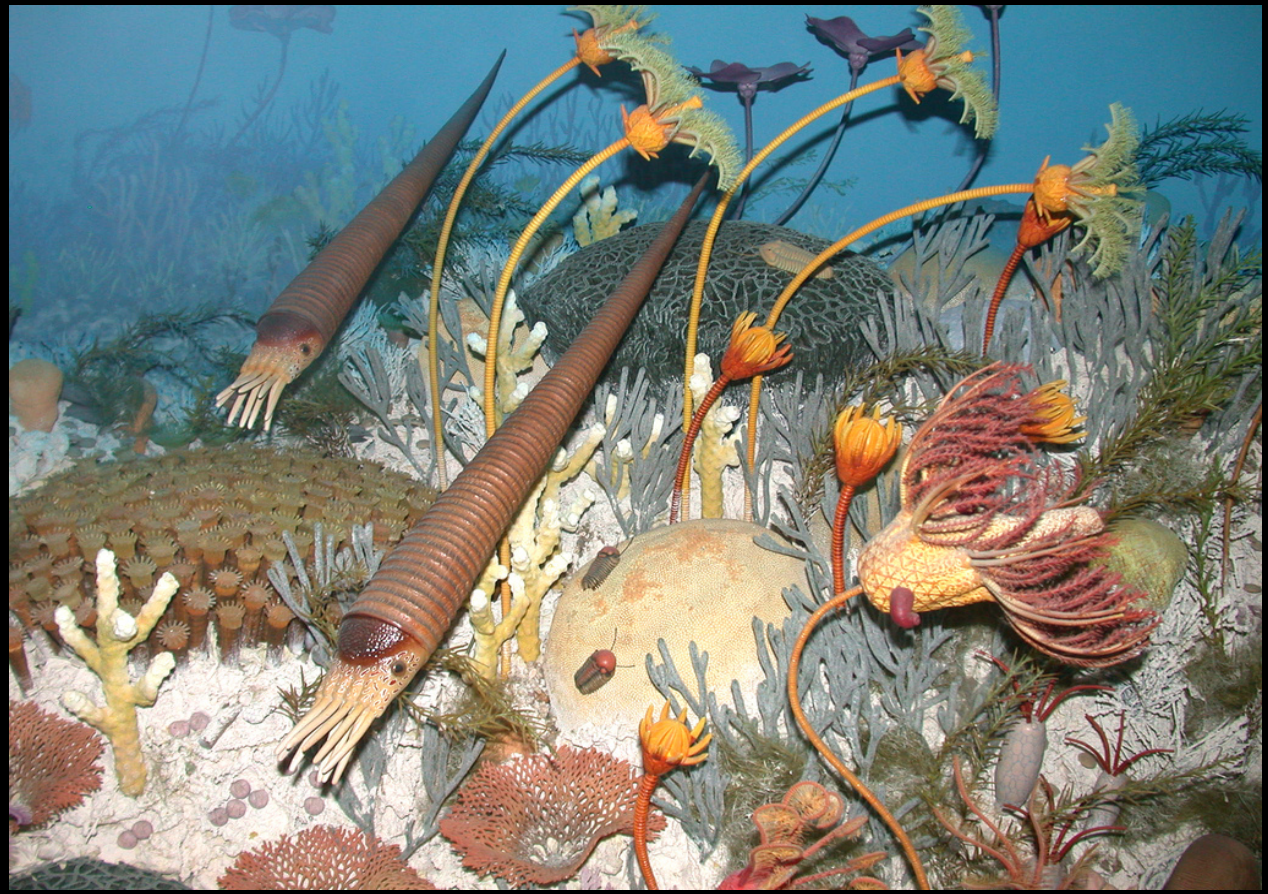


"Assorted diatoms found living between crystals of annual sea ice in Antarctica" (Public Domain)
by Prof. Gordon T. Taylor, Stony Brook University - corp2365, NOAA Corps Collection

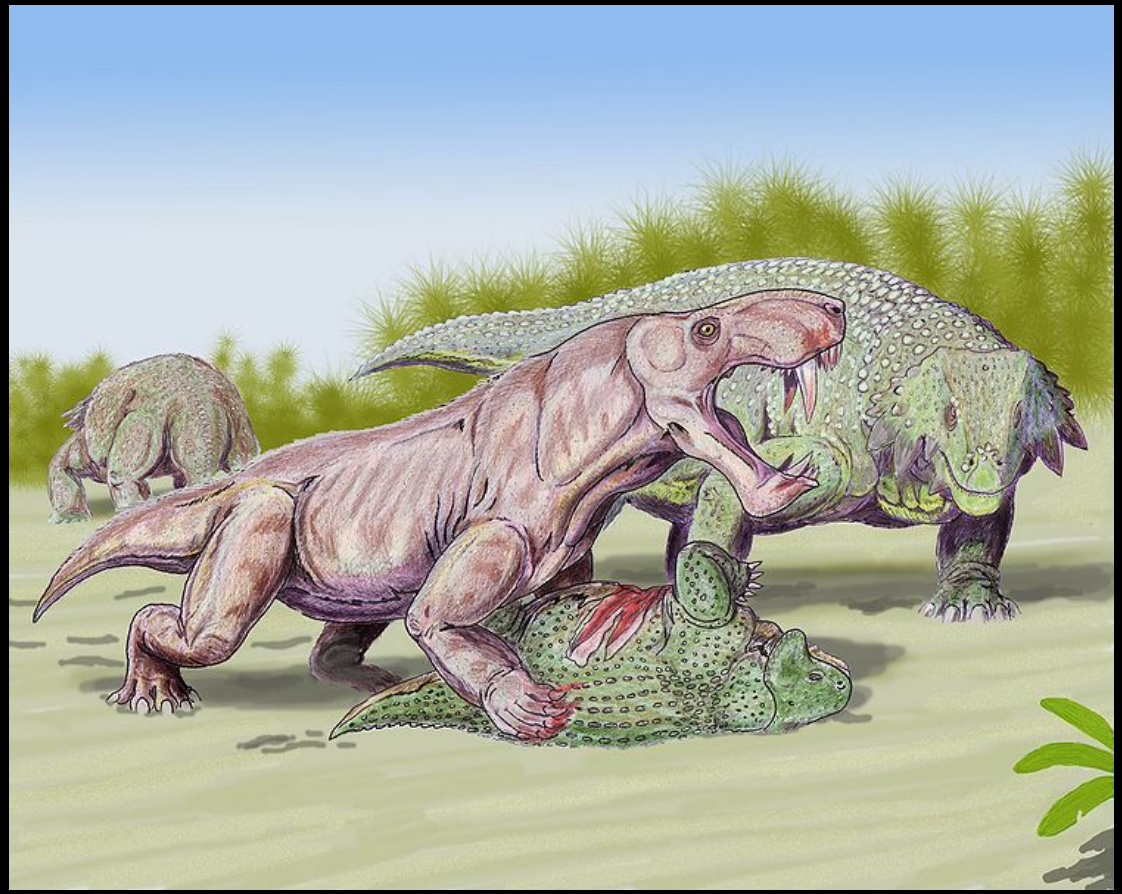
Diversification and Adaption



Diversification and Adaption



Diversification and Adaption



Extinction Events

The Age of the Mammals

The Anthropocene

The Anthropocene

More than 75 percent decline over 27 years in total flying insect biomass in protected areas

Caspar A. Hallmann, Martin Sorg, Eelke Jongejans, Henk Siepel, Nick Hofland, Heinz Schwan, Werner Stenmans, Andreas Müller, Hubert Sumser, Thomas Hörren, Dave Goulson, Hans de Kroon

Extinction rates rise...

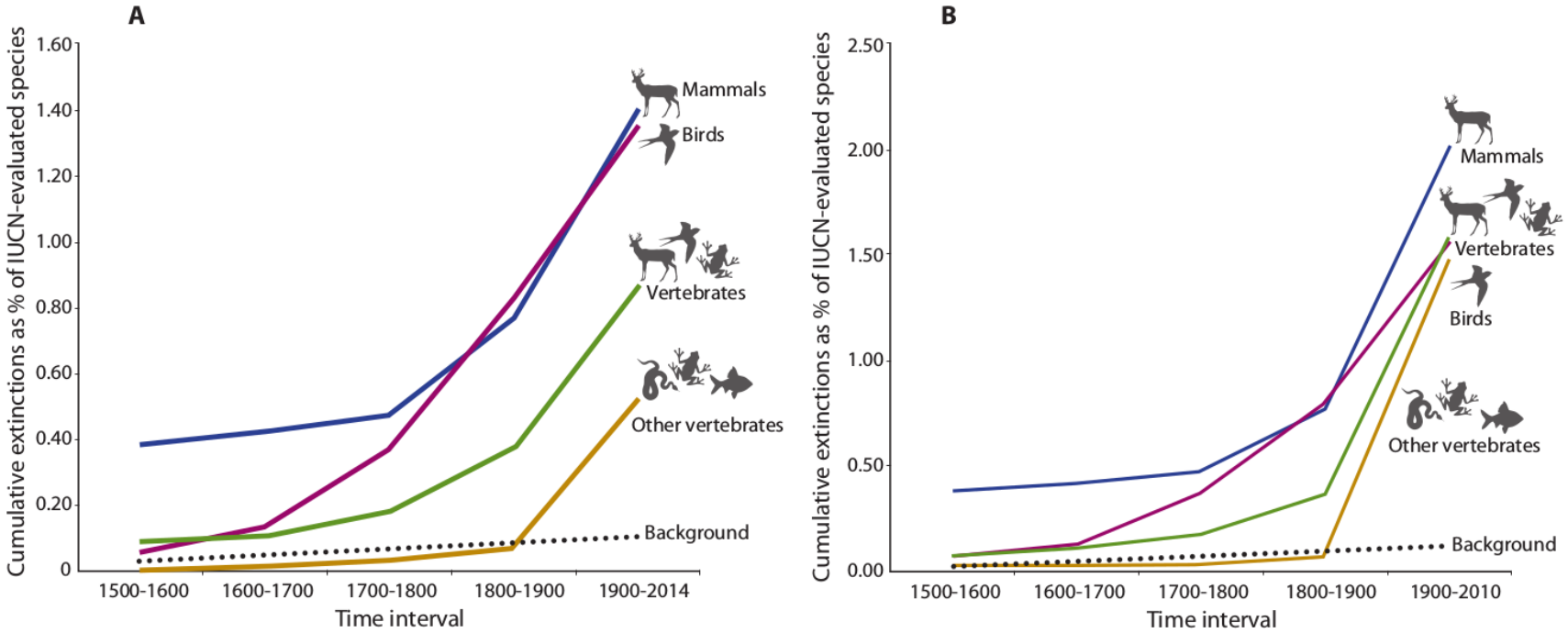
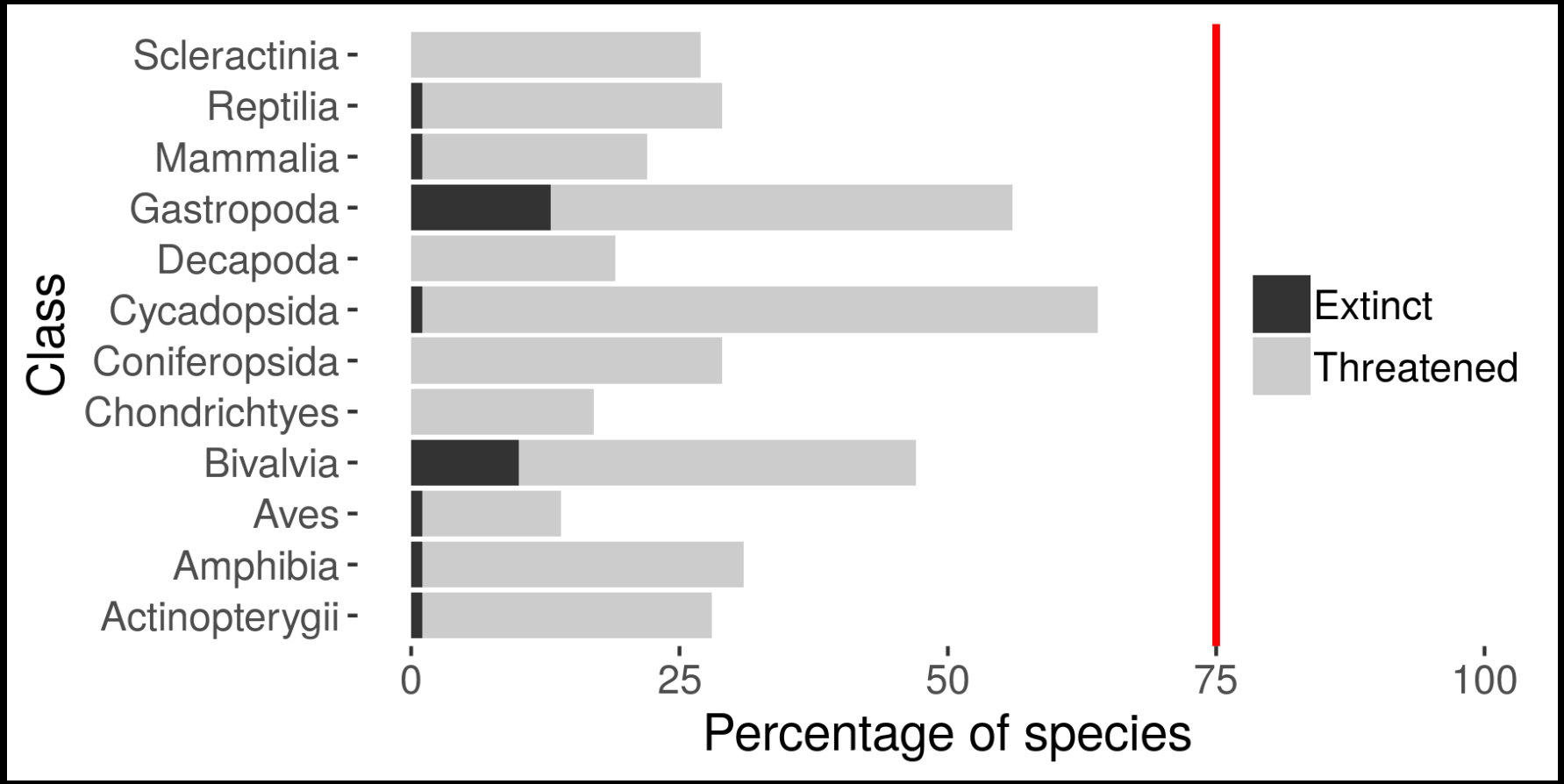


Fig. 1. Cumulative vertebrate species recorded as extinct or extinct in the wild by the IUCN (2012). Graphs show the percentage of the number of species evaluated among mammals (5513; 100% of those described), birds (10,425; 100%), reptiles (4414; 44%), amphibians (6414; 88%), fishes (12,457; 38%), and all vertebrates combined (39,223; 59%). Dashed black curve represents the number of extinctions expected under a constant standard background rate of 2 E/MSY. (**A**) Highly conservative estimate. (**B**) Conservative estimate.

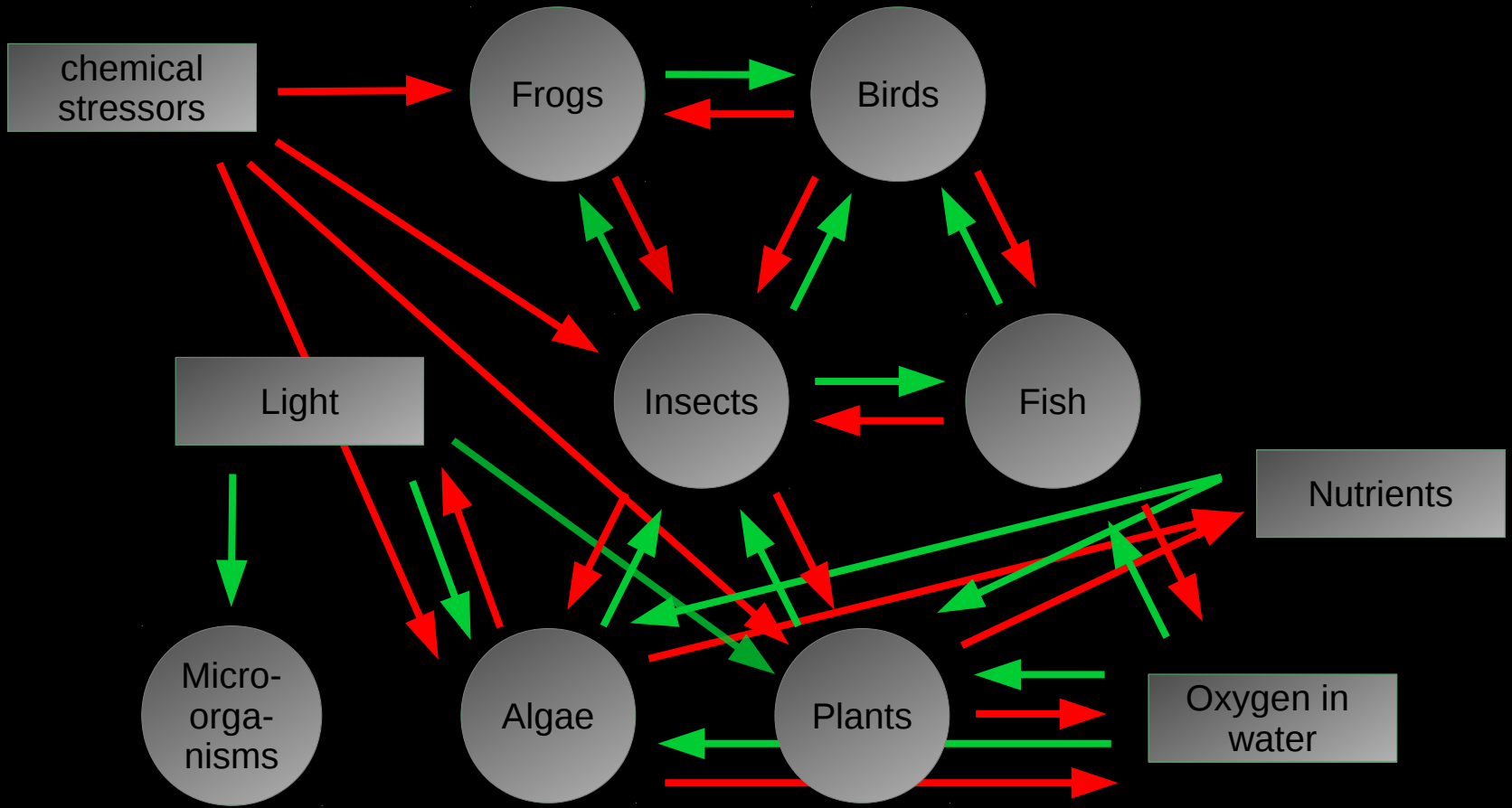
Extinction rates rise...



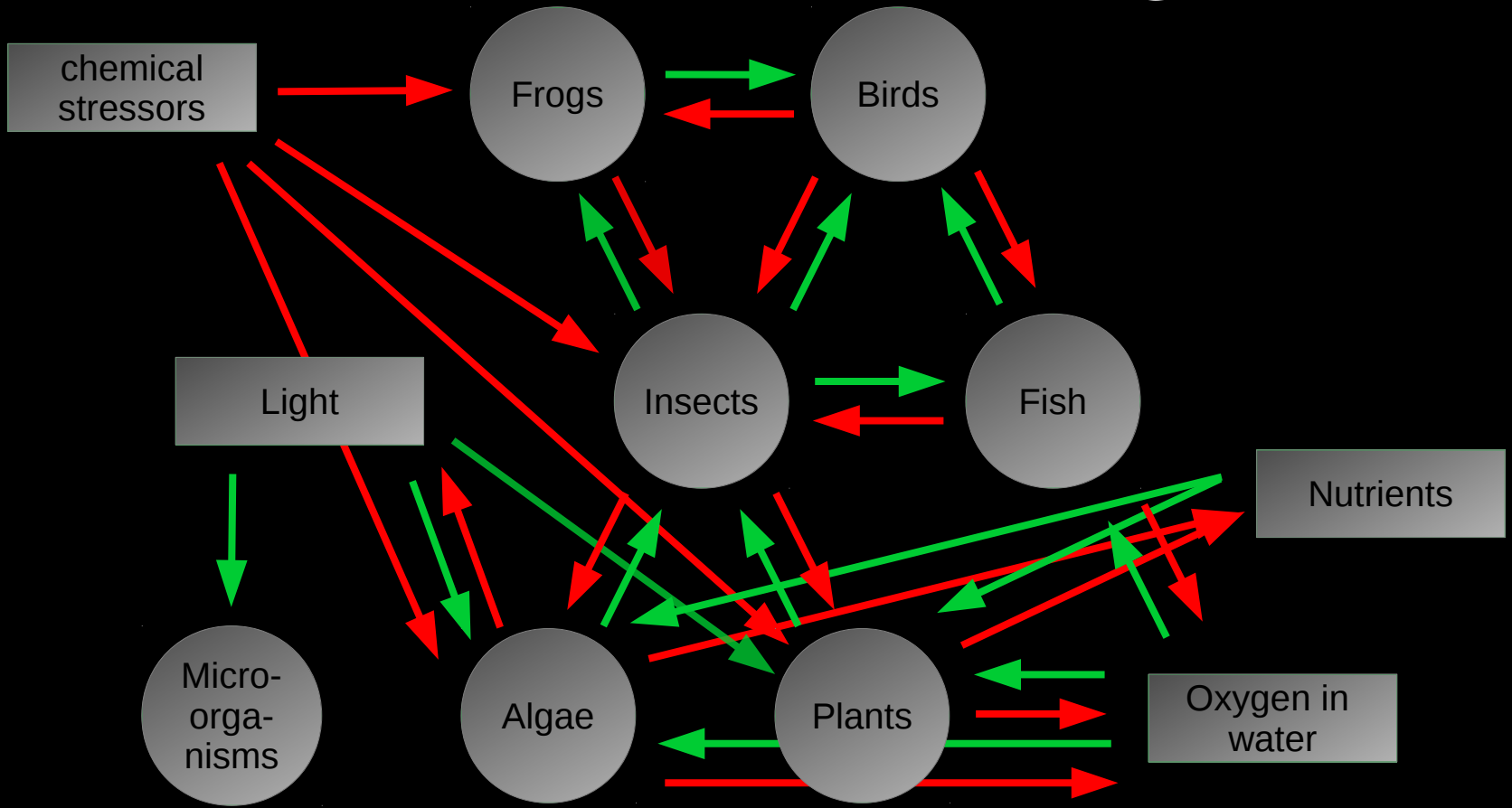
Data from Barnosky et al., Nature (2011)

And everyone knows it

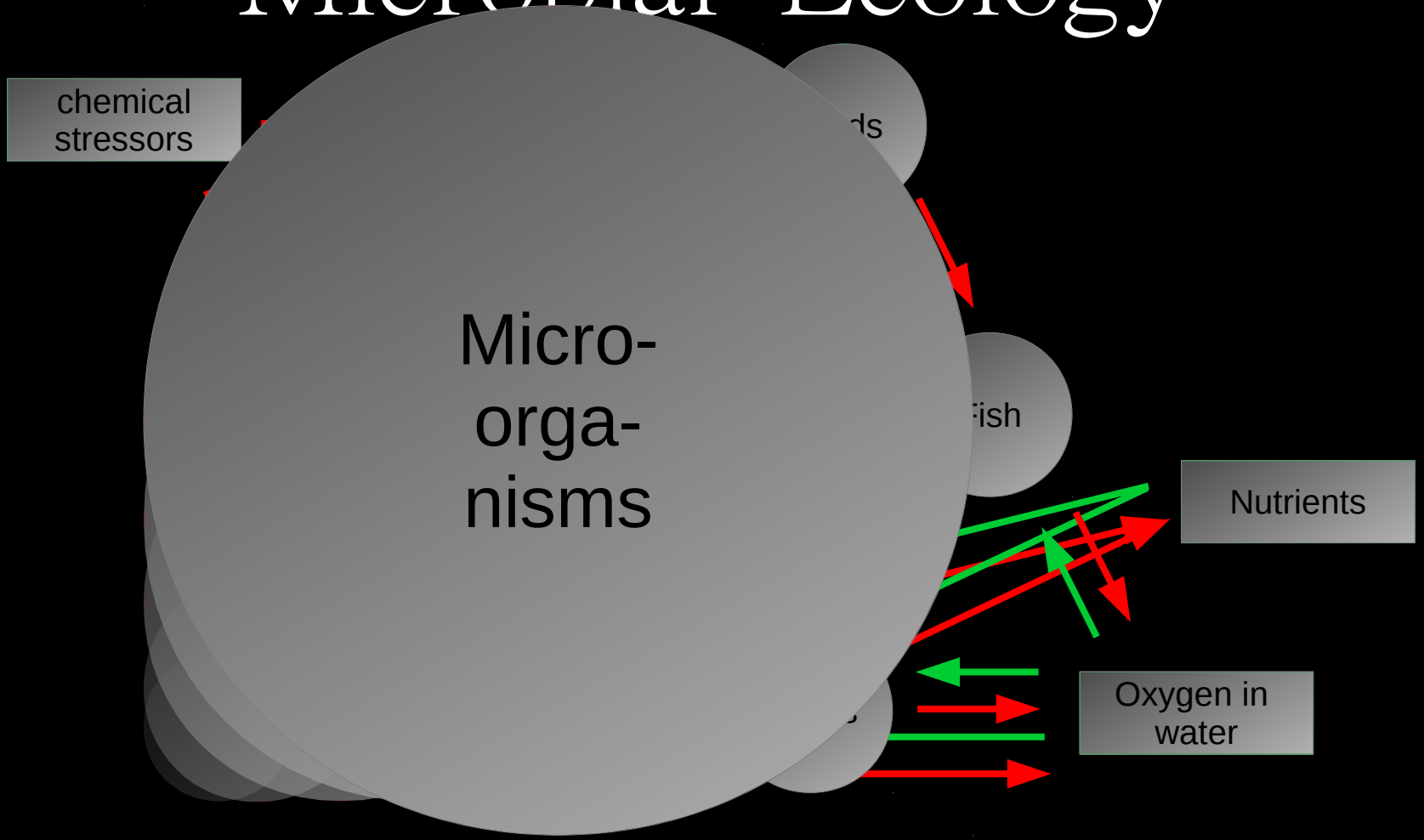
What is an ecosystem, anyway?



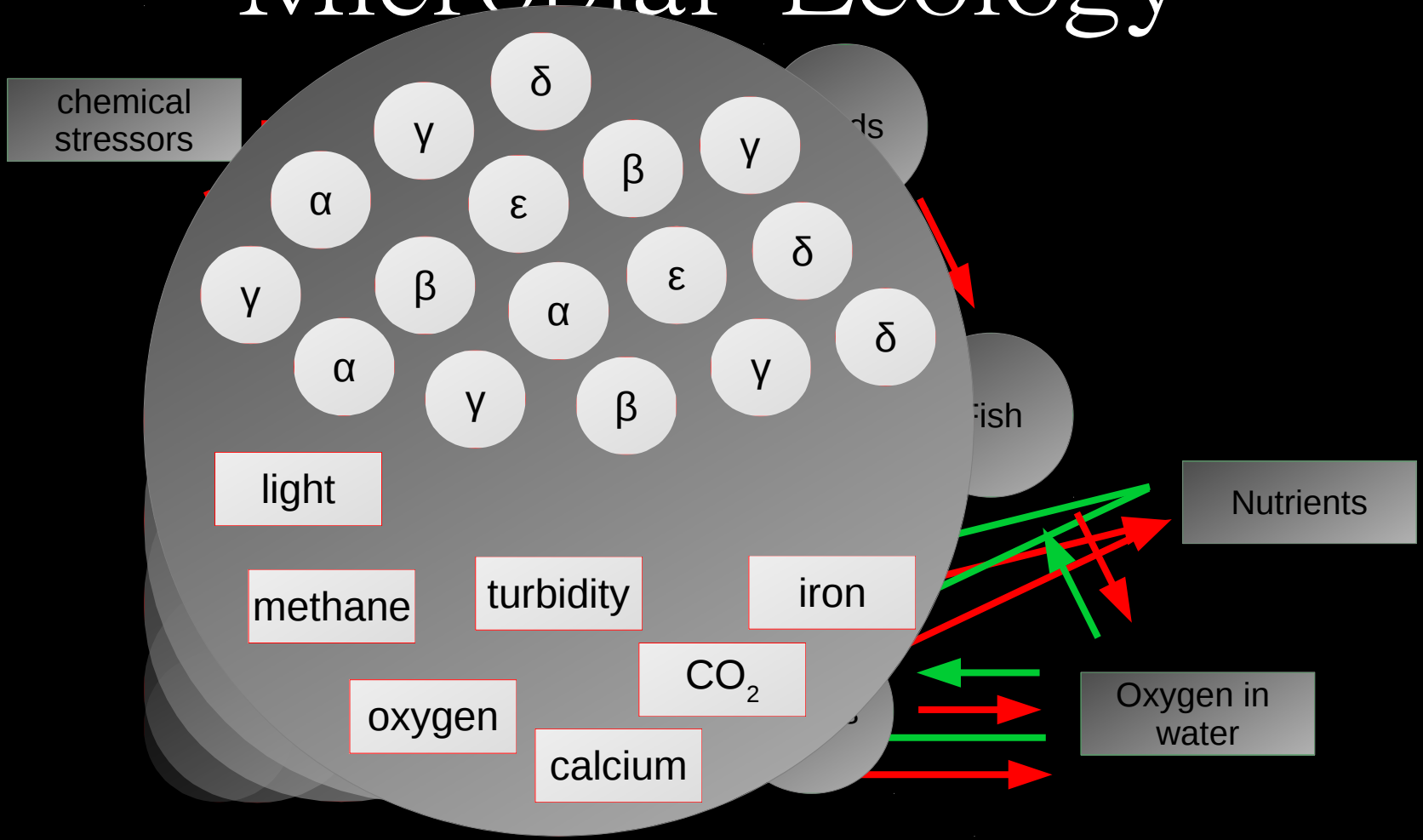
Microbial Ecology



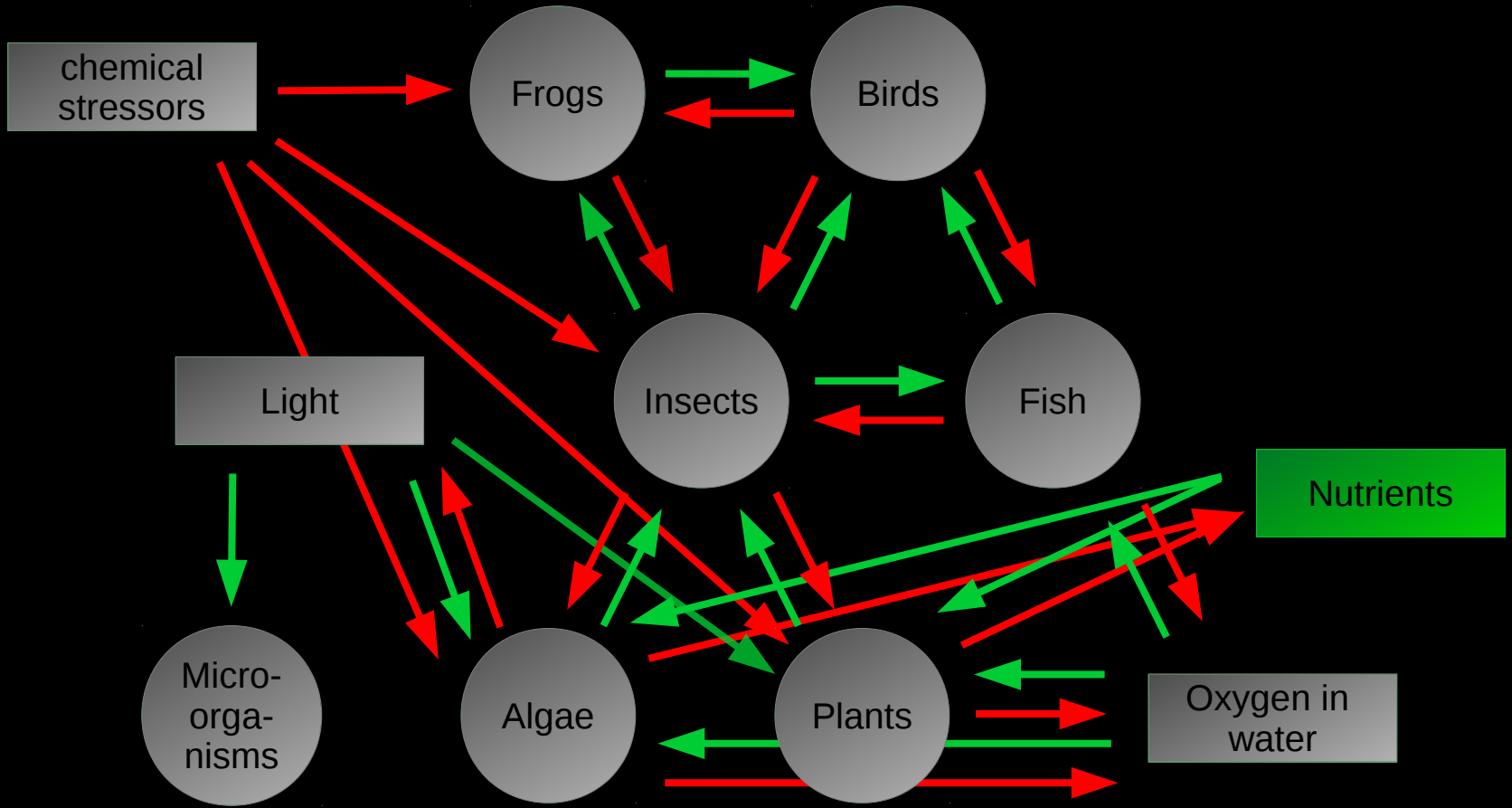
Microbial Ecology



Microbial Ecology



Disruption I: Nutrient excess



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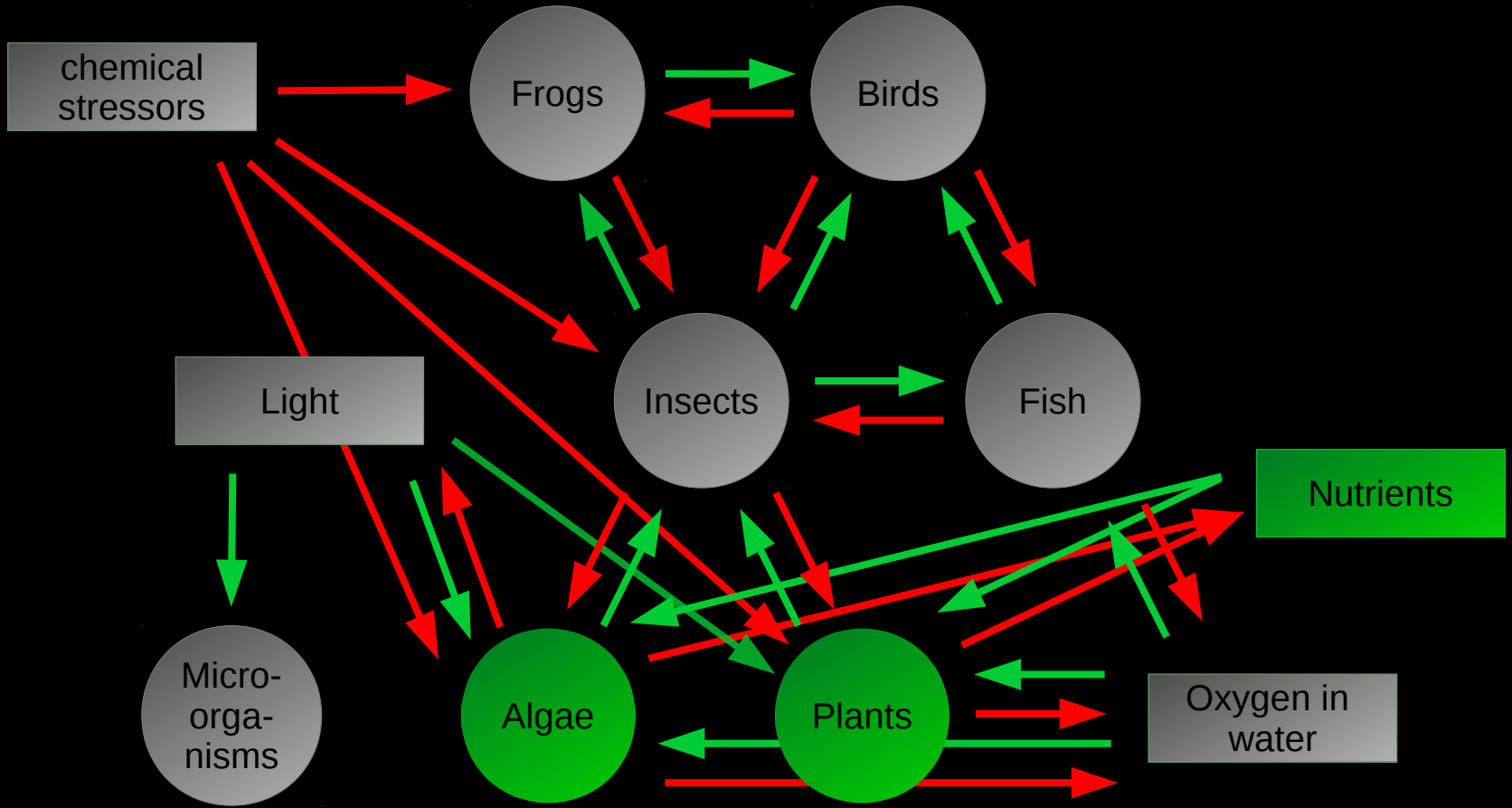

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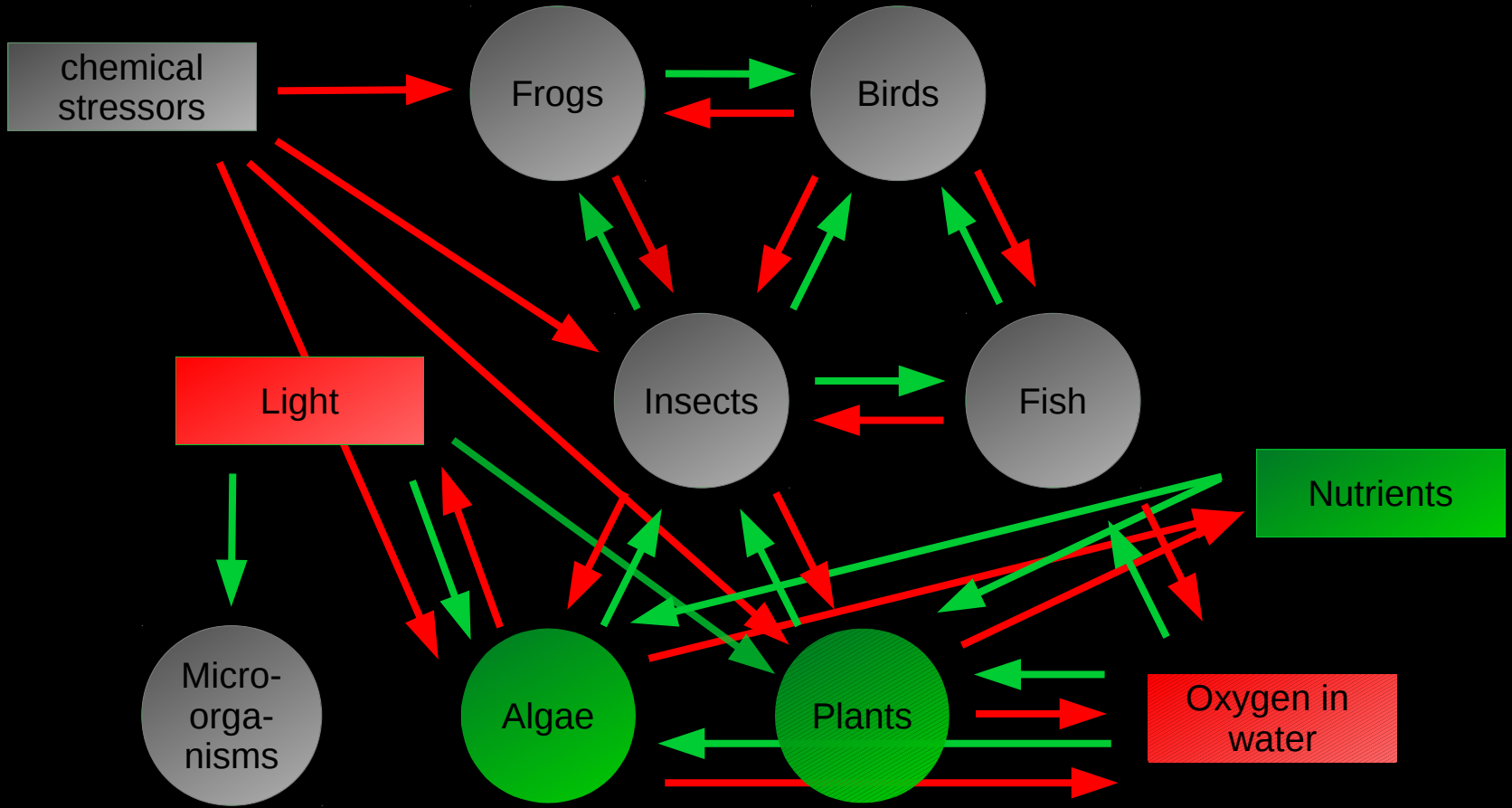

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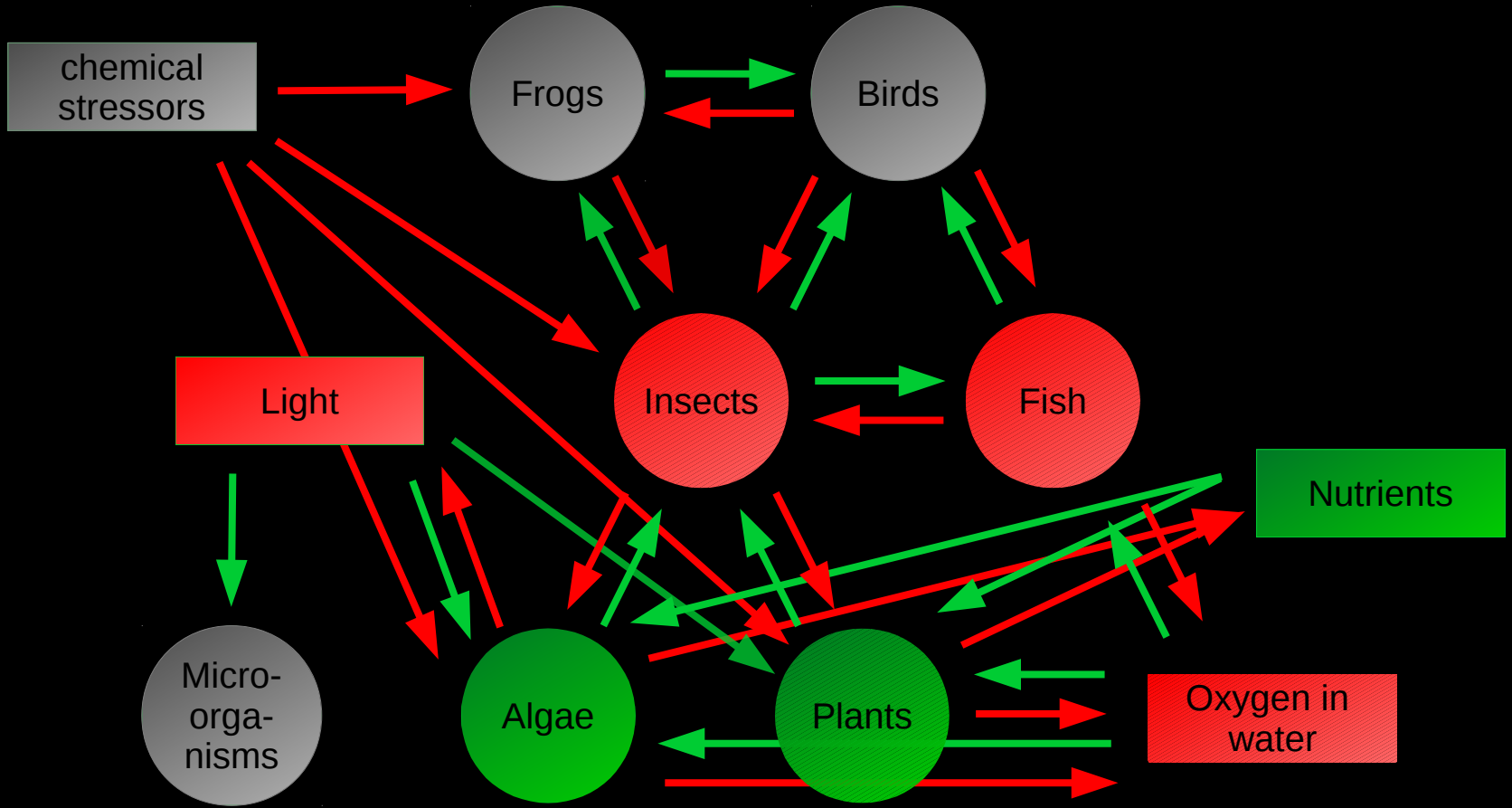

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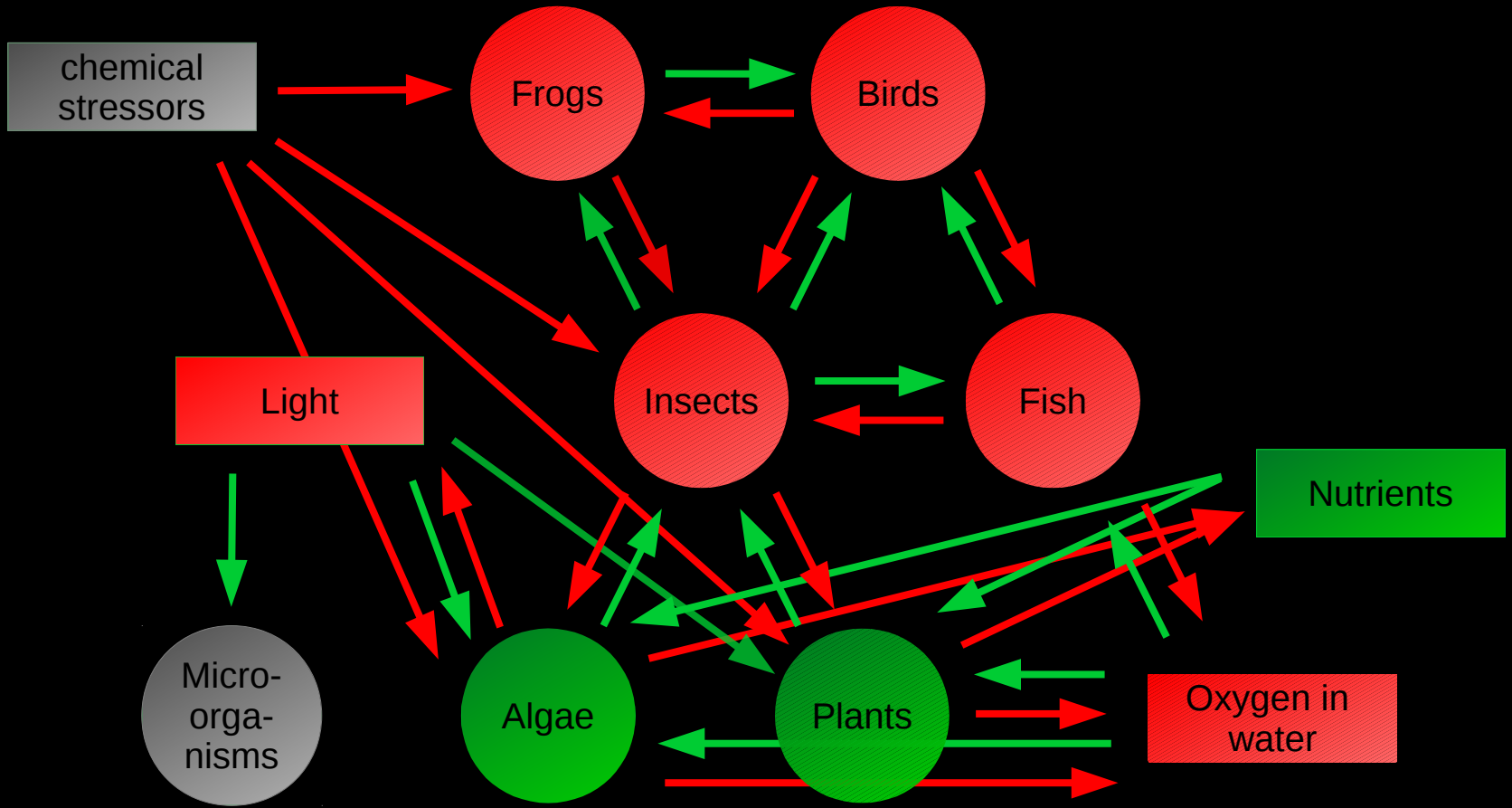
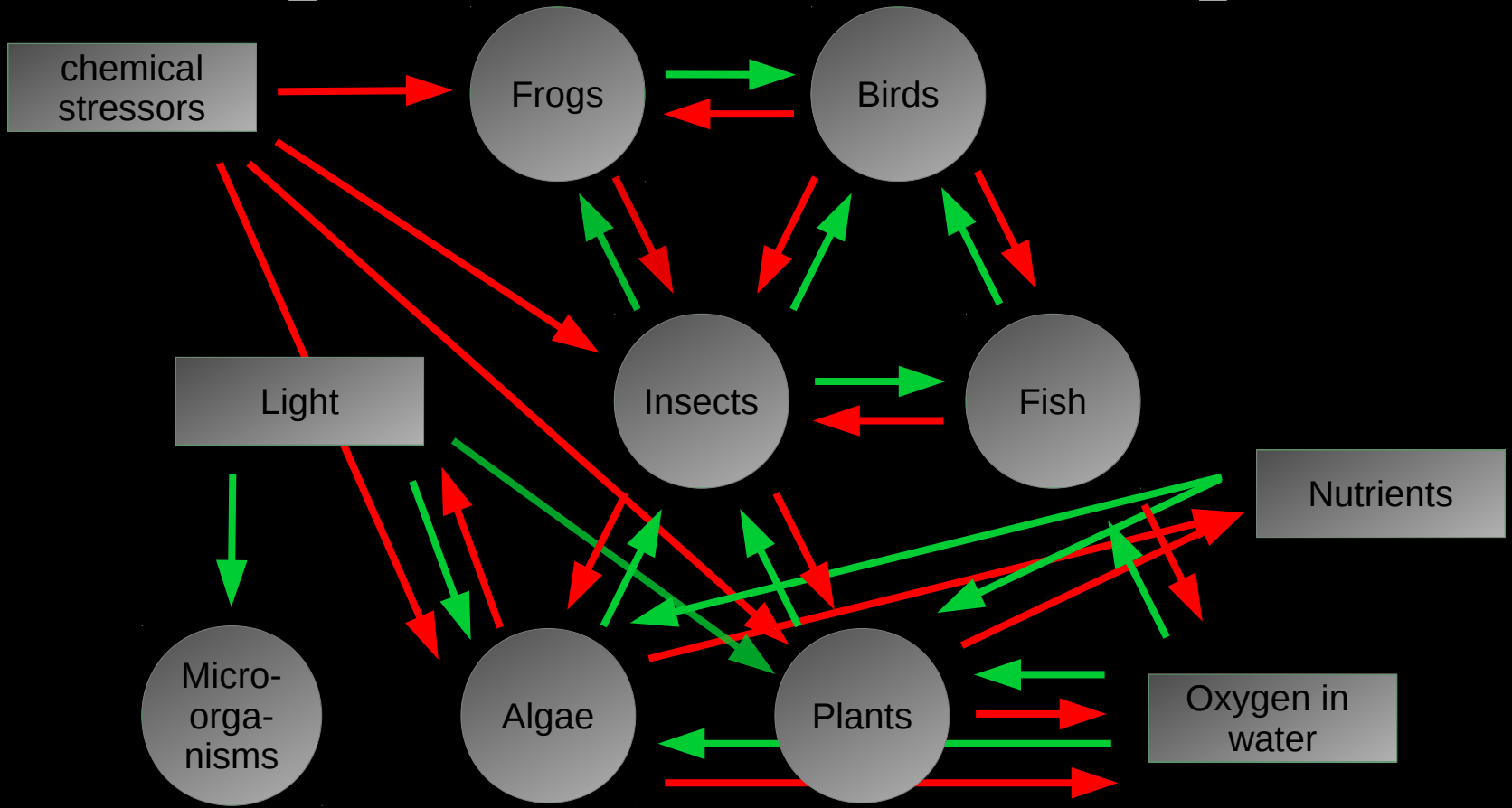


Disruption II: Alien species



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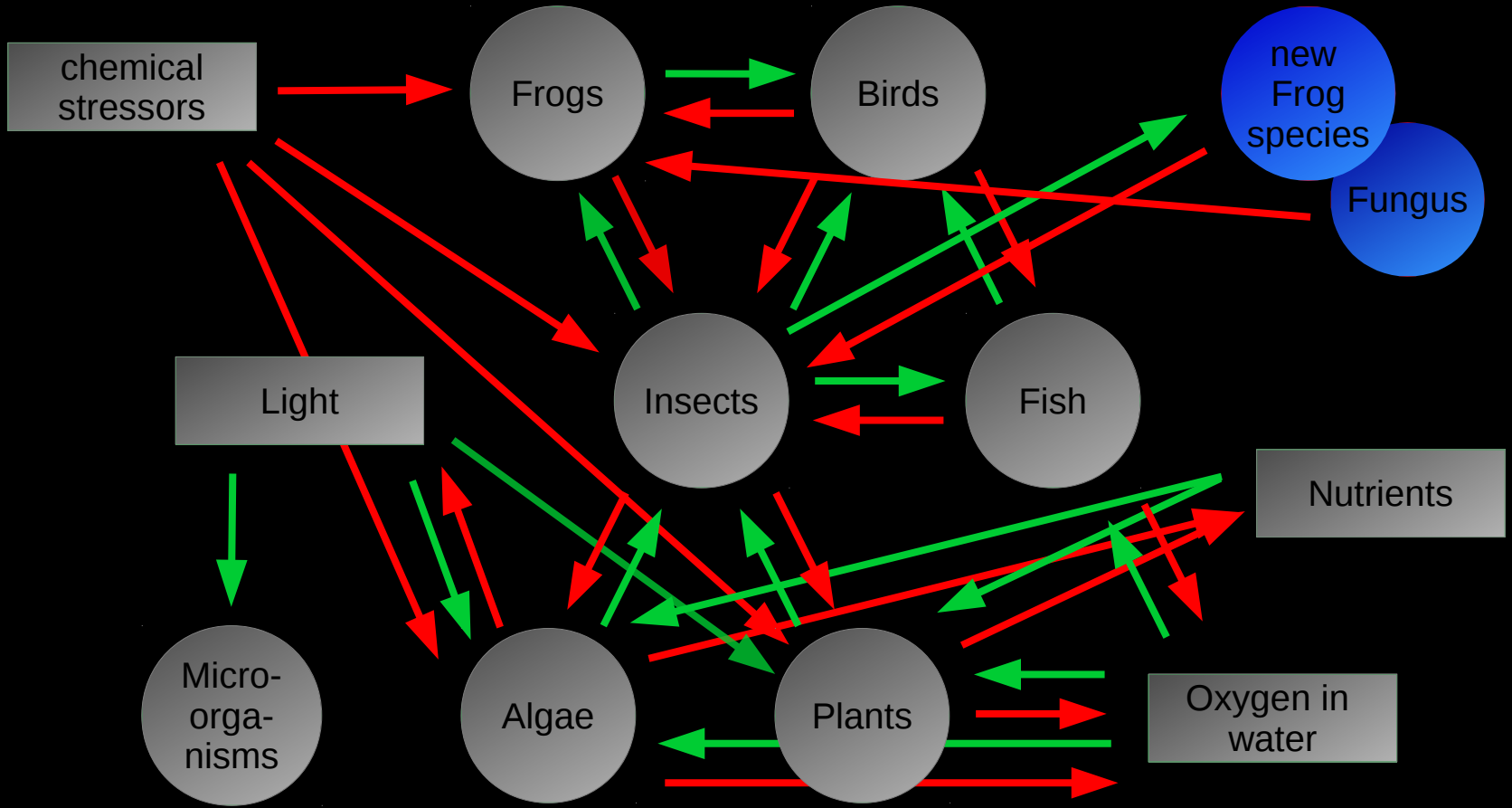

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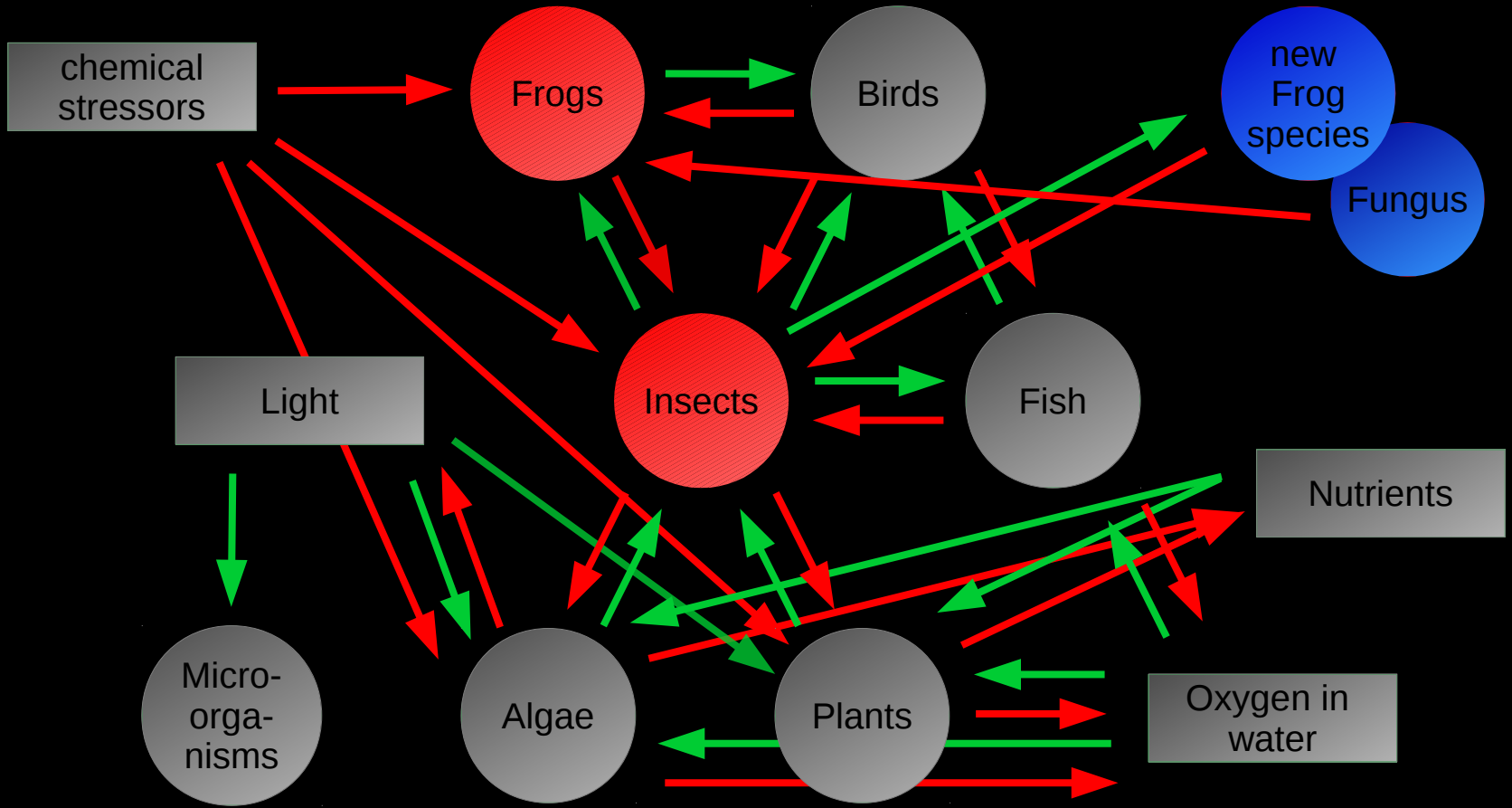

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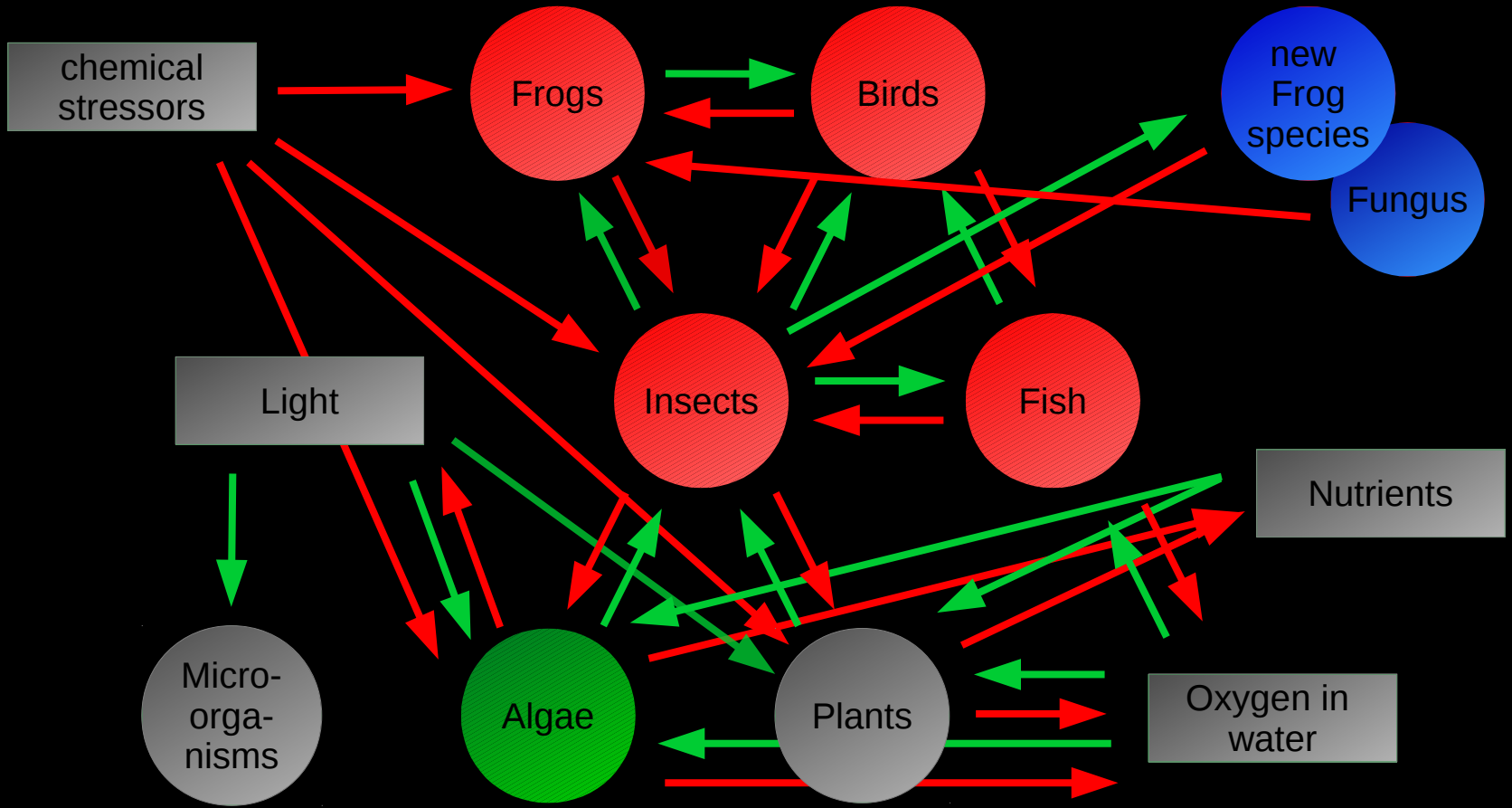
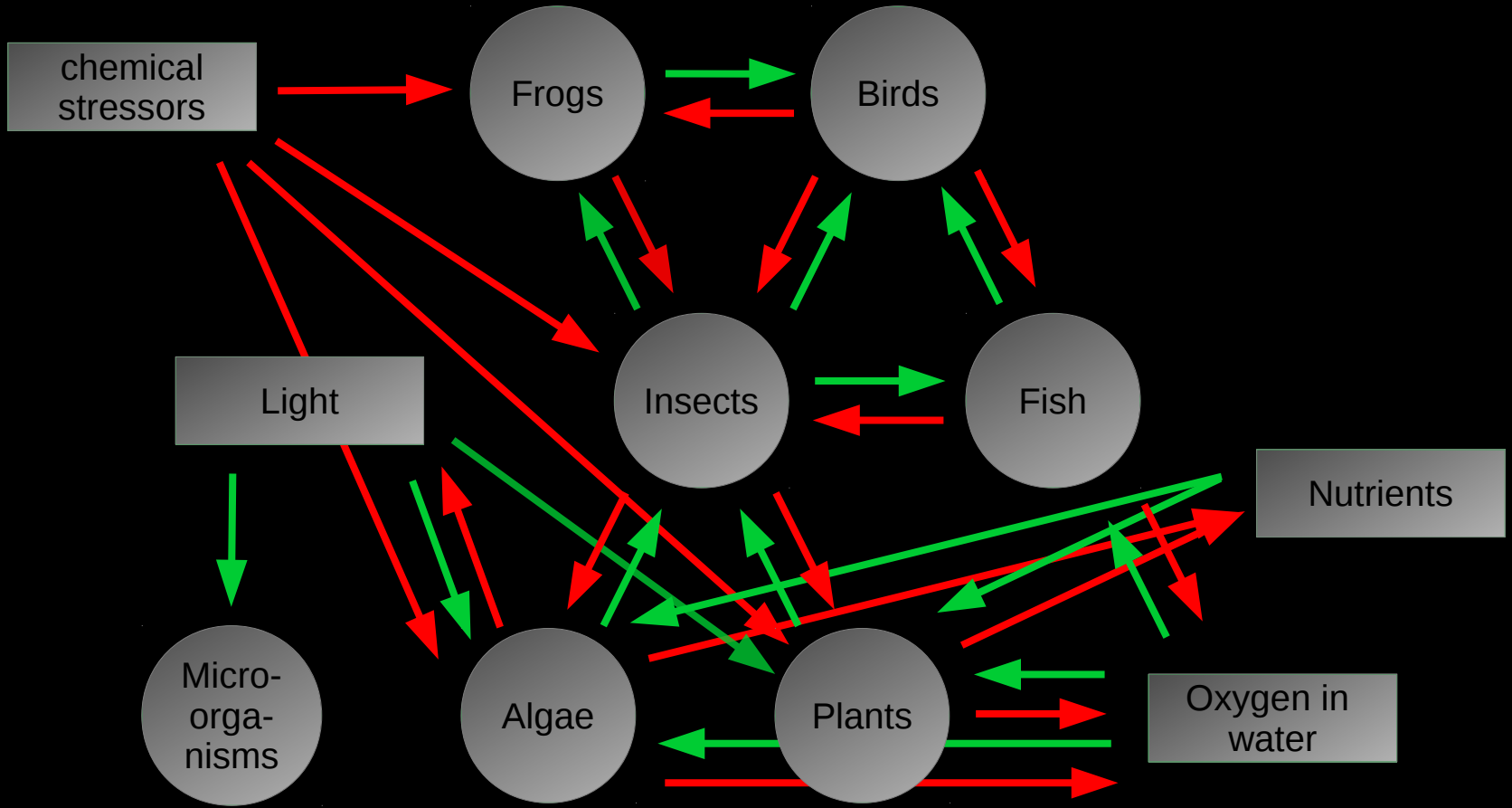


Disruption III: A Dam

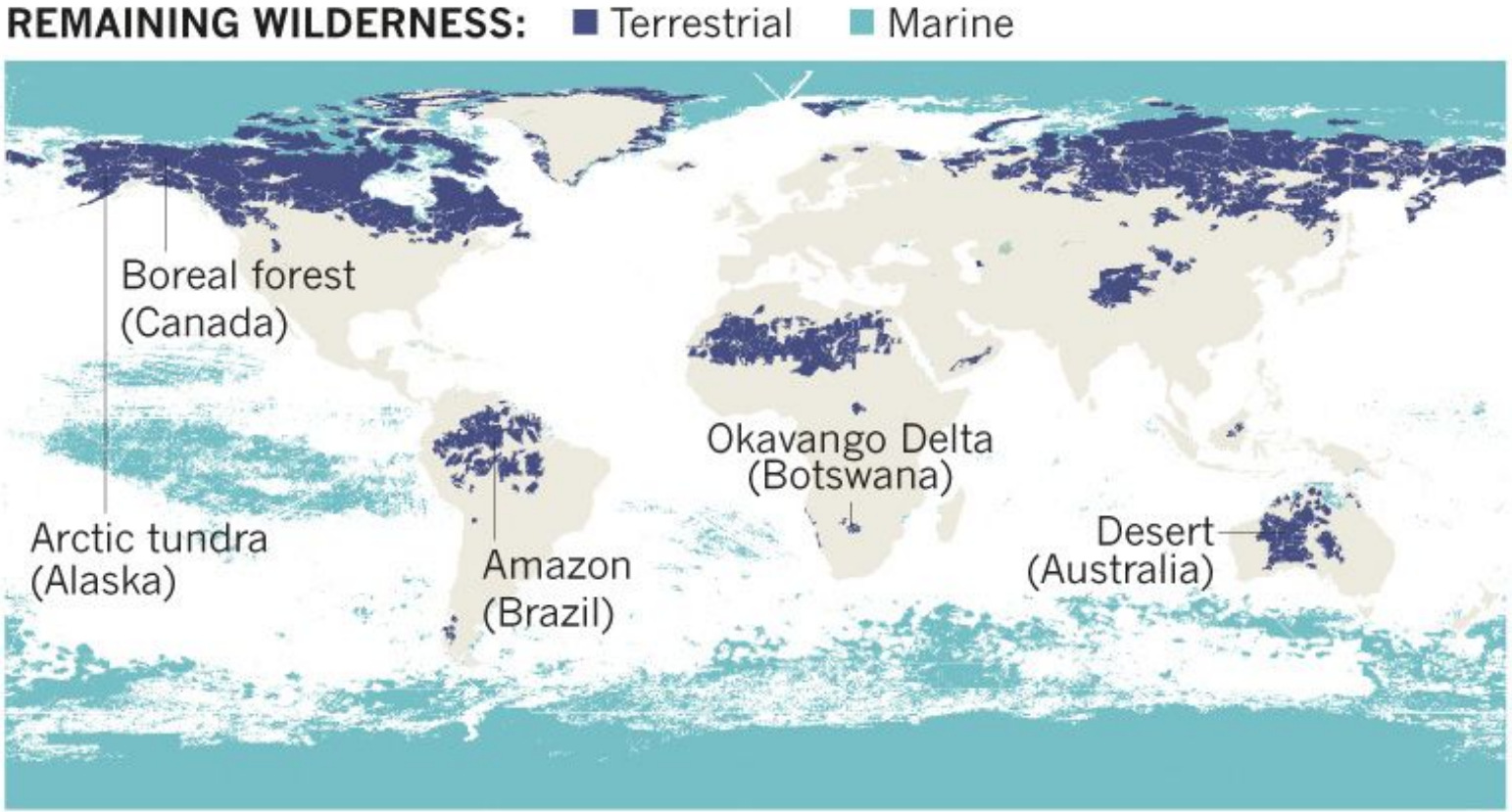


Solution I:
Leave Earth alone.

https://www.half-earthproject.org/

THE HUMAN FOOTPRINT

77% of land (excluding Antarctica) and 87% of the ocean has been modified by the direct effects of human activities.



Adapted after Watson et al., "Protect the last of the wild." Comment in Nature 563, 27-30 (2018)

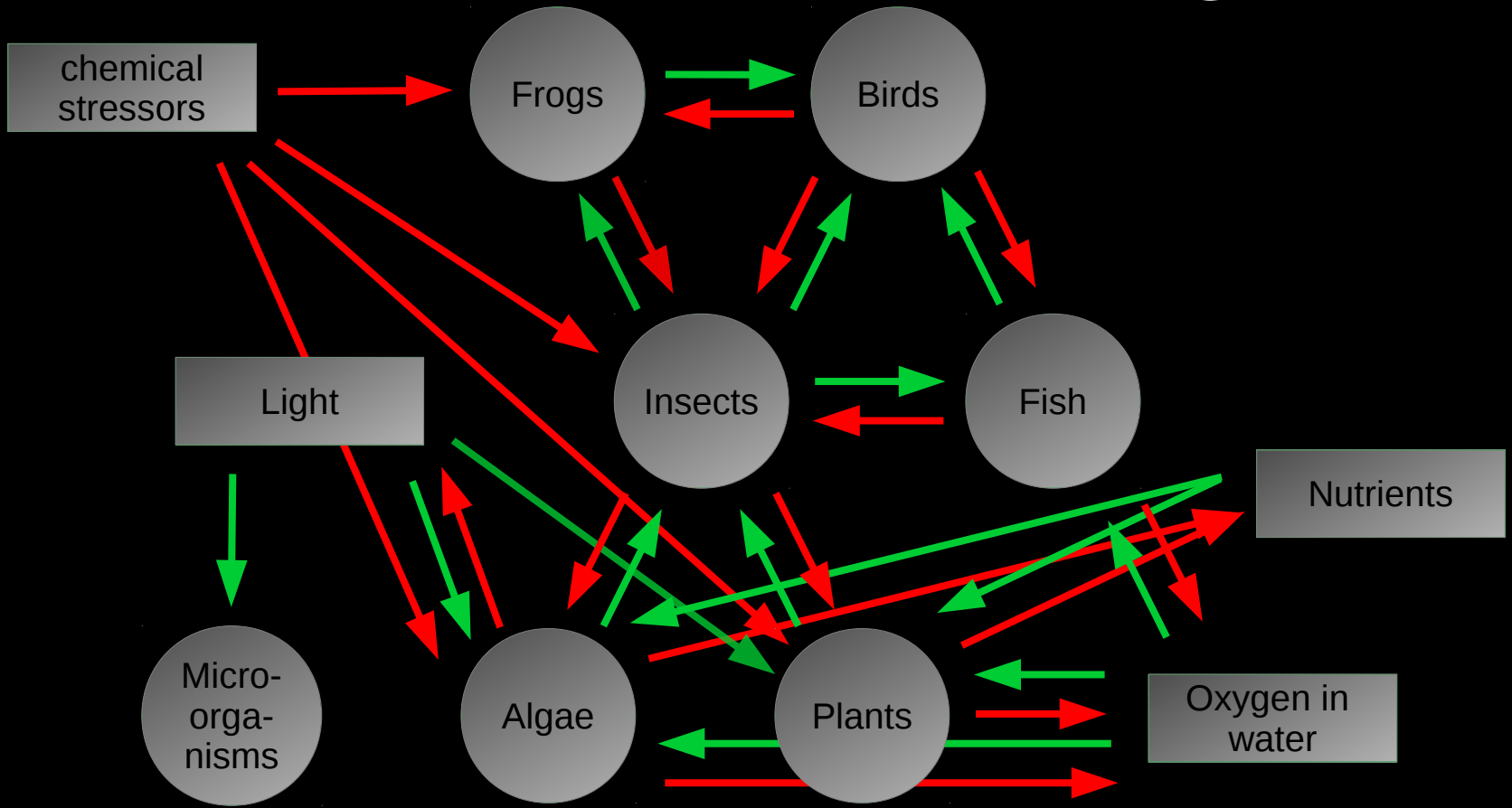
Solution II: Hack Ecosystems.

Hacking-cyber-blackandwhite-crime-2903156 (CC0) by iAmMrRob

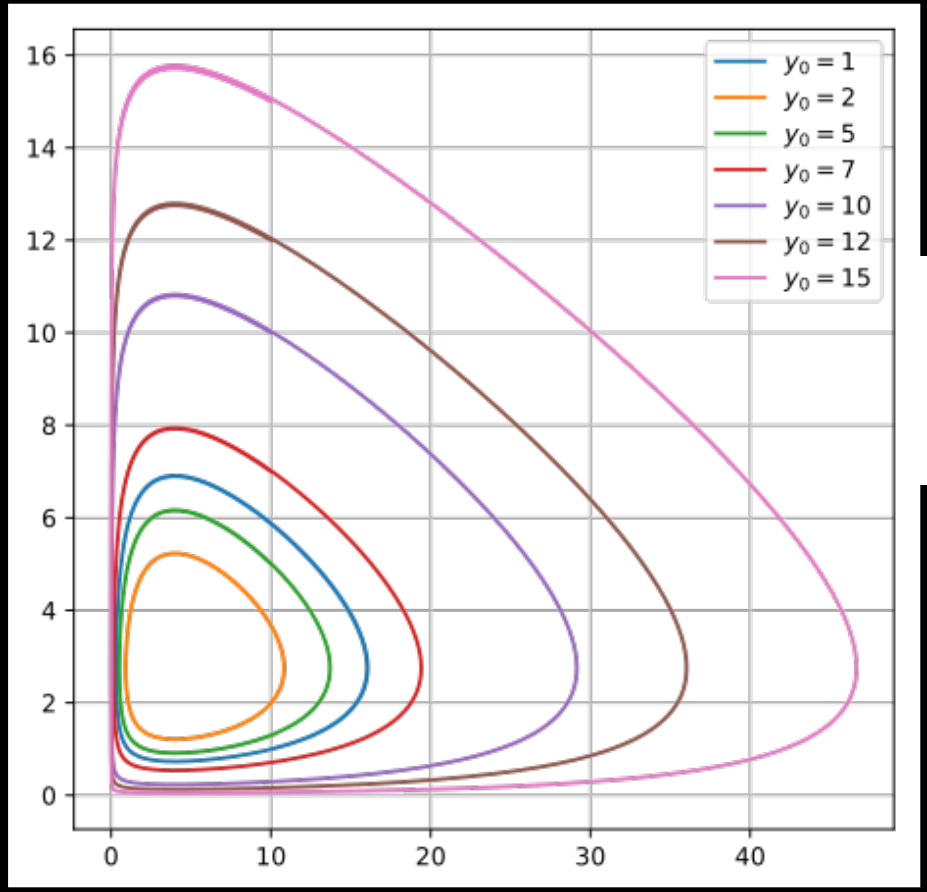
Solution II: Hack Ecosystems.

"The Earth seen from Apollo 17.jpg" (Public Domain) by NASA, Hacking-cyber-blackandwhite-crime-2903156 (CC0) by iAmMrRob

Data-driven ecology



Data-driven ecology: Modeling



$$\frac{dx}{dt} = \alpha x - \beta x y$$

$$\frac{dy}{dt} = \delta x y - \gamma y$$

Data-driven ecology: Modeling

The physical model is mathematically transposed by the balance equation of phytoplankton biomass (A), herbivore zooplankton biomass (Z), total phosphorus (P), ammonia (NH_4) and nitrate (NO_3) [5]:

$$\frac{\partial A}{\partial t} = k_{max} f_{nutri} A - c_{za} AZ \,, \tag{1}$$

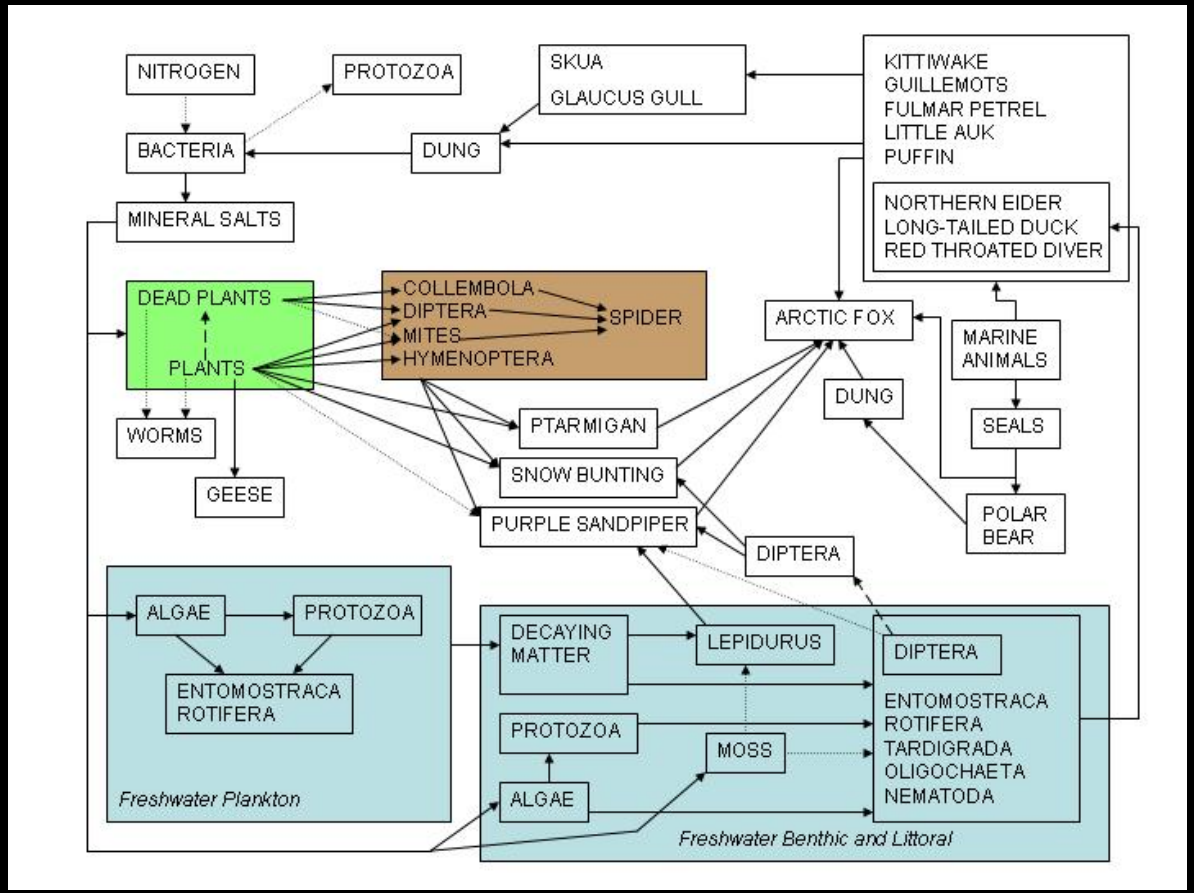
$$\frac{\partial Z}{\partial t} = a_{ca} \varepsilon c_{za} AZ - k_{dz} Z \,, \tag{2}$$

$$\frac{\partial P}{\partial t} = a_{pa}(1-\varepsilon) c_{za} AZ + a_{pc} k_{dz} Z - a_{pa} k_{max} f_{nutri} A, \tag{3}$$

$$\frac{\partial NH_4}{\partial t} = a_{na}(1-\varepsilon) c_{za} AZ + a_{nc} k_{dz} Z - F_{am} a_{na} k_{max} f_{nutri} A - k_{nt} NH_4 \,, \tag{4}$$

$$\frac{\partial NO_3}{\partial t} = k_{nt} NH_4 - a_{na}(1-F_{am}) k_{max} f_{nutri} A \,. \tag{5}$$

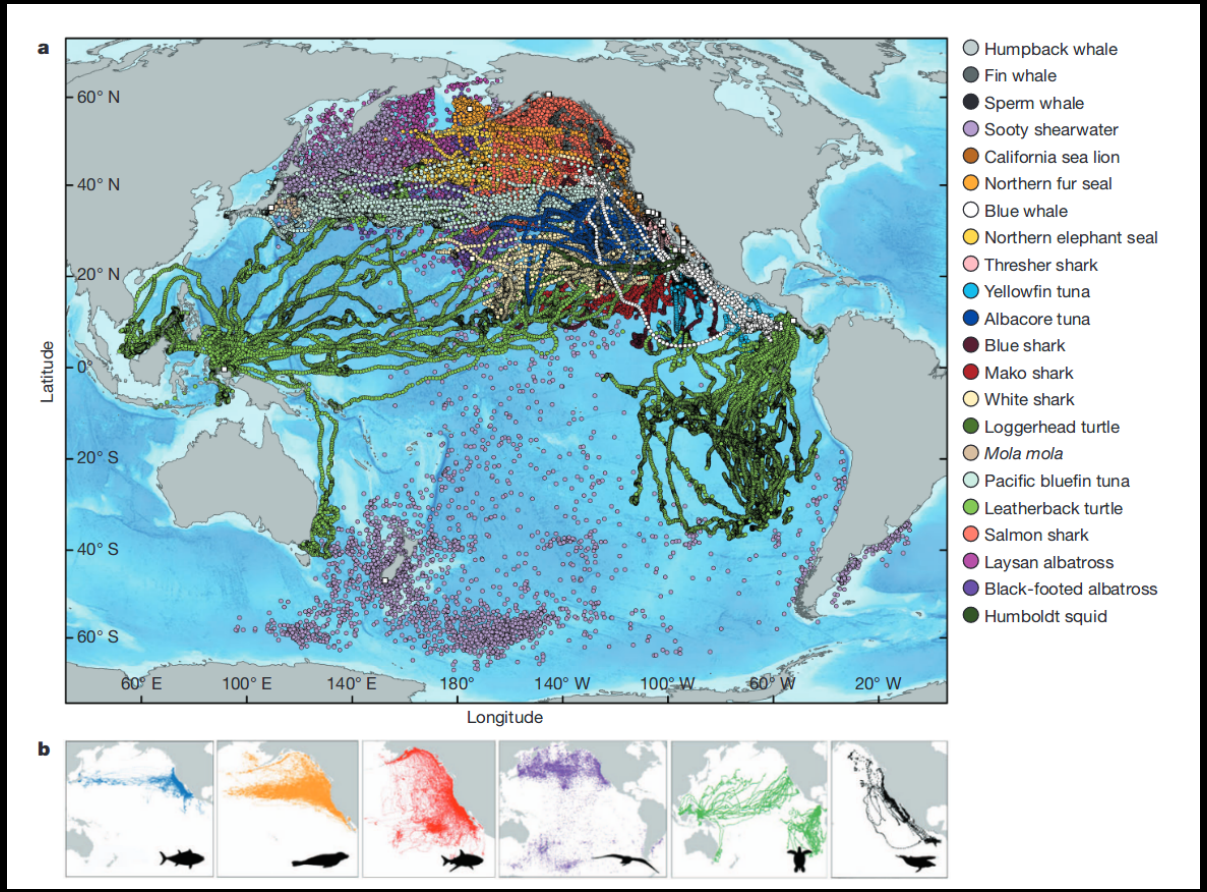
Data-driven ecology: Interactions



EltonFW.jpg (Public Domain), Original by by Summerhayes and Elton (1923)

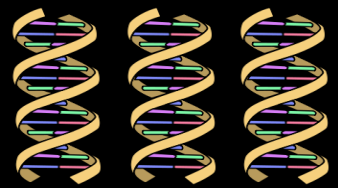
Data-driven ecology: Interactions

Data-driven ecology: Movement

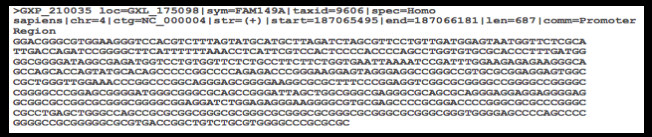


Block et al., Nature (2011)

Data-driven ecology: DNA sequencing



Sequencing



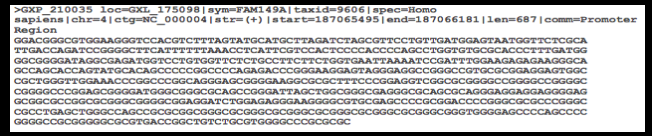
Assembly, mapping

List of (micro-) organisms

Correlation analyses

Co-occurrence network

RNA Sequencing



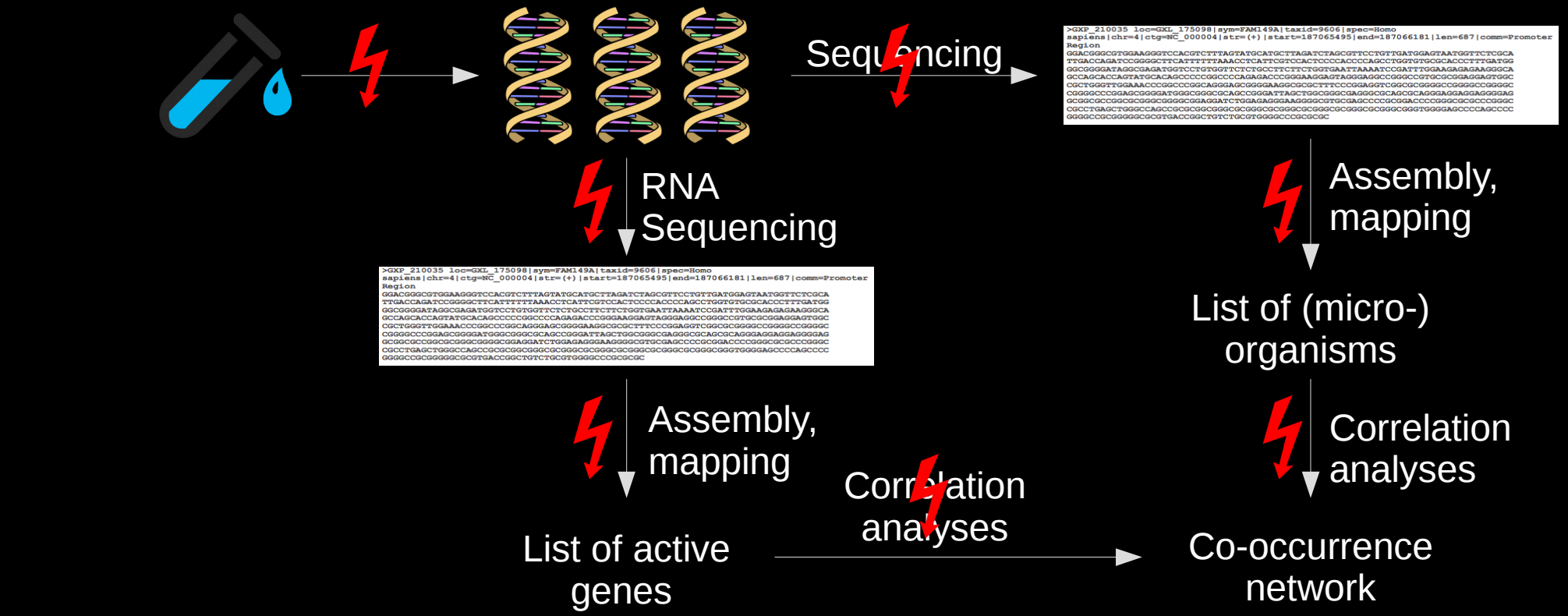
Assembly, mapping

List of active genes

Correlation analyses

The good news

The bad news: Batch effects



Summary

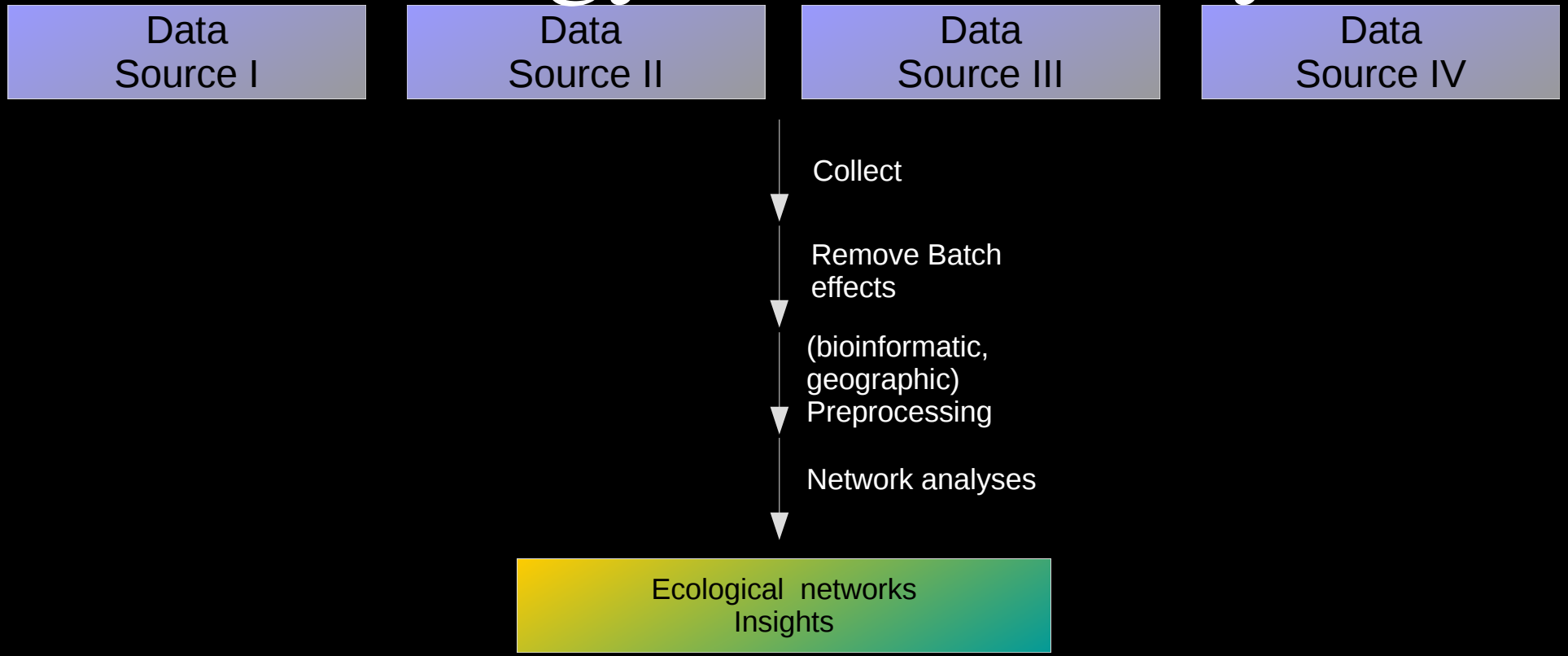
My invitation: Open Digital Ecology Community

- Open as in “Open Source”
- Digital as in “Data Science”
- Community as in “Citizen Science”

My invitation: Open Digital Ecology Community

- Open as in “Open Source”
- Digital as in “Data Science”
- Community as in “Citizen Science”
- The name is provisional

My invitation: Open Digital Ecology Community



Thank you!

sperleath@posteo.net
Twitter: @TSperlea
… or meet me around!

Further reading

- Berry, David, and Stefanie Widder. 2014. "*Deciphering Microbial Interactions and Detecting Keystone Species with Co-Occurrence Networks.*" Frontiers in Microbiology 5 (May). https://doi.org/10.3389/fmicb.2014.00219.
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