Environmental risks of biodiversity

ZA210 (Z5, Wednesday 15.00-16.50)

DEPARTMENT OF GEOGRAPHY
FACULTY OF SCIENCE MASARYK UNIVERSITY

Karel Brabec, Ph.D.

brabec@sci.muni.cz

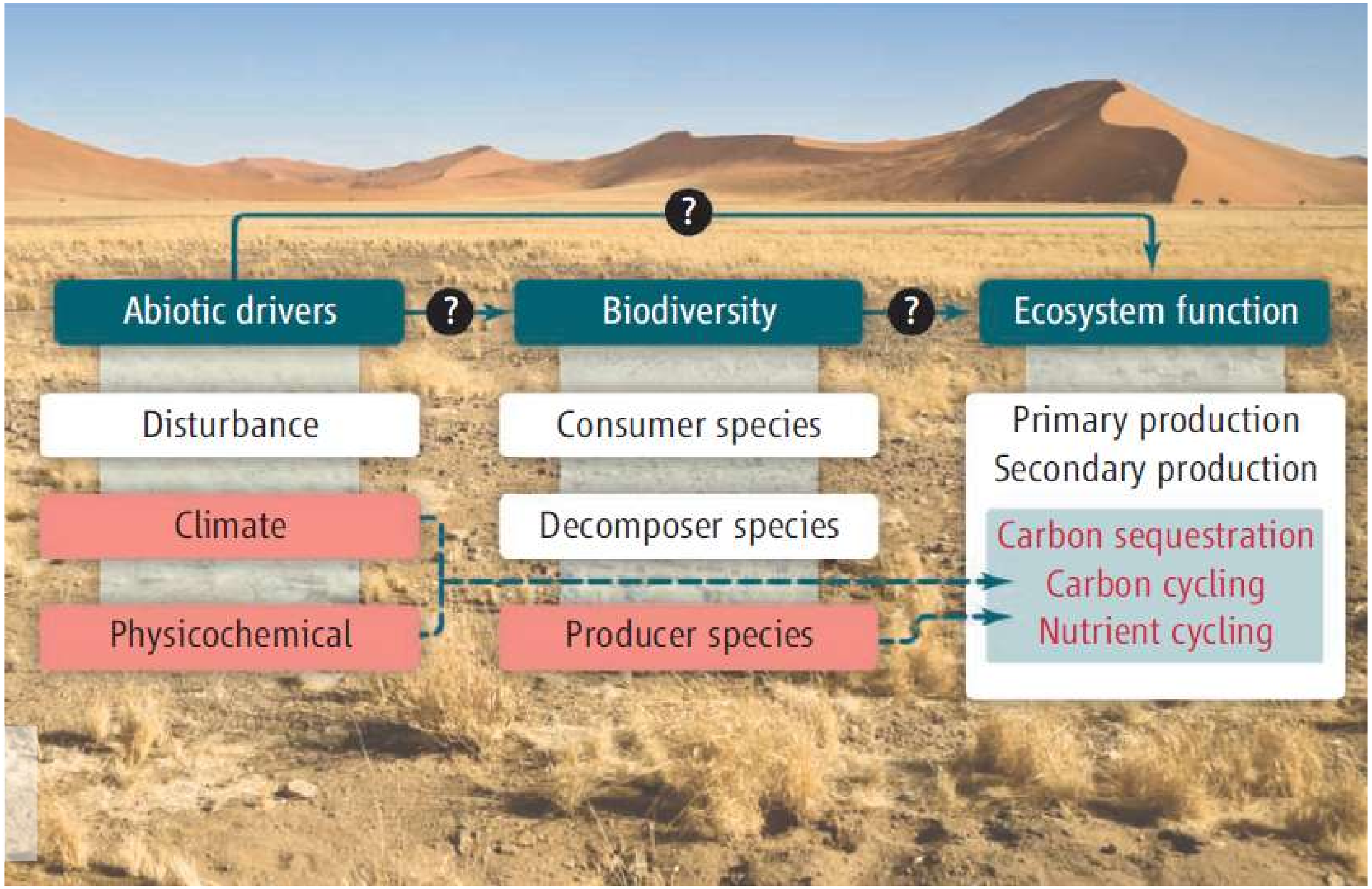
7. Biodiversity and ecosystem processes

SYLABUS

1) Introduction (Ecological Risk Assessment)
2) Ecosystem structure, biological diversity, ecological processes
3) Biodiversity – concepts, attributes, drivers
4) Biodiversity – spatio-temporal patterns
5) Environmental risks (typology); DPSIR scheme (Driving forces, Pressures, States, Impacts, Responses)
6) Stress ecology
7) **Biodiversity and ecosystem processes**
8) Climate-biodiversity relationships
9) Scenarios of land use change
10) Habitat changes (Natura 2000 sites, Habitat Directive, Nature Conservation)
11) Influence of chemical pollution on biodiversity
12) Ecosystem services

BIODIVERSITY – PROCESSES - FUNCTIONS

- impact of biodiversity decline on ecosystem functions
- impacts on goods and services provided by ecosystems
- disruption of biodiversity on local and regional scales may also reduce resilience across larger spatial scales as a result of degradation of ecosystem functions



ECOLOGY
Biodiversity and Ecosystem Function
Guy F. Midgley

ECOSYSTEM PROCESSES

Definition

the intrinsic properties of an ecosystem by which an ecosystem maintains its integrity.

Ecosystem processes are also seen as "ecosystem functions"

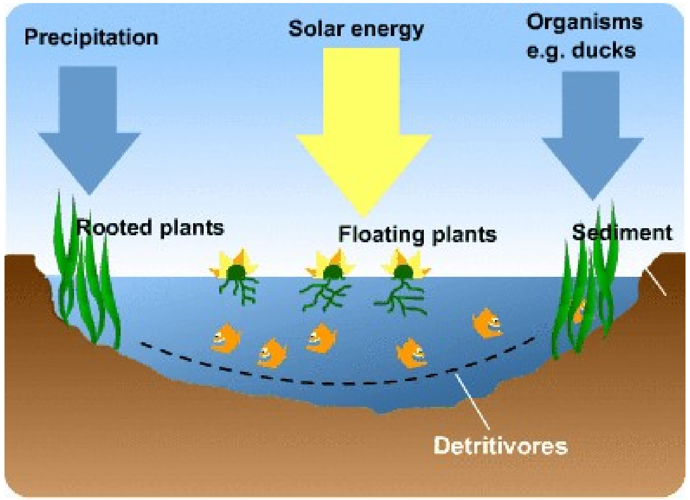
Millennium Ecosystem Assessment (2005)

Ecosystem processes

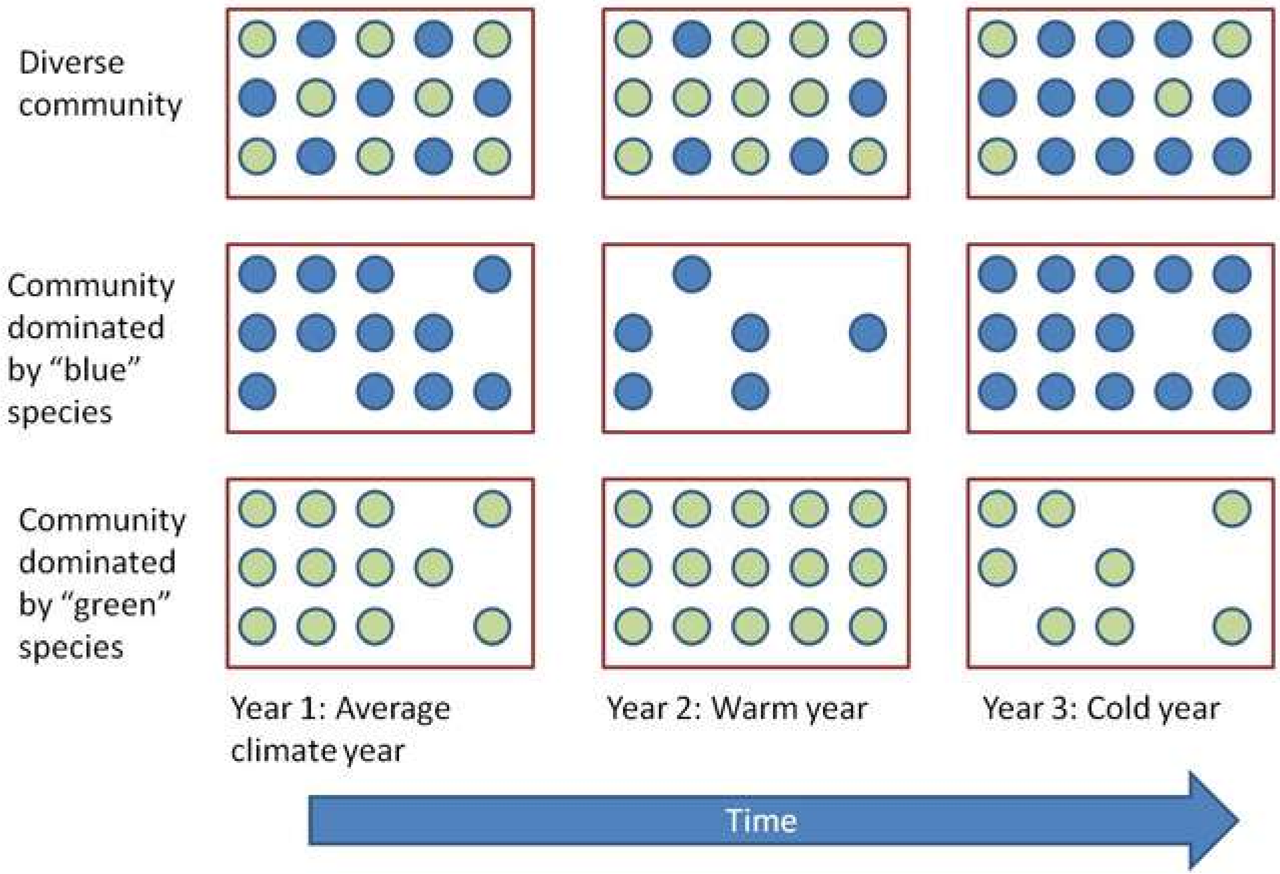
physical, chemical and biological activities and phenomena that link organisms with the environment

Ecosystem processes:

- production (plant matter)
- decomposition
- nutrient cycling
- nutrient and energy flows



BIODIVERSITY AND ECOSYSTEM FUNCTIONS

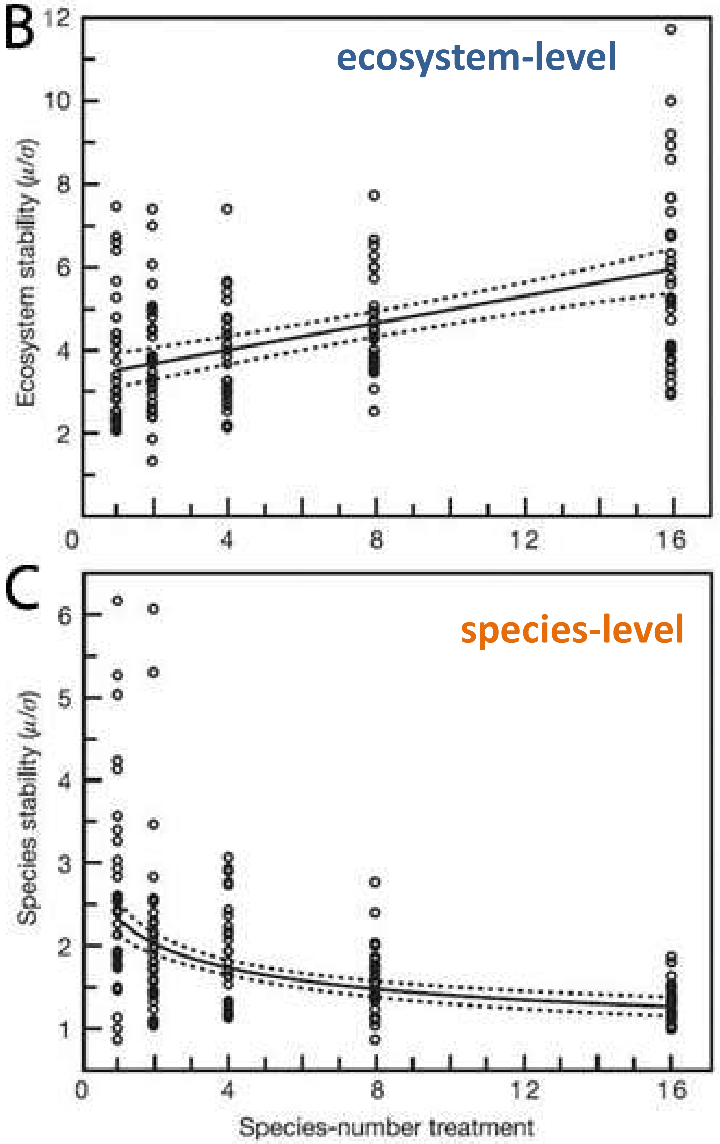


Conceptual diagram showing how increasing diversity can stabilize ecosystem functioning
Cleland, E. E. (2011) Biodiversity and Ecosystem Stability. Nature Education Knowledge 3(10):14

(www.nature.com/scitable/knowledge/library/biodiversity-and-ecosystem-stability-17059965)

BIODIVERSITY AND ECOSYSTEM FUNCTIONS

increasing species diversity would be positively correlated with **increasing stability at the ecosystem-level** and negatively correlated with **species-level stability** due to declining population sizes of individual species



A biodiversity experiment at the Cedar Creek Ecosystem Science Reserve (a) demonstrates the relationship between the number of planted species and ecosystem stability (b) or species stability (c).
Cleland, E. E. (2011) Biodiversity and Ecosystem Stability. Nature Education Knowledge 3(10):14

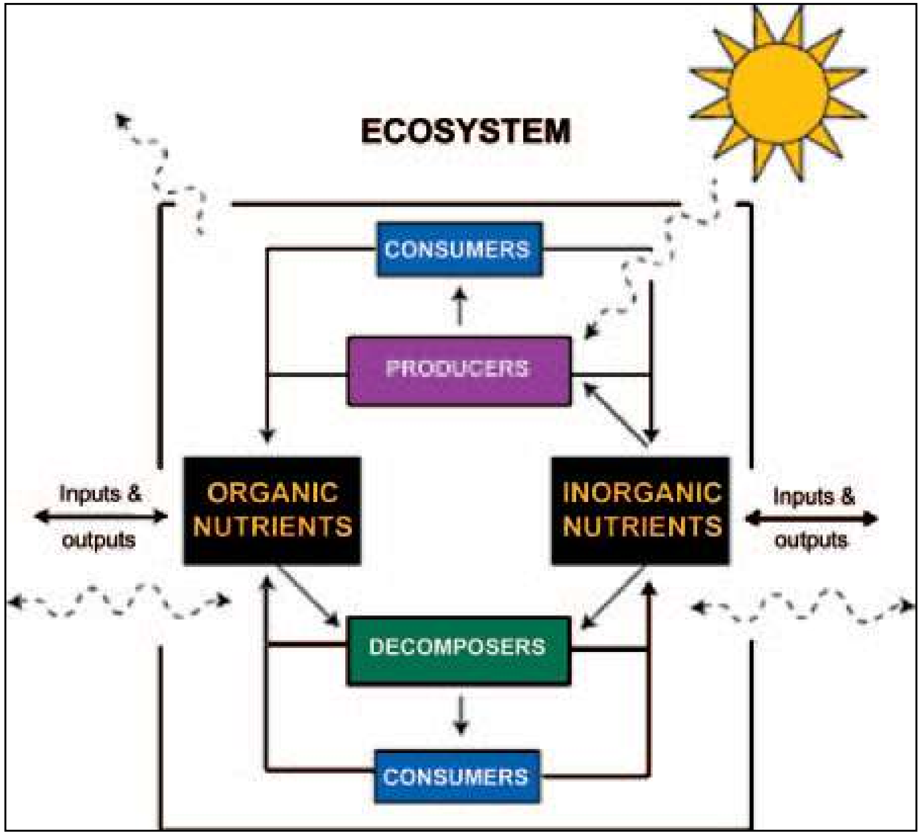
BIODIVERSITY AND ECOSYSTEM FUNCTIONS

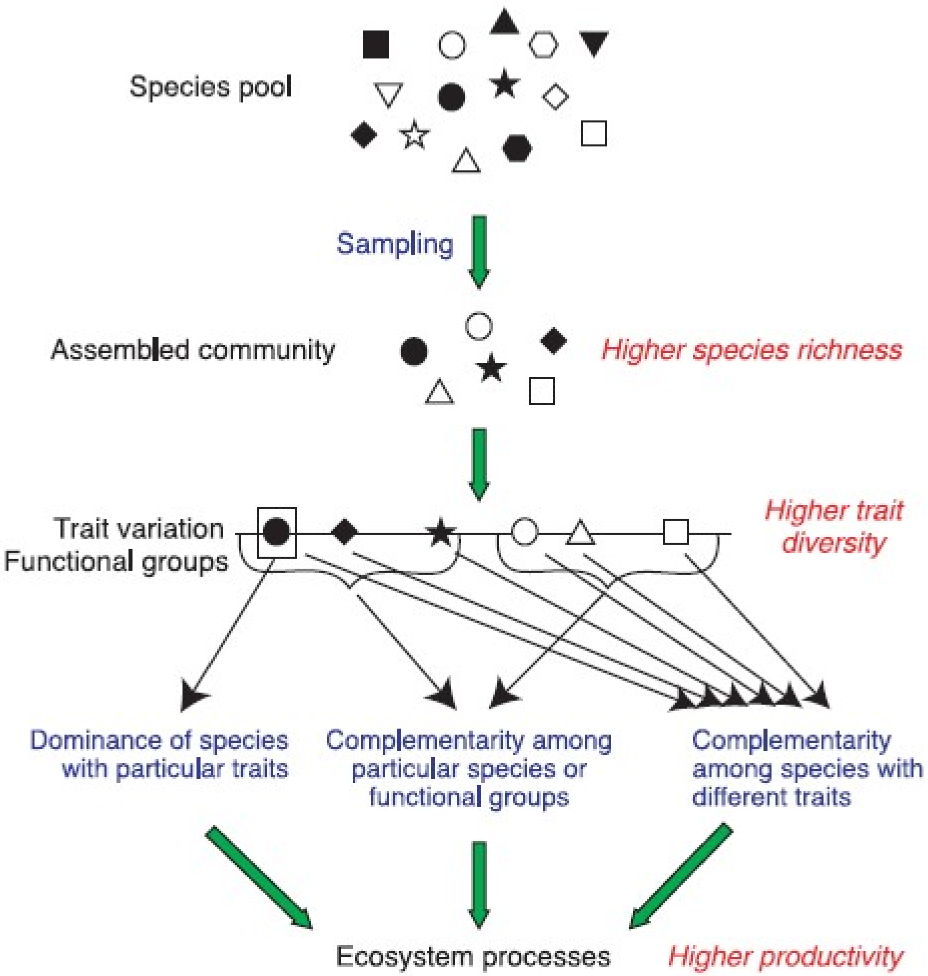
REVIEW

Biodiversity and Ecosystem Functioning: Current Knowledge and Future Challenges

M. Loreau[1,*], S. Naeem[2], P. Inchausti[1], J. Bengtsson[3], J. P. Grime[4], A. Hector[5], D. U. Hooper[6], M. A. Huston[7], D. Raffaelli...
+ See all authors and affiliations

Science 26 Oct 2001:
Vol. 294, Issue 5543, pp. 804-808
DOI: 10.1126/science.1064088





BIODIVERSITY AND ECOSYSTEM FUNCTIONS

REVIEW

Biodiversity and Ecosystem Functioning: Current Knowledge and Future Challenges

M. Loreau[1,*], S. Naeem[2], P. Inchausti[1], J. Bengtsson[3], J. P. Grime[4], A. Hector[5], D. U. Hooper[6], M. A. Huston[7], D. Raffaelli...
+ See all authors and affiliations

Science 26 Oct 2001:
Vol. 294, Issue 5543, pp. 804-808
DOI: 10.1126/science.1064088

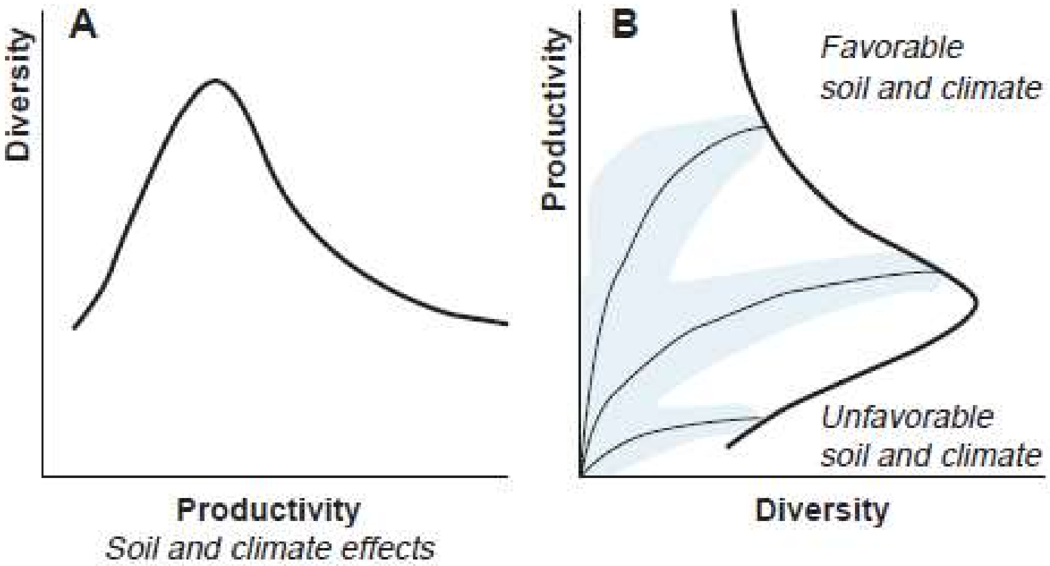


Fig. 4. Hypothesized relationships between (**A**) diversity-productivity patterns driven by environmental conditions across sites, and (**B**) the local effect of species diversity on productivity. (A) Comparative data often indicate a unimodal relationship between diversity and productivity driven by changes in environmental conditions. (B) Experimental variation in species richness under a specific set of environmental conditions produces a pattern of decreasing between-replicate variance and increasing mean response with increasing diversity, as indicated by the thin, curved regression lines through the scatter of response values (shaded areas).

BIODIVERSITY AND ECOSYSTEM FUNCTIONS (IN A DYNAMIC LANDSCAPE)

- relationships between biodiversity and ecosystem functions influence **ecosystem services**
- mostly studied in the form of **experiments** on a small area and of short duration; controlled conditions and stable composition of communities
- the challenge is to study the **real environment and dynamic communities**
- there is ample evidence that the decline in biodiversity in certain trophic groups is reflected in a decline in their **biomass** and consequently in **resource use efficiency**

(i) multi-trophic diversity

(ii) non-equilibrium biodiversity under disturbance and varying environmental conditions

(iii) large spatial and long temporal scales

Brose U, Hillebrand H. 2016. Biodiversity and ecosystem functioning in dynamic landscapes. Phil. Trans. R. Soc. B 371: 20150267. http://dx.doi.org/10.1098/rstb.2015.0267

(I) MULTI-TROPHIC DIVERSITY

Brose U, Hillebrand H. 2016. Biodiversity and ecosystem functioning in dynamic landscapes. Phil. Trans. R. Soc. B 371: 20150267.

(i) multi-trophic diversity

(ii) non-equilibrium biodiversity under disturbance and varying environmental conditions

(iii) large spatial and long temporal scales

- multi-trophic relationships are often specific, while taking into account the autecological characteristics of species allows predictive evaluation
- further direction lies in the study of complex communities based on ecological theory based on <u>average biomass</u> of individual species, stoichiometry and effect of environmental factors (e.g. temperature)

(II) NON-EQUILIBRIUM BIODIVERSITY UNDER DISTURBANCE AND VARYING ENVIRONMENTAL CONDITIONS

(i) multi-trophic diversity

(ii) non-equilibrium biodiversity under disturbance and varying environmental conditions

(iii) large spatial and long temporal scales

- disturbances and variable environmental conditions have a direct and indirect impact on the relationships between biodiversity and ecosystem functions (through the number of species, the composition of communities and the characteristics of species).
- variations in biodiversity can significantly affect its links to ecosystem functions

Brose U, Hillebrand H. 2016. Biodiversity and ecosystem functioning in dynamic landscapes. Phil. Trans. R. Soc. B 371: 20150267.

(III) LARGE SPATIAL AND LONG TEMPORAL SCALES

(i) multi-trophic diversity

(ii) non-equilibrium biodiversity under disturbance and varying environmental conditions

(iii) large spatial and long temporal scales

- the links between biodiversity and ecosystem functions on larger spatial scales are dependent on factors other than local scales
- while the **number of species and the biomass** of a community are highly important on **large scales**, the implications of **species identity** (belonging to functional guilds/their niche within a community) and the **composition of a community** are less important on large scales than on **small**
- over long time scales, mass extinctions represent serious changes in biodiversity with disparate effects on ecosystem functions

Brose U, Hillebrand H. 2016. Biodiversity and ecosystem functioning in dynamic landscapes. Phil. Trans. R. Soc. B 371: 20150267.

BIODIVERSITY AND ECOSYSTEM PROCESSES

- ecosystem function: biomass production and resource use
- predation within the guild and competition interference = reduced level of resource use

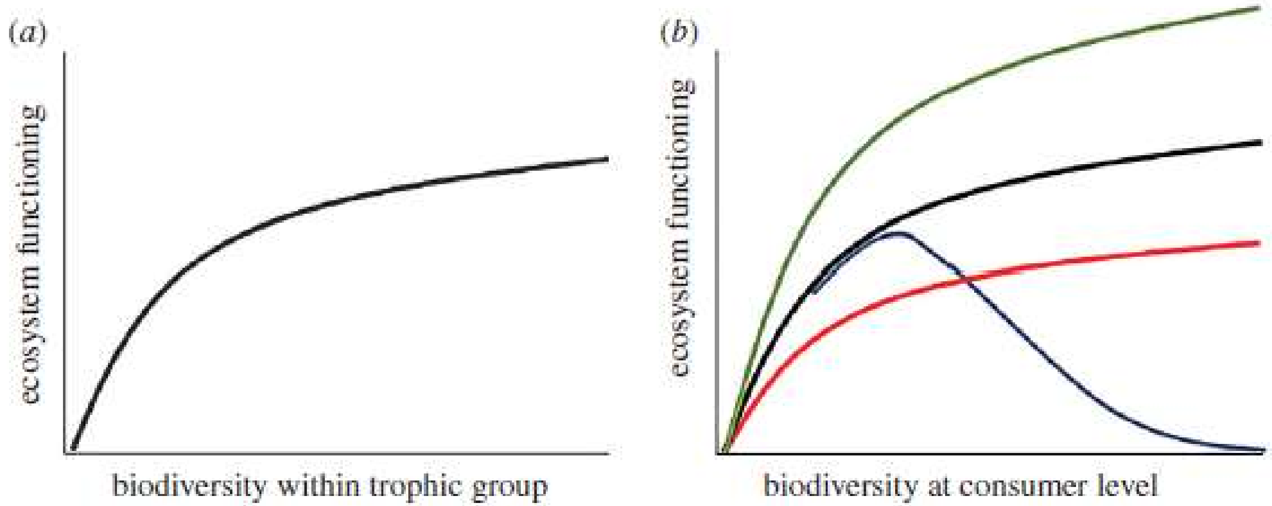


Figure 1. Biodiversity within a trophic level is predicted to enhance ecosystem functioning (biomass production and resource capture) by this trophic group (*a*). However, changes in the degree of intraguild predation or interference competition with increasing consumer diversity may lead to reduced resource capture at higher diversity ((*b*), blue line). Moreover, alterations of biodiversity at the prey level may lead to associational resistance (lower edibility, red line) or prey complementarity (higher edibility, green line).

Brose U, Hillebrand H. 2016. Biodiversity and ecosystem functioning in dynamic landscapes. Phil. Trans. R. Soc. B 371: 20150267.

STRUCTURE – PROCESSES - FUNCTIONS

Atlantic herring (Clupea harengus)

common eelgrass (Zostera marina)

Example from the seashore

The composition and arrangement of biological communities is determined by processes (wave exposure, sediment transport, freshwater inflows) and 'structures' (relief, shore sediments, salinity).

The structure of coastal ecosystems is the result of the action of ecosystem processes and at the same time influences them retroactively. For example, the shore relief is the result of the action of waves and at the same time influences them.

- specific functions of coastal ecosystems
- habitats of coastal organisms
- habitat functions are integrated and hierarchical

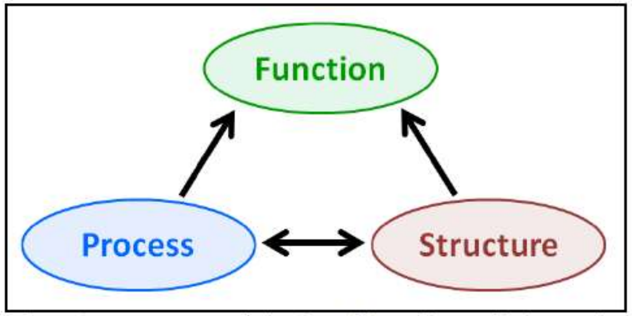


Figure 4.1. Ecosystem processes and structures interact to manifest ecosystem functions such as the provision of habitat (Goetz et al. 2004).

Goetz, F., C. Tanner, C.S. Simenstad, K. Fresh, T. Mumford, and M. Logsdon. 2004. Guiding restoration principles. Puget Sound Nearshore Partnership Technical Report No. 2004-03. Published by Washington Sea Grant Program, University of Washington, Seattle, Washington.

STRUCTURE – PROCESSES - FUNCTIONS

fish habitat (function) ⟵ structure of vegetation

Atlantic herring (Clupea harengus)

common eelgrass (Zostera marina)

function of vegetation habitats ⟵ structure of beach sediments

Vocha mořská (Zostera marina)

ECOLOGICAL PROCESSES

Fundamental ecological processes of ecosystems

- water cycle
- biogeochemical (or nutrient) cycling
- energy flow
- community dynamics: i.e. how the composition and structure of an ecosystem changes following a disturbance (succession)

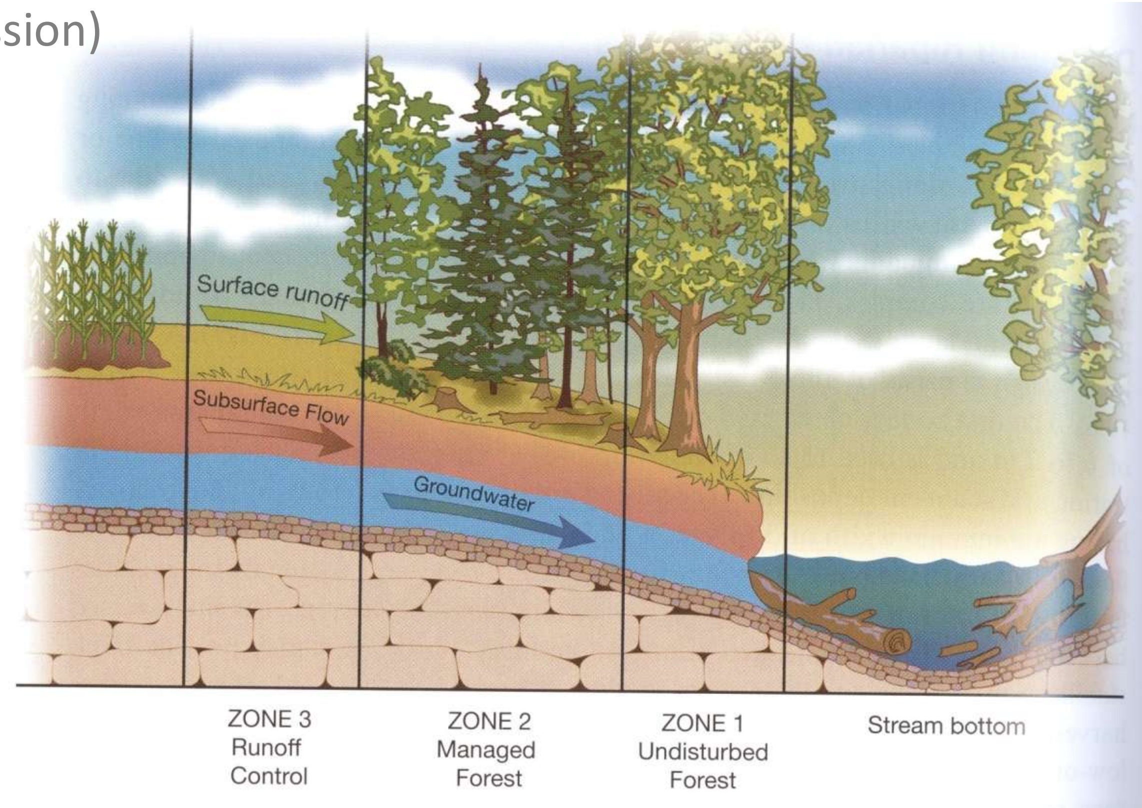
ECOSYSTEM PROCESSES

Fundamental ecosystem processes

- water cycle
- mineral cycle
- solar energy flow
- community dynamics (succession)

Joy Livingwell, February 2003

https://managingwholes.com/-ecosystem-processes.htm/



ECOSYSTEM FUNCTION

Ecosystem functions are biological, geochemical, physical processes and components that are part of or occur in an ecosystem.

- in some cases ecosystem functions are called ecological processes
- the ecosystem function of "pollination" is crucial for the reproduction of most wild plants
- this ecosystem function provides a direct contribution to agriculture in the form of crop pollination

ECOSYSTEM PROCESSES

nature Vol 448|12 July 2007|doi:10.1038/nature05947

LETTERS

Biodiversity and ecosystem multifunctionality

Andy Hector[1] & Robert Bagchi[1]†

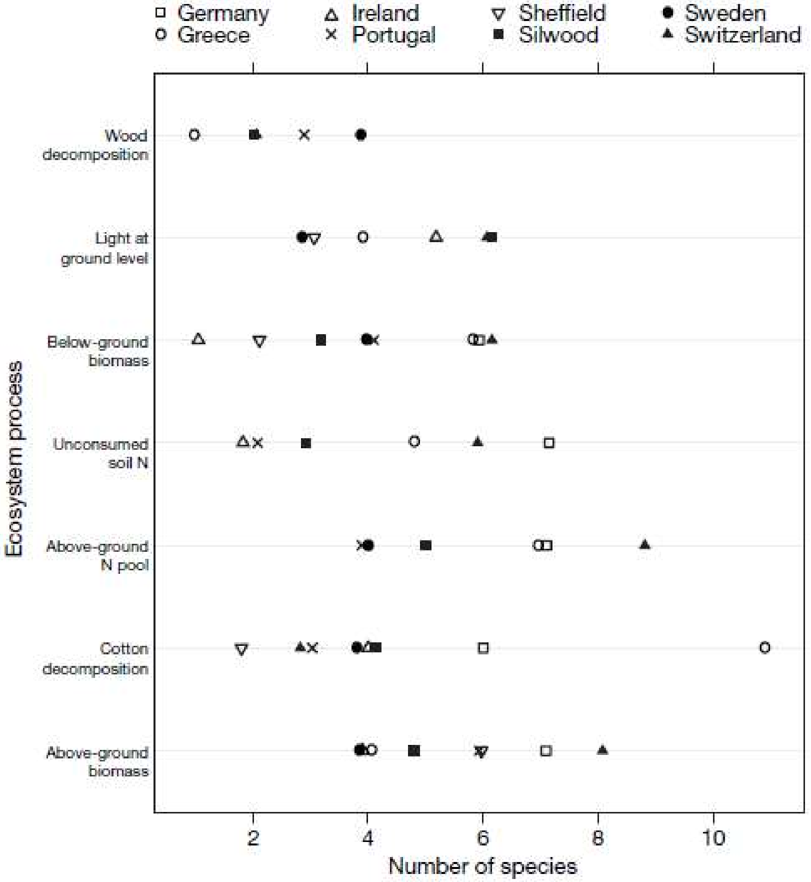


Figure 1 | Number of species with desirable effects on the suite of ecosystem processes measured in the different BIODEPTH project experiments. The number of species was identified by the AIC-based multiple regression (and species with effects with undesirable signs were then excluded).

ECOSYSTEM PROCESSES

nature Vol 448|12 July 2007|doi:10.1038/nature05947

LETTERS

Biodiversity and ecosystem multifunctionality

Andy Hector[1] & Robert Bagchi[1]†

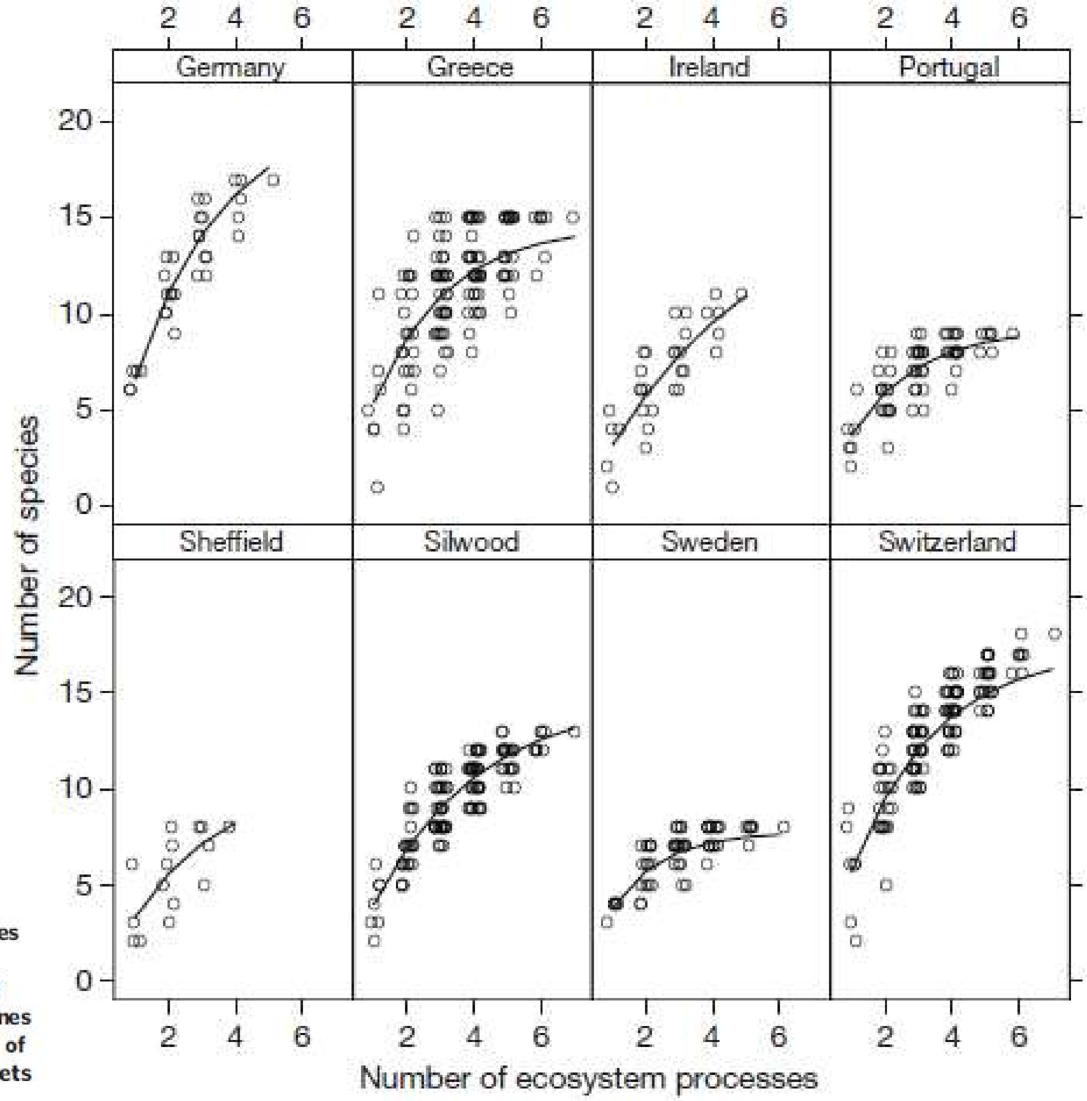


Figure 2 | Positive relationship between the range of ecosystem processes considered and the number of species that affect one or more aspect of ecosystem functioning. The points (jittered for clarity) show numbers of species required for all possible combinations of ecosystem processes. Lines are theoretical predictions from the model based on the average number of species required for a single process, $\bar{x}$, and the average overlap in the sets of species required for each pair of processes, $\bar{o}$, using equation (2).

ECOSYSTEM PROCESSES

ECOLOGICAL NICHE

- biodiversity responds to the environment through the ecological niches of individual species
- simplification of environmental conditions provides less diversity of resources
- results in a simplification of the community in terms of species or functional diversity
- ecosystem processes are connected predominantly through functional diversity

FUNCTIONAL BIODIVERSITY

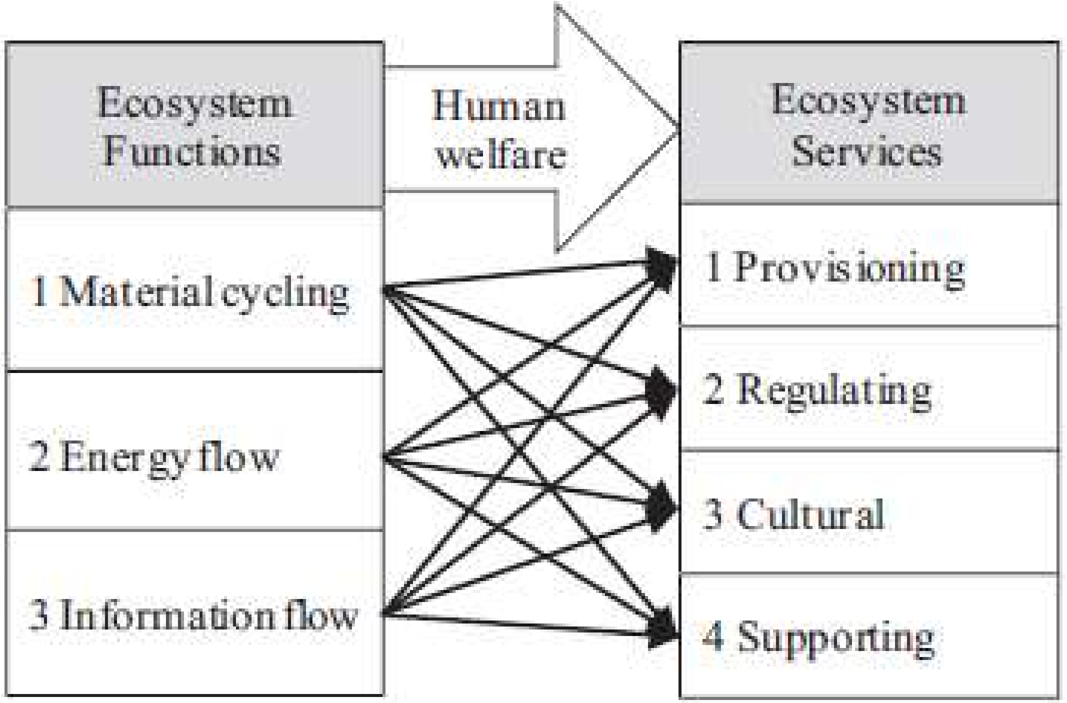
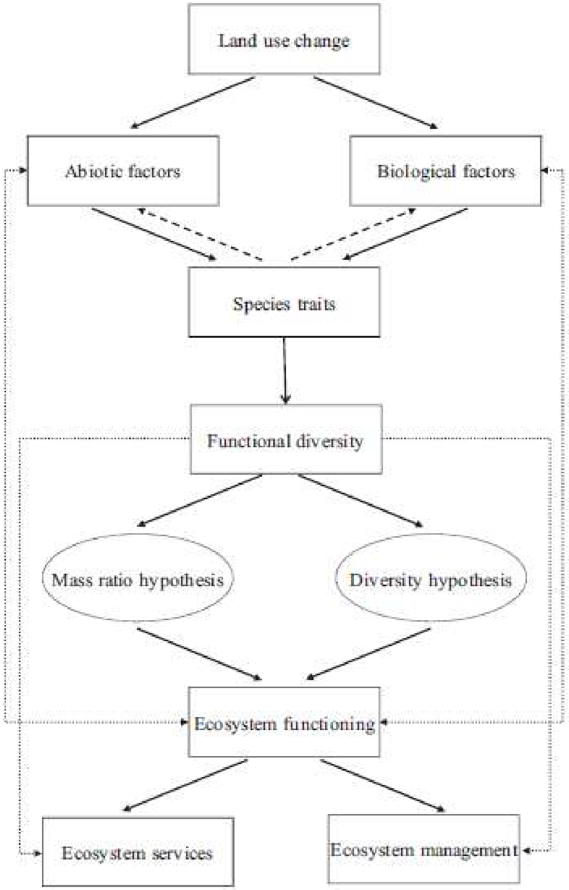


Fig. 1. Relationships between ecosystem functioning and ecosystem services [68]. Ecosystem functioning and services do not necessarily show a one to one correspondence. In some cases a single ecosystem function contributes to two or more ecosystem services whereas in other cases a single ecosystem service is the product of two or more ecosystem functions [55].



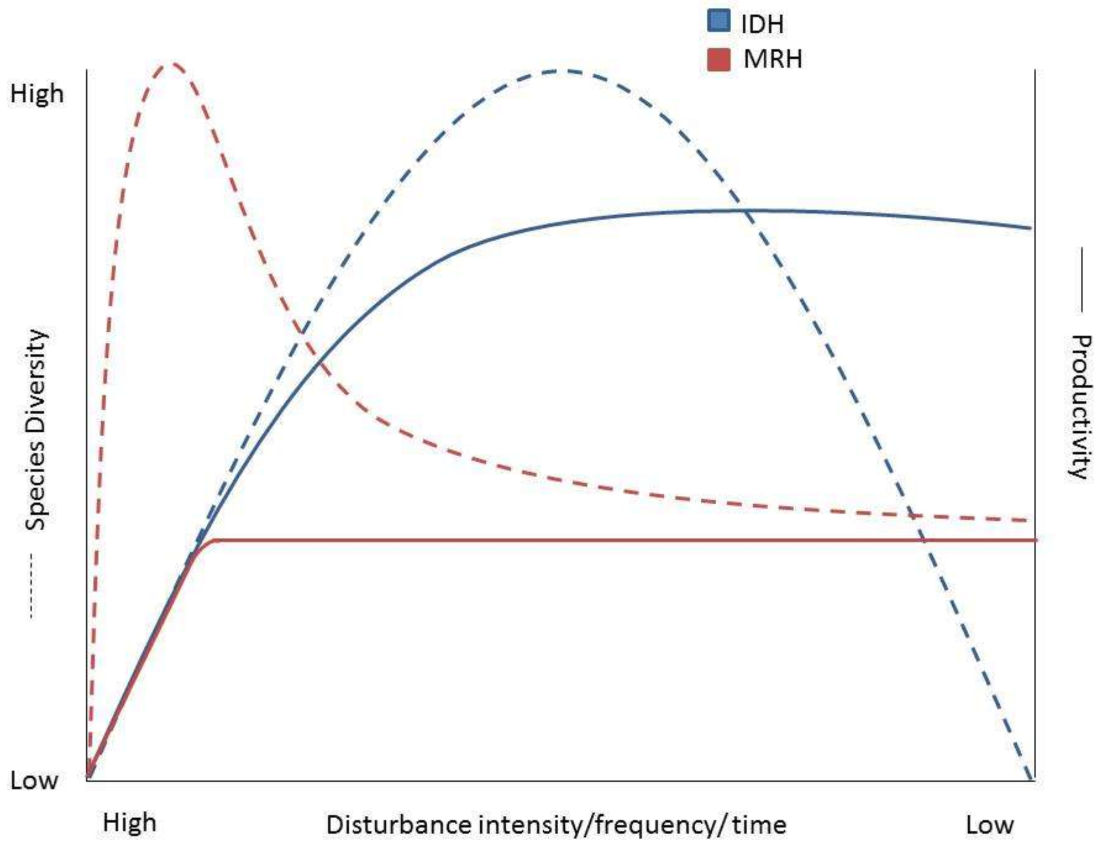
Acta Ecologica Sinica 34 (2014) 85–91
Contents lists available at ScienceDirect
Acta Ecologica Sinica
journal homepage: www.elsevier.com/locate/chnaes

Relationships between functional diversity and ecosystem functioning: A review

Yantao Song [a,c], Ping Wang [b], Guangdi Li [a,c], Daowei Zhou [a,*]

FUNCTIONAL BIODIVERSITY

Modified from Kershal and Mallik (2013), theoretical relationships between biomass, species diversity and disturbance according to the Intermediate Disturbance and Mass Ratio Hypotheses.



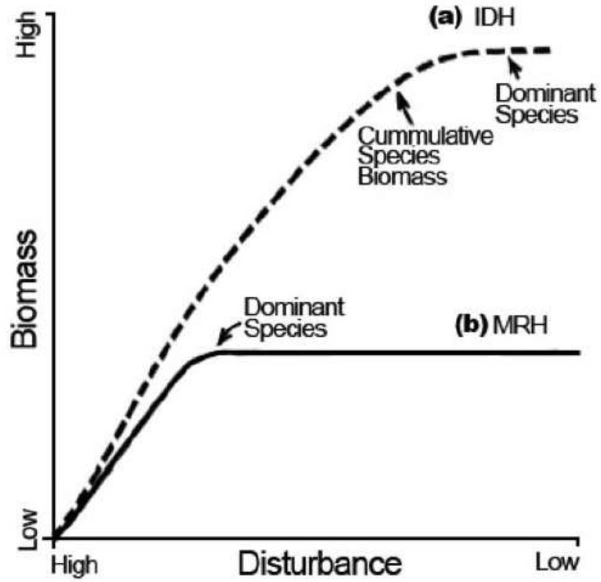


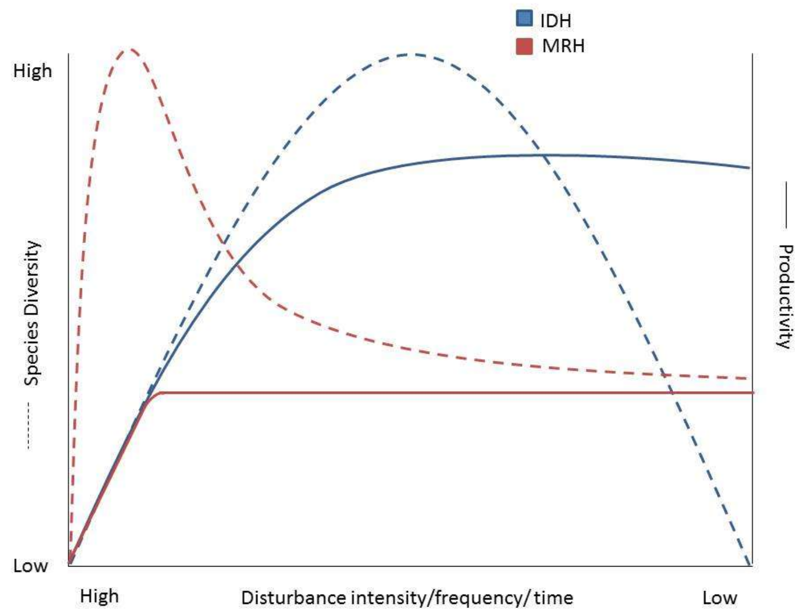
FIG. 2. Predicted relationship between community productivity and disturbance in IDH and MRH. (a) Community productivity (biomass) increases with decreasing disturbance frequency/intensity/time since disturbance until it reaches an equilibrium at climax condition when mostly the long-lived species account for the community biomass, commonly observed in mineral rich productive sites as per IDH. (b) Community productivity (biomass) increases with decreasing disturbance frequency/intensity/time since disturbance until it levels when only a few stress tolerating competitive species achieve dominance and contribute most of the community biomass observed in organic rich, nutrient-poor acidic soil as per MRH.

https://www.biodiverseperspectives.com/2013/08/14/idh-mrh-wtf/

MASS RATIO HYPOTHESIS (MRH)

The Mass Ratio Hypothesis (MRH), on the other hand, proposes that the biological traits of the dominant species contributing to productivity (defined by biomass) are the critical regulators of ecosystem function (Grime, 1998).

MRHis often associated with ecosystems with longer periods between major stand replacing disturbances. It proposes that biodiversity is held low by the dominance of one or a few species (see right side of the graph, Figure 1b) and that this configuration sustains site productivity

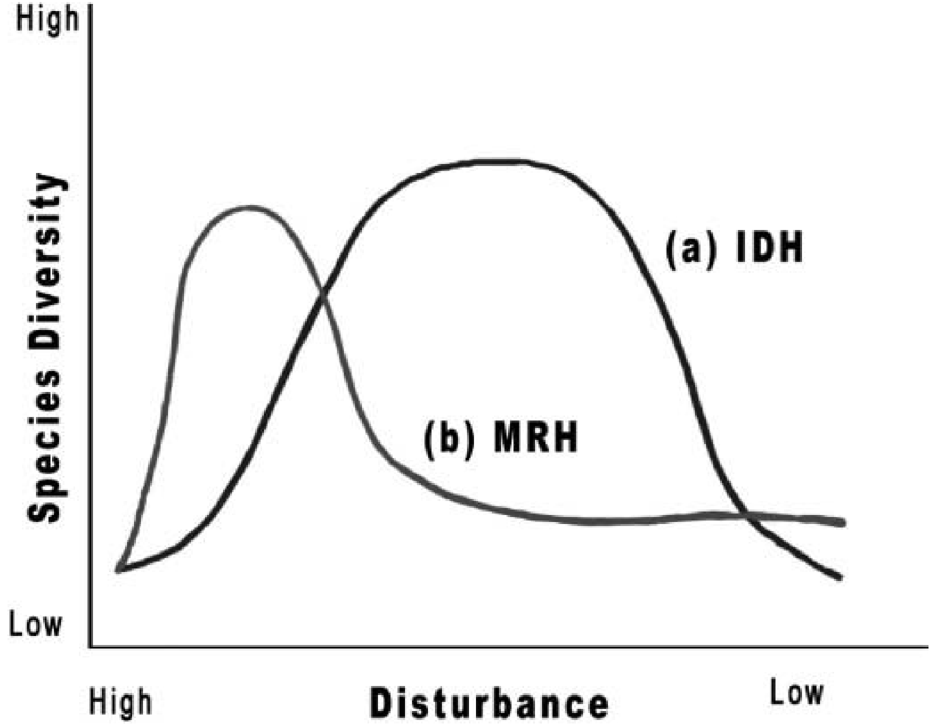


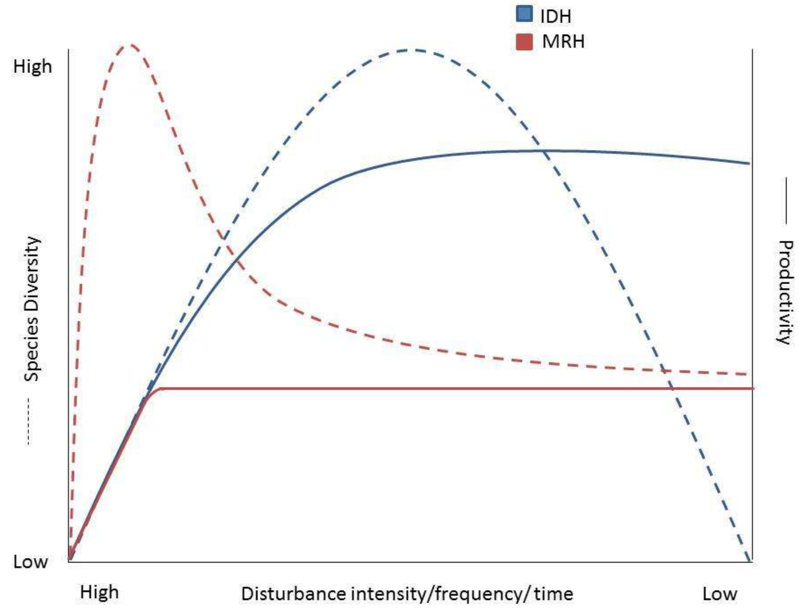
https://www.biodiverseperspectives.com/2013/08/14/idh-mrh-wtf/

INTERMEDIATE DISTURBANCE HYPOTHESIS (IDH)

The IDH (Connell, 1978) proposes that species diversity displays a humpshaped response curve to disturbance, peaking at intermediate disturbance levels.

IDH is portrayed as a cyclic pattern of disturbances in terms of intensity and frequency, describing communities that become less stable with time (as diversity decreases) and more vulnerable to disturbance. It is commonly associated with **fire-driven terrestrial ecosystems** (Mackey and Currie, 2001).





https://www.biodiverseperspectives.com/2013/08/14/idh-mrh-wtf/

BIODIVERSITY AND PROCESSES

(SPECIES TRAITS)

Table 2 Biological traits (11) used in the analysis and their categories (57)

Traits	No.	Categories
Maximal size (cm)	1	≤0.5
	2	>0.5 to 1
	3	>1 to 2
	4	>2 to 4
	5	>4
Life span (year)	6	≤1
	7	>1
Number of reproductive cycles per year	8	<1
	9	1
	10	>1
Aquatic stages	11	Egg
	12	Larva
	13	Nymph/pupa
	14	Adult
Reproduction	15	Ovoviviparity
	16	Isolated eggs, free
	17	Isolated eggs, cemented
	18	Clutches, cemented or fixed
	19	Clutches, free
	20	Clutches, in vegetation
	21	Clutches, terrestrial
	22	Asexual reproduction
Dispersal	23	Aquatic, passive
	24	Aquatic, active
	25	Aerial, passive
	26	Aerial, active
Resistance forms	27	Eggs, statoblasts
	28	Cocoons
	29	Diapause or dormancy
	30	None
Respiration	31	Tegument
	32	Gill
	33	Plastron (aerial)
	34	Spiracle (aerial)
Locomotion	35	Flier
	36	Surface swimmer
	37	Full water swimmer
	38	Crawler
	39	Burrower (epibenthic)
	40	Interstitial (endobenthic)
	41	Attached
Food	42	Fine sediment + microorganisms
	43	Fine detritus <1 mm
	44	Dead plant (>1 mm)
	45	Microphytes
	46	Macrophytes
	47	Dead animal (>1 mm)
	48	Living microinvertebrates
	49	Living macroinvertebrates
	50	Vertebrates
Feeding habits	51	Absorber/deposit feeder
	52	Shredder
	53	Scraper
	54	Filter-feeder
	55	Piercer
	56	Predator
	57	Parasite

Archaimbault et al., 2010

BIODIVERSITY AND PROCESSES

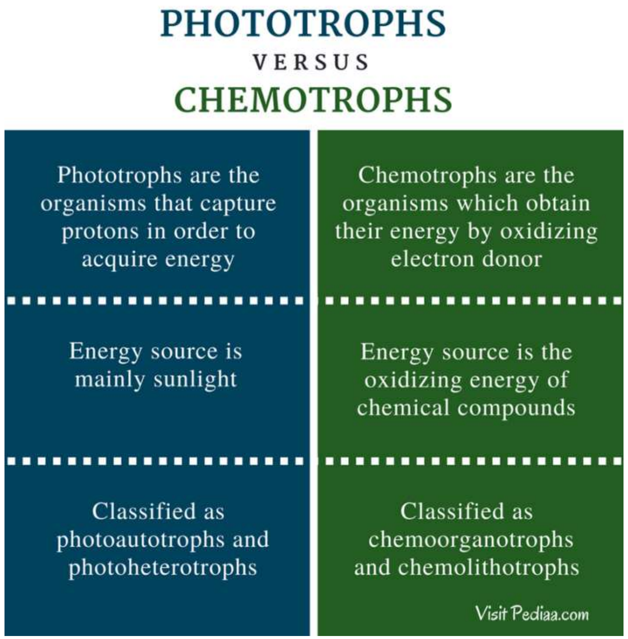
(SPECIES TRAITS)

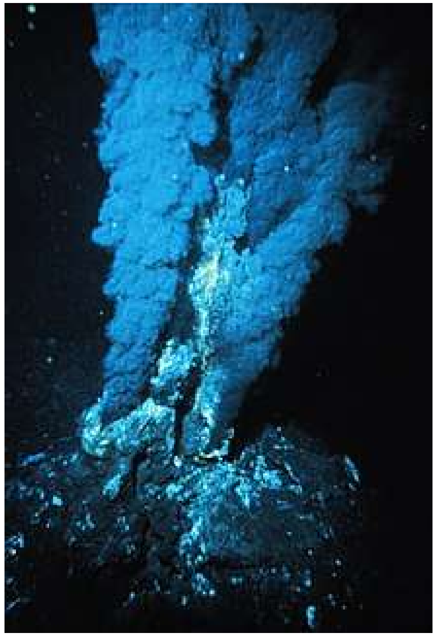
Table 1. Functional traits selected for the current study and their functional significance relevant to the current study.

Functional Trait	Unit	Functional significance of relevance to current study	Refs
Leaf Traits			
Delta 13 C ($\delta^{13}C$)	‰	Correlated to plant water use efficiency and may also segregate plants of different successional status.	1
Leaf Area	mm^2	Consequential for leaf energy and water balance. Interspecific variation in leaf size has been connected with climatic variation, where heat stress, cold stress, drought stress and high radiation all tend to select for relatively small leaves.	2
Leaf mass per area (LMA)	$g\ m^{-2}$	Correlated with potential relative growth rate. Higher values correspond with high investments in structural leaf defences and leaf lifespan, but also slower growth.	3
Leaf Slenderness	Unitless	Involved in control of water and temperature status. Slender leaves have a reduced boundary layer resistance and are can thus regulating their temperature through convective cooling more effectively.	4
Bole Traits			
Wood density	$g\ cm^{-3}$	Positively correlated with drought tolerance and tolerance of mechanical or fire damage; related to stem water storage capacity, efficiency of xylem water transport, regulation of leaf water status and avoidance of turgor loss.	5
Maximum height	M	Positively correlated with competitive ability of plants.	6
Bark thickness	Unitless	Correlated to fire resistance with thicker bark expected in fire prone areas.	7

PRIMARY PRODUCTION

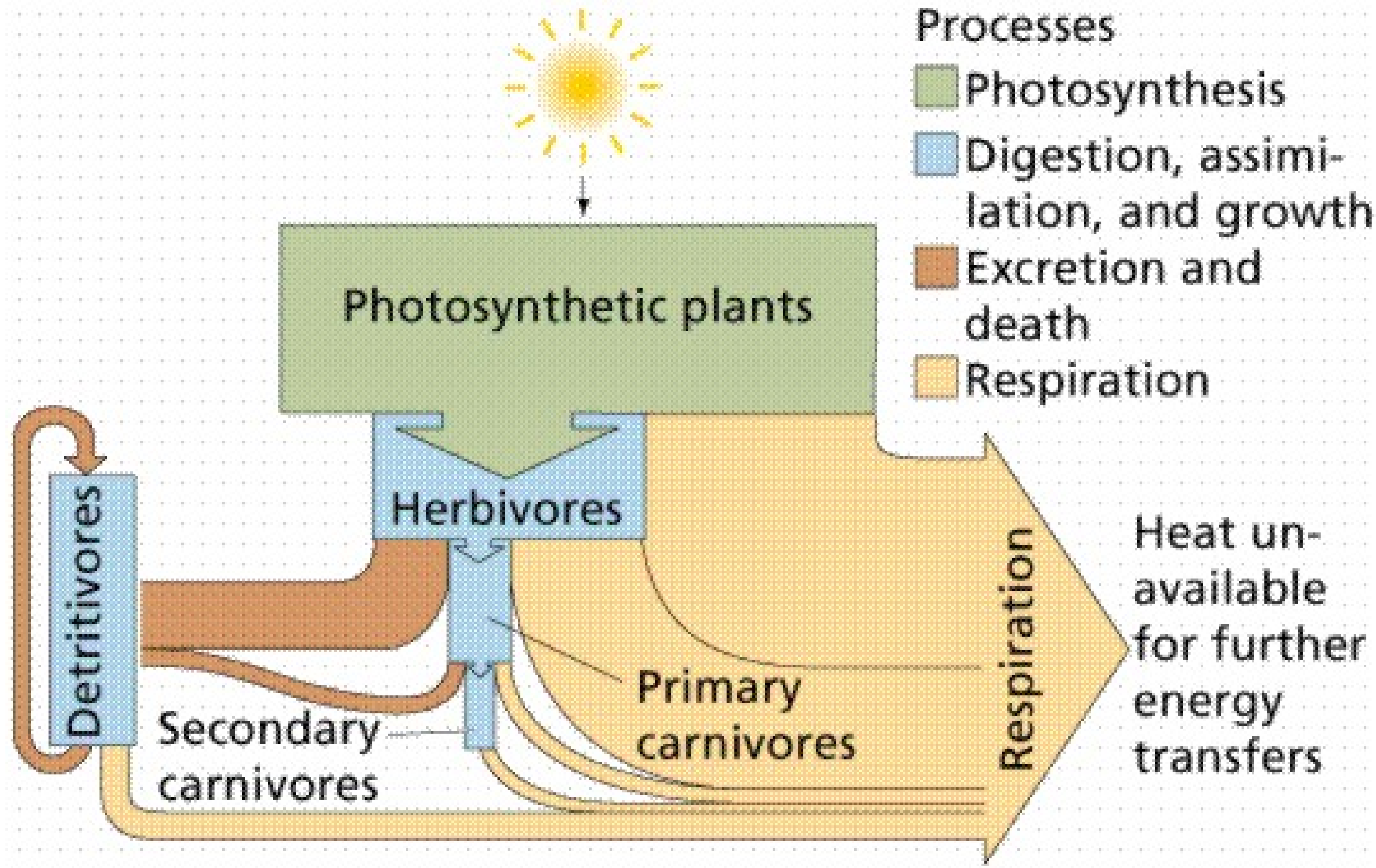
- the formation of organic matter
- the energy source of solar radiation (photosynthesis) or chemotrophy
- an ecosystem with greater diversity can store more carbon as a result of increased inputs from photosynthesis
- not only organic matter produced by the activity of primary producers, but also its decomposition and involvement in other ecosystem processes





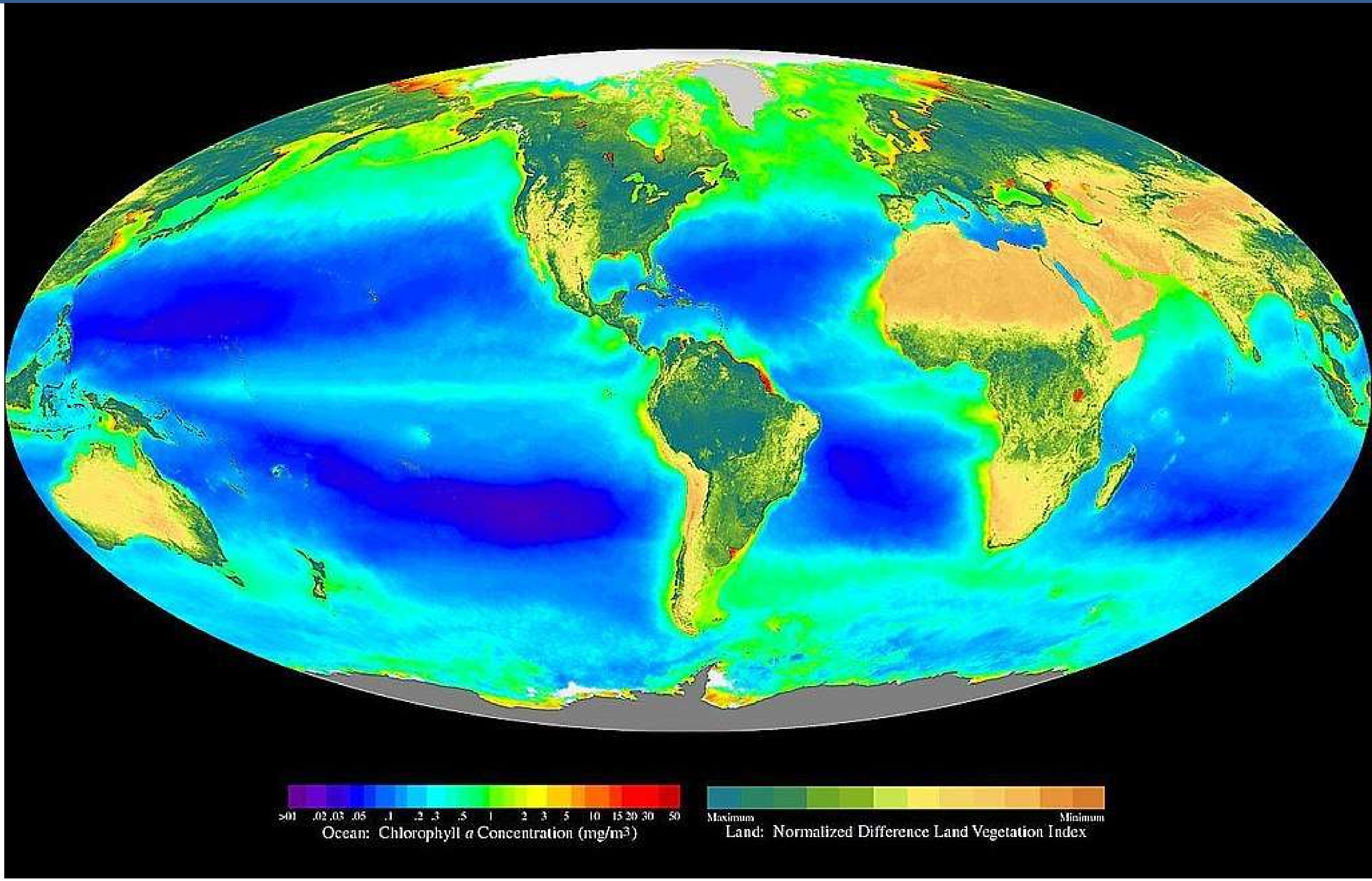
https://en.wikipedia.org/wiki/Chemotroph#/media/File:Blacksmoker_in_Atlantic_Ocean.jpg

PRIMARY PRODUCTION



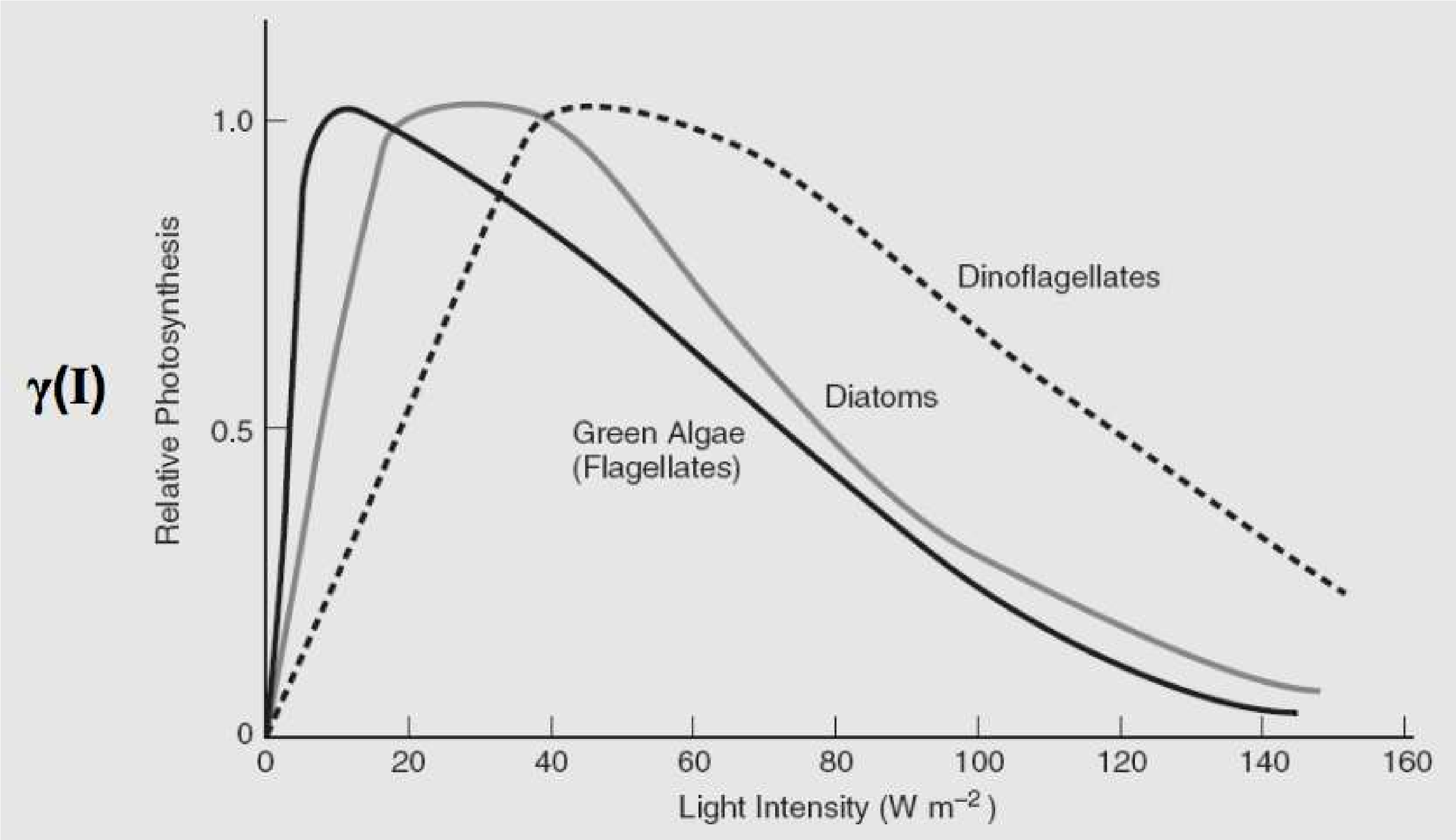
The flow of energy through an ecosystem. Image from Purves et al., Life: The Science of Biology, 4th Edition, by Sinauer Associates (www.sinauer.com) and WH Freeman (www.whfreeman.com)

PRIMARY PRODUCTION



Global oceanic and terrestrial photoautotroph abundance, from September 1997 to August 2000. As an estimate of autotroph biomass, it is only a rough indicator of primary-production potential, and not an actual estimate of it. Provided by the SeaWiFS Project, NASA/Goddard Space Flight Center and ORBIMAGE.

PRIMARY PRODUCTION



https://upload.wikimedia.org/wikipedia/commons/7/75/Phytoplankton_Intensity.png

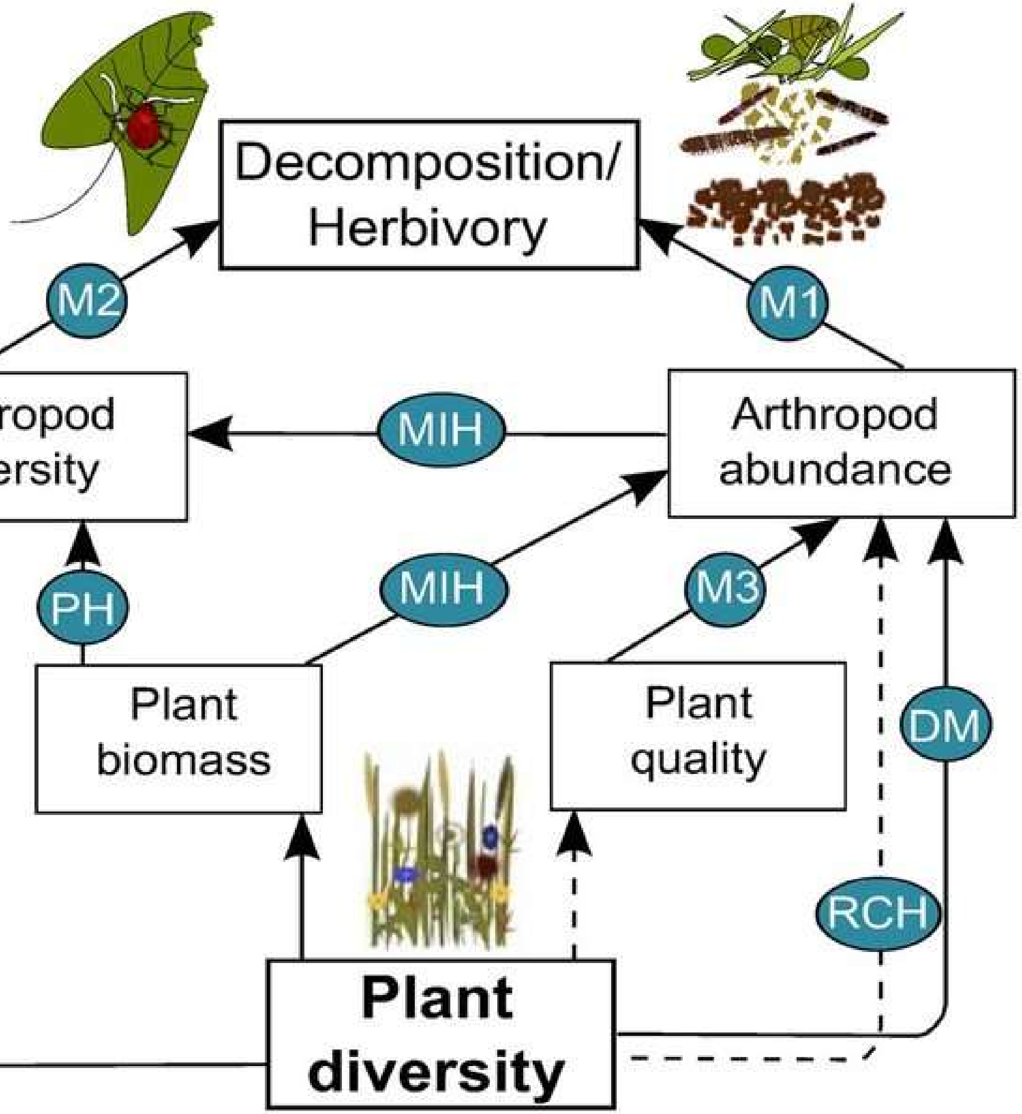
DECOMPOSITION OF ORGANIC MATTER

OPEN ACCESS Freely available online PLOS | ONE

Plant Diversity Impacts Decomposition and Herbivory via Changes in Aboveground Arthropods

Anne Ebeling[1]*, Sebastian T. Meyer[2], Maike Abbas[3], Nico Eisenhauer[1], Helmut Hillebrand[3], Markus Lange[4], Christoph Scherber[5], Anja Vogel[1], Alexandra Weigelt[6], Wolfgang W. Weisser[1,2]

DM=Dietary Mixing
RCH=Resource Concentration Hypothesis
RHH=Resource Heterogeneity Hypothesis
MIH=More Individuals Hypothesis
PH=Productivity Hypothesis



DECOMPOSITION OF ORGANIC MATTER

Resource concentration hypothesis – RCH (Root 1973)

- Herbivorous insect specialists should be more numerous on larger areas of host plants, as insects are more likely to be found and remain on these larger areas for longer time

DECOMPOSITION OF ORGANIC MATTER

MIH and **PH** assume a positive relationship between plant biomass and consumer diversity, but the mechanisms on which they are based differ

More Individuals Hypothesis (MIH)

- relates to communities that are limited in productivity
- predicts higher consumer abundance in more productive places, as well as increasing consumer diversity depending on abundance

Productivity Hypothesis (PH)

- higher overall level of resources in the form of diverse plant communities directly attracts more kinds of consumer-generalists

Resource Concentration Hypothesis (RCH)

- assumes lower abundances of specialized herbivore pests in more diverse habitats, which is related to lower densities of host plants

Dietary Mixing (DM)

- for herbivore generalists (e.g. locusts) the ability to combine different food sources to achieve an optimal combination of nutrients or to dilute toxins may increase their fitness and consequently their abundance. A positive relationship between plant diversity and arthropod abundance is shown

Resource Heterogeneity Hypothesis (RHH)

- predicts that due to the increased number of different food sources related to the increasing diversity of plants, the species richness of consumers-specialists increases

DECOMPOSITION OF ORGANIC MATTER

DECOMPOSITION

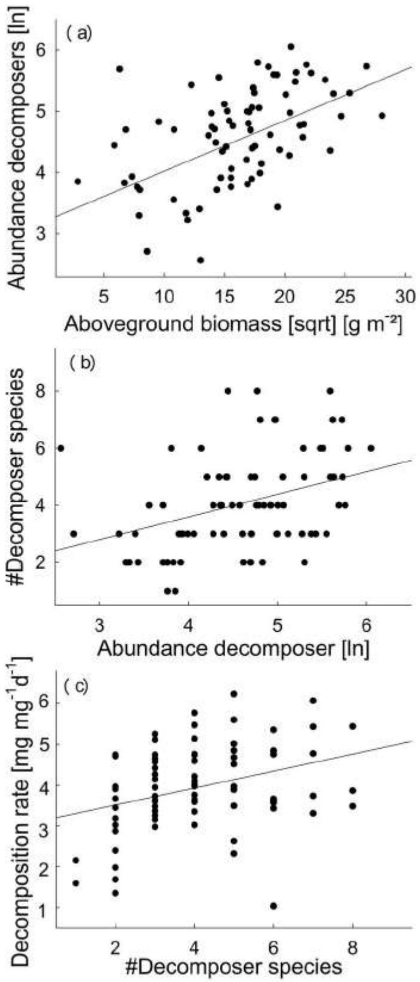


Figure 3. Pairwise correlations visualizing the significant links detected in the path analysis relating plants, decomposers and decomposition. We show the relationships between aboveground plant biomass and decomposer abundances (a), between decomposer abundances and their species richness (b) and decomposer species richness and decomposition (c). For statistics, see Table S2.
doi:10.1371/journal.pone.0106529.g003

HERBIVORY

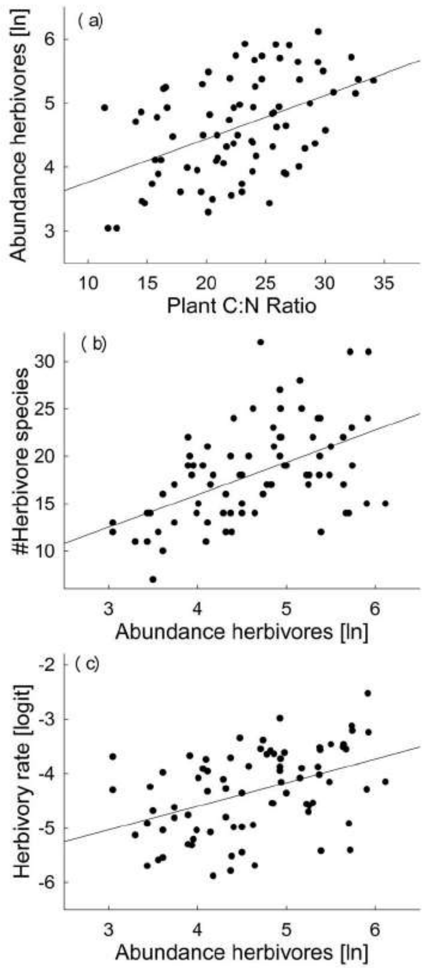


Figure 4. Pairwise correlations visualizing the significant links detected in the path analysis relating plants, herbivores and herbivory. We show the relationships between plant C:N ratio and herbivore abundance (a), herbivore species richness and their abundance (b), and between herbivore abundance and herbivory rate (c). For statistics, see Table S4.
doi:10.1371/journal.pone.0106529.g004

DECOMPOSITION OF ORGANIC MATTER

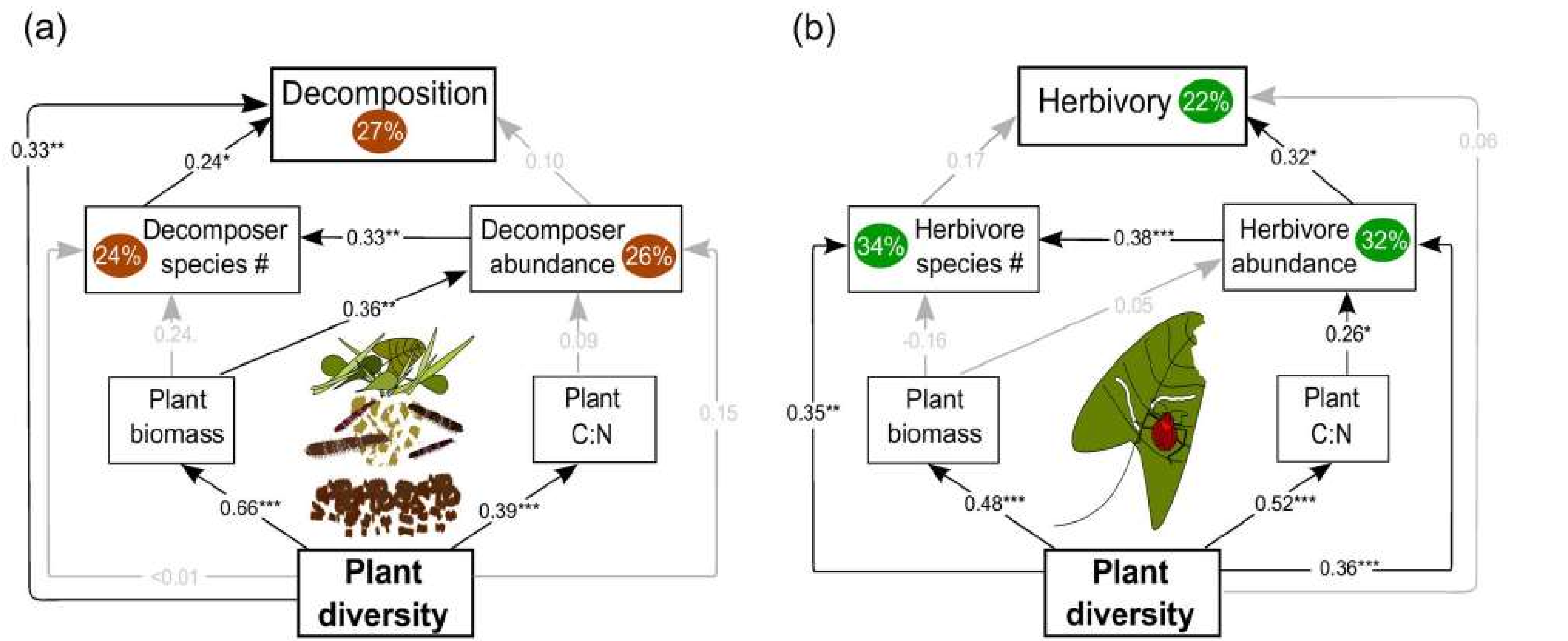


Figure 2. Path diagram explaining plant community effects on decomposition and herbivory. Models relate plant community variables (diversity, quantity and quality), species richness and abundance of (a) decomposer arthropods to decomposition, and (b) herbivorous insects to herbivory. Standardised path coefficients are given on top of the path arrows with significances indicated by *, $P<0.05$; **, $P<0.01$; ***, $P<0.001$. Non-significant paths are given in grey.

doi:10.1371/journal.pone.0106529.g002

DECOMPOSITION OF ORGANIC MATTER

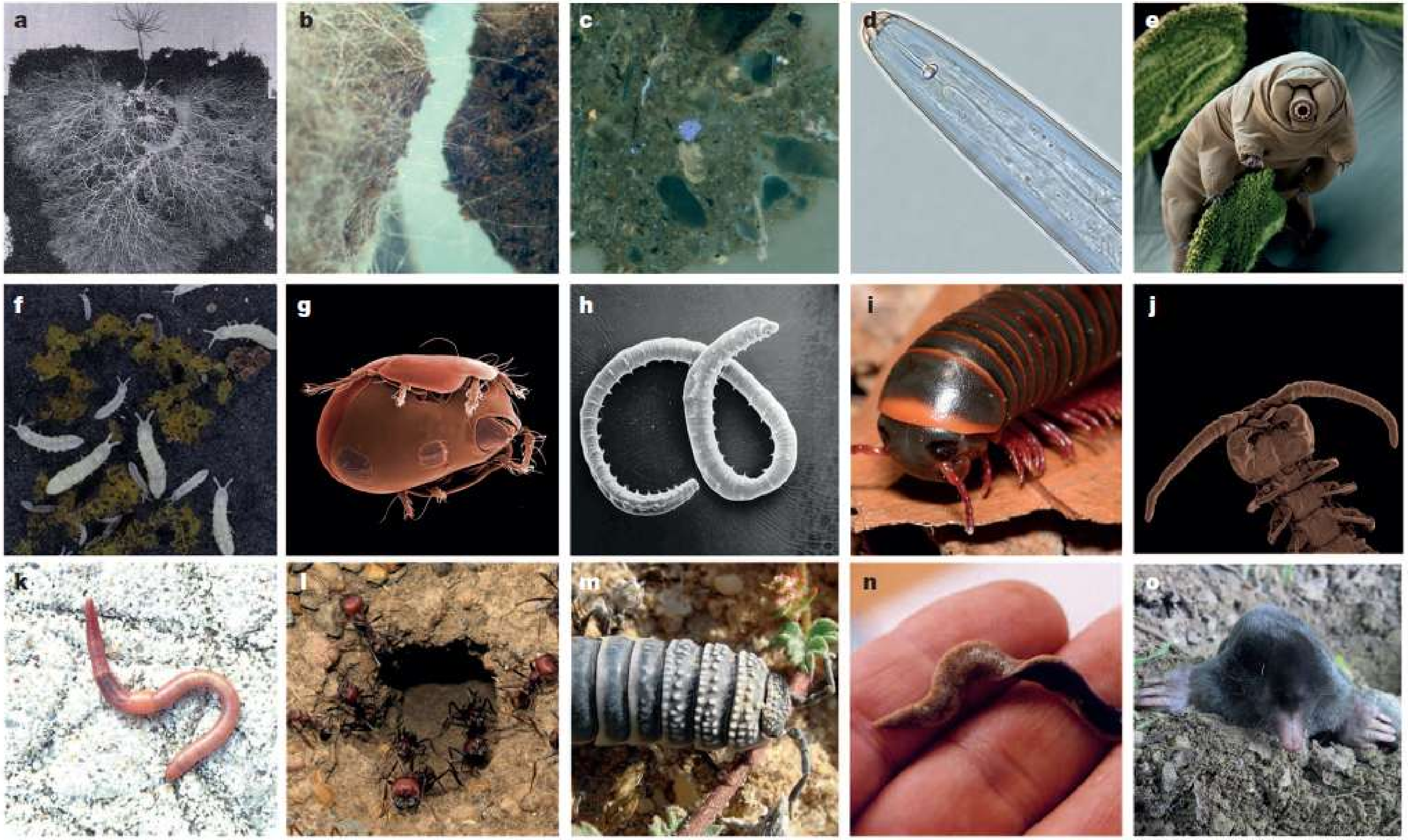


Figure 1 | A selection of organisms of the soil food web. a–o, The selection of organisms includes ectomycorrhizal (**a**) and decomposer fungi (**b**), bacteria (**c**), nematode (**d**), tardigrade (**e**), collembolan (**f**), mite (**g**), enchytraeid worm (**h**), millipede (**i**), centipede (**j**), earthworm (**k**), ants (**l**), woodlice (**m**), flatworm (**n**) and mole (**o**). All photographs are from the European Soil Biodiversity Atlas, courtesy of A. Jones; individual photo credits are: K. Ritz (**b**, **c**); H. van Wijnen (**d**); Water bear in moss, Eye of Science/Science Photo Library (**e**); P. Henning Krog (**f**); D. Walter (**g**); J. Rombke (**h**); J. Mourek (**i**, **j**); D. Cluzeau (**k**); European Soil Biodiversity Atlas, Joint Research Centre (**l**, **n**); S Taiti (**m**); and H. Atter (**o**).

DECOMPOSITION OF ORGANIC MATTER

LETTER

doi:10.1038/nature13247

Consequences of biodiversity loss for litter decomposition across biomes

I. Tanya Handa[1,2], Rien Aerts[3], Frank Berendse[4], Matty P. Berg[3], Andreas Bruder[5,6], Olaf Butenschoen[7], Eric Chauvet[8,9], Mark O. Gessner[5,6,10,11], Jérémy Jabiol[8,9], Marika Makkonen[3,12], Brendan G. McKie[13,14], Björn Malmqvist‡, Edwin T. H. M. Peeters[15], Stefan Scheu[7], Bernhard Schmid[16], Jasper van Ruijven[4], Veronique C. A. Vos[4] & Stephan Hättenschwiler[1]

- mixing of waste from different functional plant types has been shown in increased dynamics of carbon and nitrogen

Biodiversity and ecosystem productivity: implications for carbon storage

Sebastian Catovsky, Mark A. Bradford and Andy Hector, NERC Centre for Population Biology, Imperial College at Silwood Park, Ascot, Berks SL5 7PY, UK (m.a.bradford@ic.ac.uk).

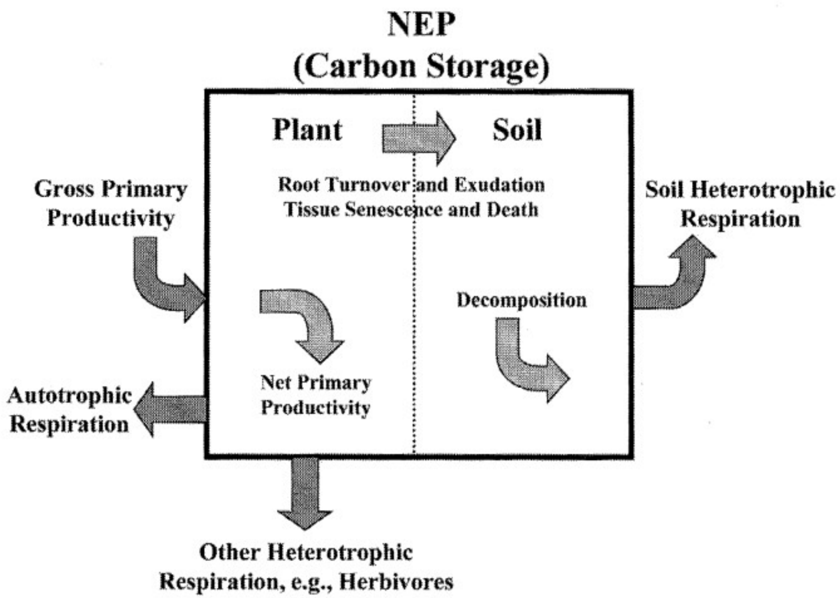


Fig. 1. Conceptual model showing the main biological components of ecosystem carbon budgets.

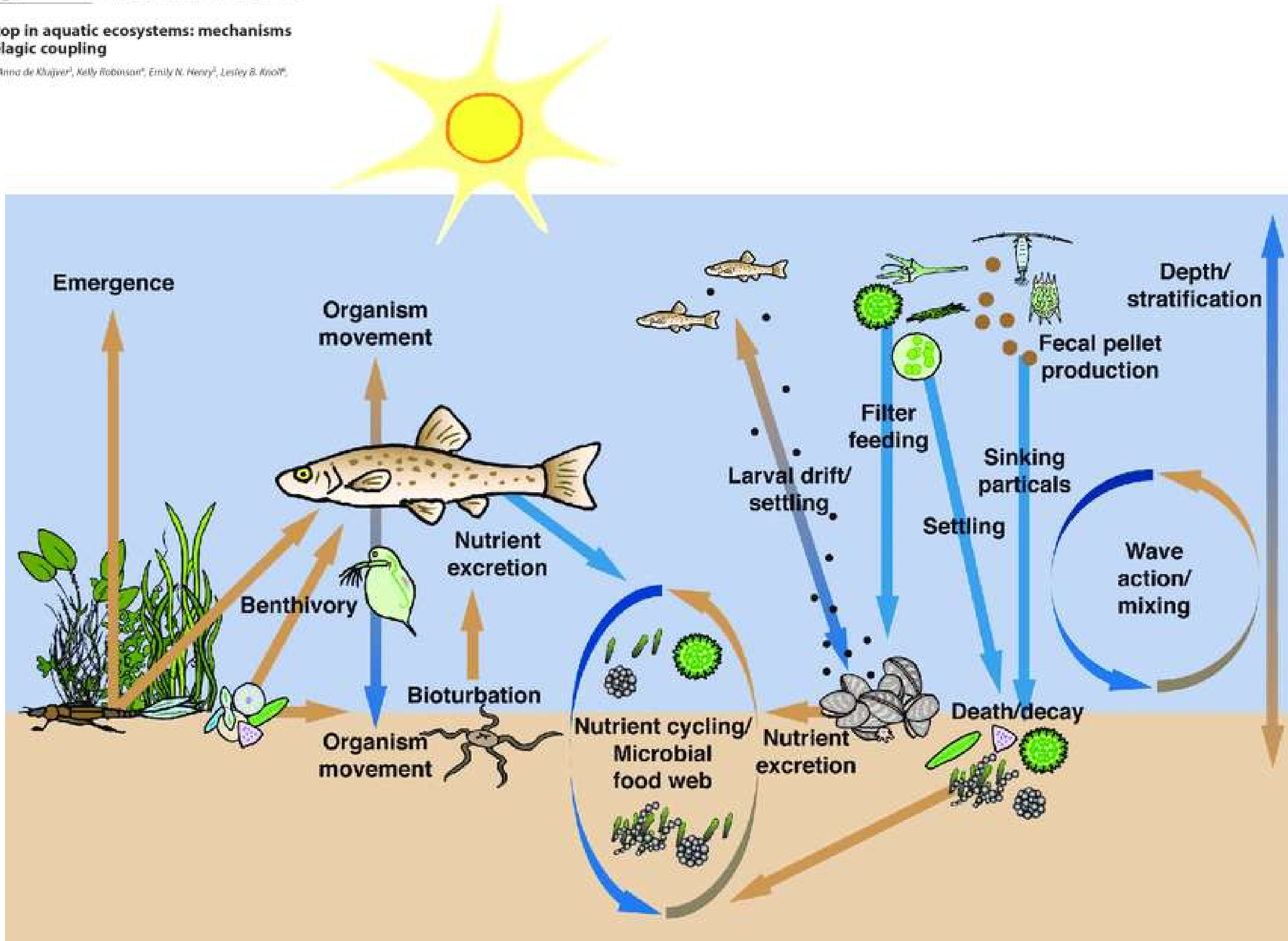
OIKOS 97:3 (2002)

NUTRIENT CYCLING

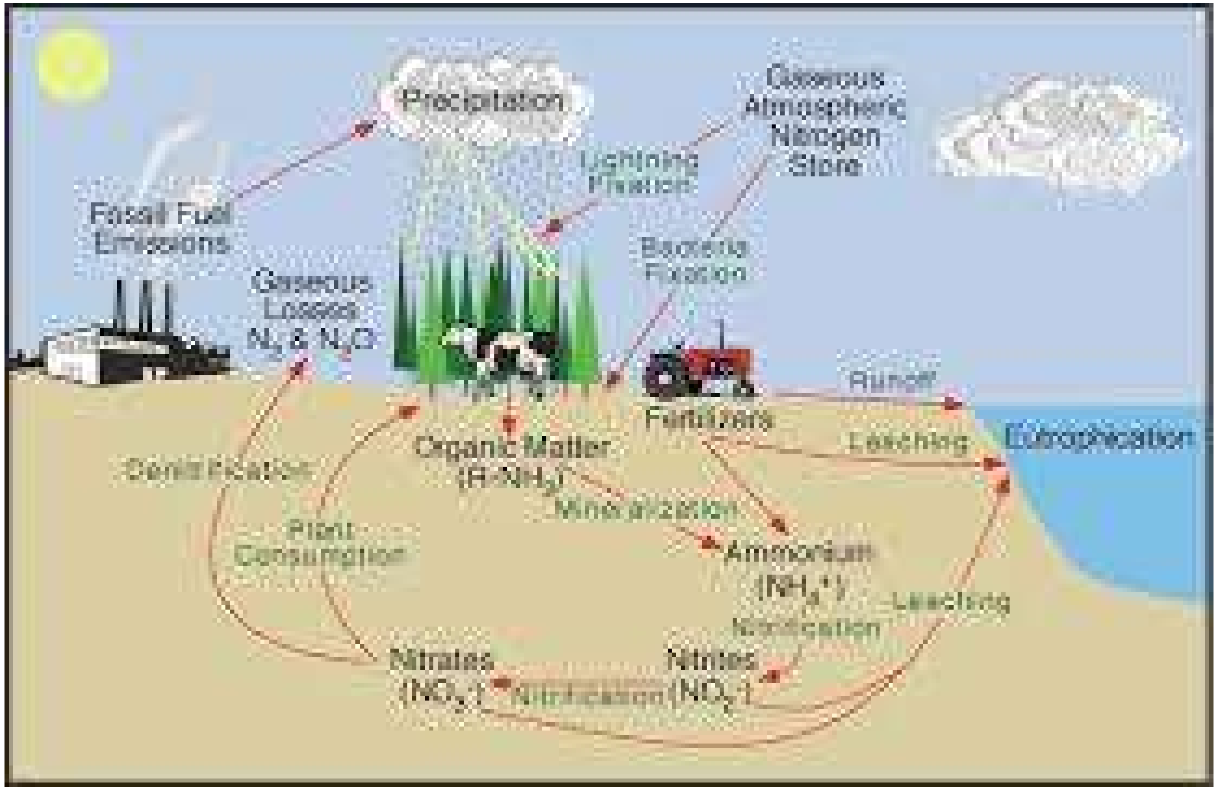
Eco-DAS X
Symposium Proceedings

Linking the bottom to the top in aquatic ecosystems: mechanisms and stressors of benthic-pelagic coupling

Melissa M. Baustian, Gretchen J. A. Hansen, Anna de Kluijver, Kelly Robinson, Emily N. Henry, Lesley B. Knoll, Kevin C. Rose, and Cayelan C. Carey



NUTRIENT CYCLING

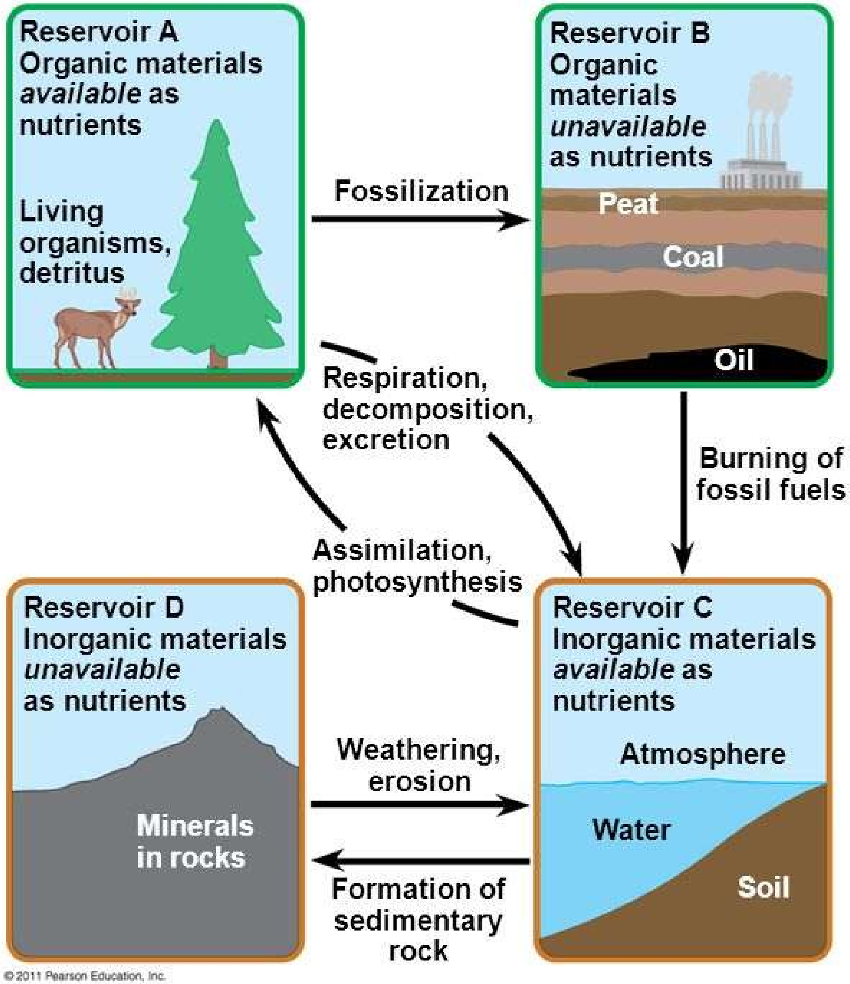


http://www.geocities.ws/jacklynn/website/pro.html

NUTRIENT CYCLING

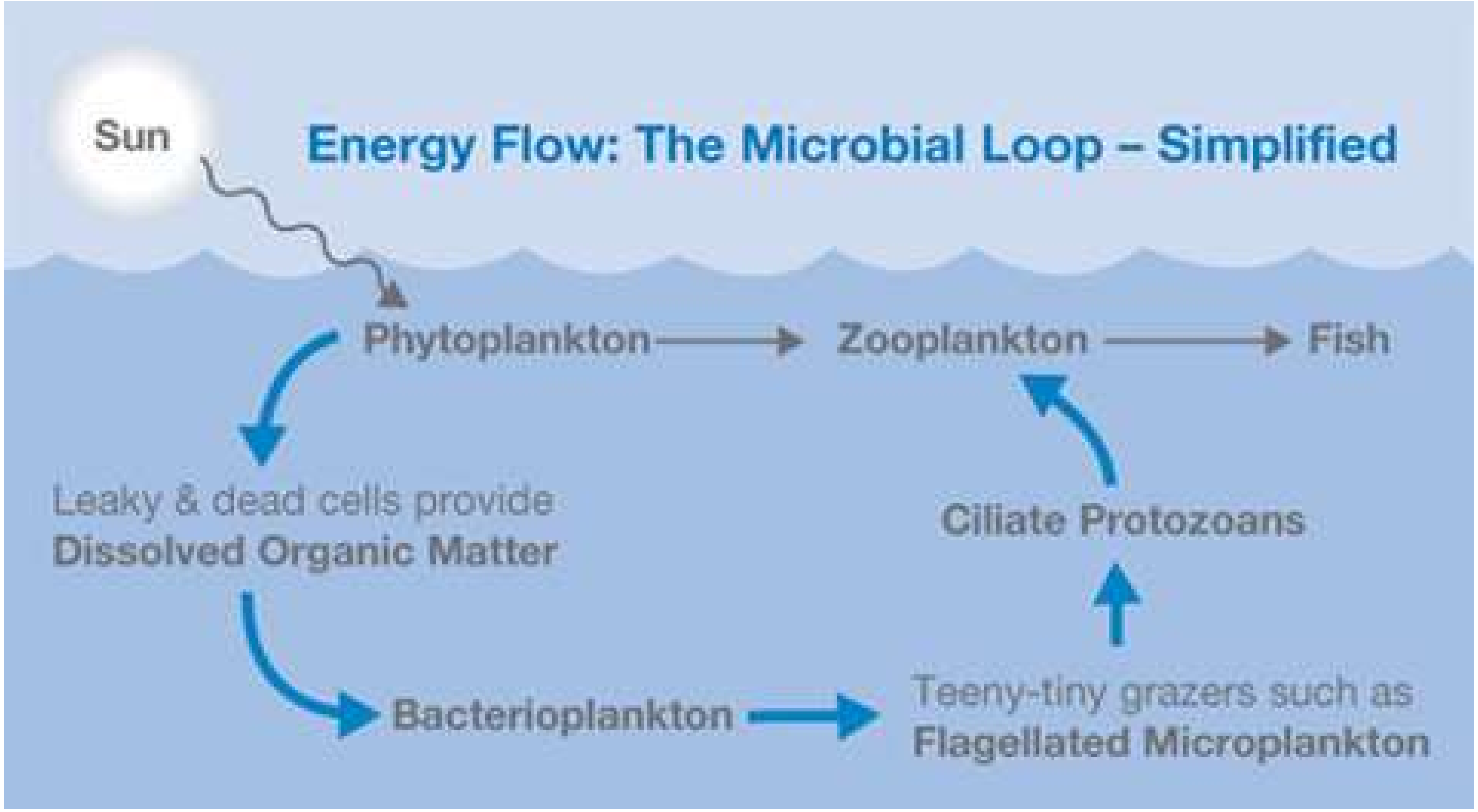
Figure 55.13

A general model of nutrient cycling.



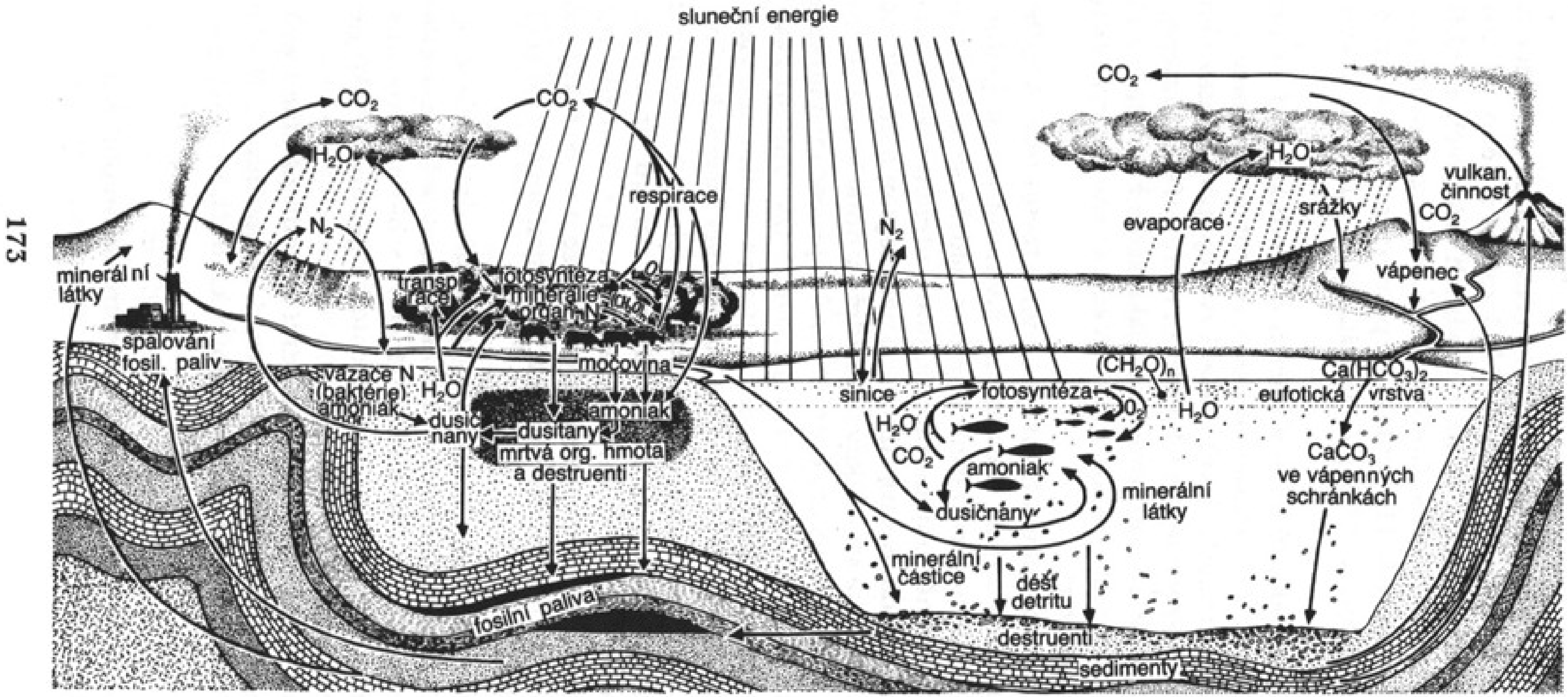
NUTRIENT CYCLING

STAGNANT WATERS



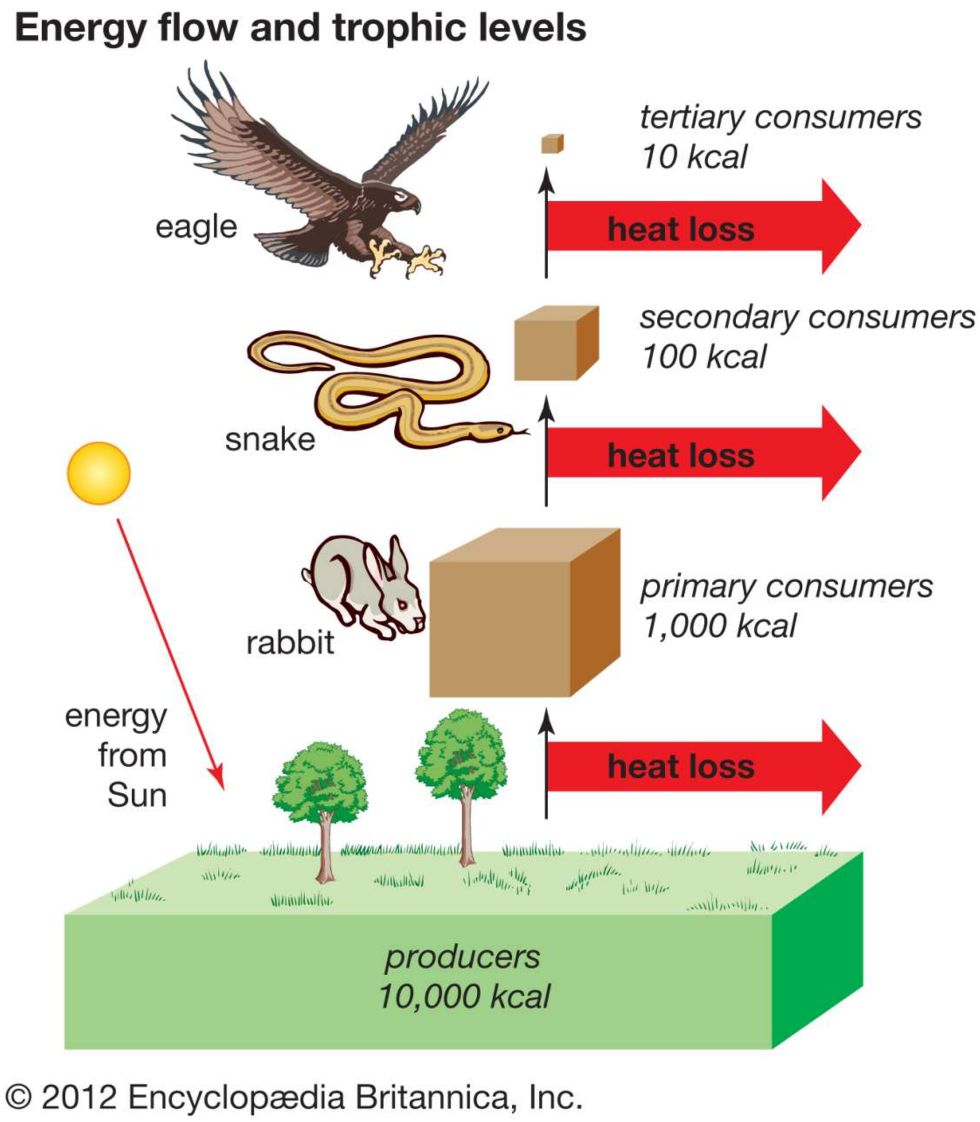
NUTRIENT CYCLING

STAGNANT WATERS



55. Schéma zapojení vodního ekosystému do velkého koloběhu látek a biologické aktivity v biosféře. Jejich základem je utilizace sluneční energie pro fotosyntetickou redukci CO_2 na tvorbu organických sloučenin $(CH_2O)_n$, při současném uvolňování molekulárního O_2. Uvedeny jsou i některé další prvky (podle různých autorů)

ENERGY AND NUTRIENT FLOWS



ECOSYSTEM SERVICES

Provisioning services

- food
- fresh water
- wood and fibre
- fuel
- raw materials (gravel)

Regulating services

- climate regulation
- flood regulation
- water purification
- pollination
- disease regulation

Cultural services

- aesthetic
- spiritual
- educational
- recreational

Supporting services

- biodiversity conservation
- nutrient cycling
- soil formation
- primary production