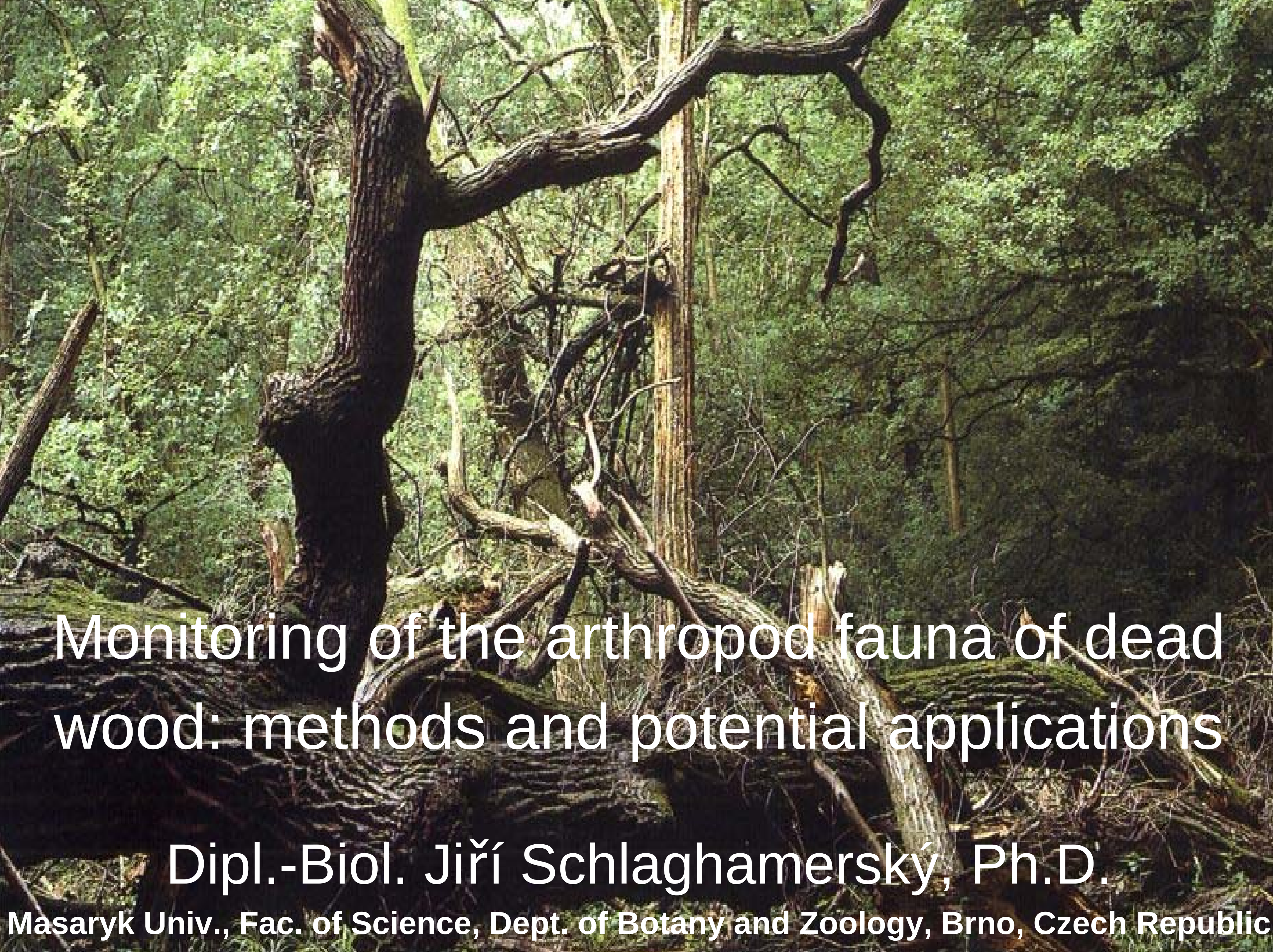

Monitoring of the arthropod fauna of dead wood: methods and potential applications

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Outline

- Why dead wood?
- Why and what arthropods?
- How to monitor?
- Conclusions

Why dead wood?

- Animals living either on live trees or on dead wood are by definition closely associated with woodlands and present a high percentage of all forest species (≈ forest biodiversity).

- The diversity of phytophagous fauna is largely dependent on the diversity of flora: many insects, for instance, are monophagous on single plant families, genera or even species.

- It is much easier (cheaper!) to collect sound data on flora and vegetation than on the associated fauna.

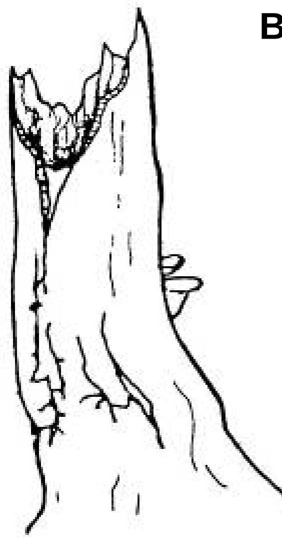
- For fauna associated with dead wood the situation is different!

- Ancient live trees (with a high proportion of dead wood structures as dry branches and cavities) and standing or fallen dead trees (including their detached parts) present an ecological resource almost limited to forest habitats (but high importance of the small portion present in open habitats!).

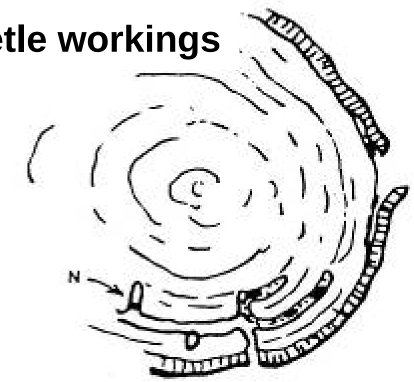
Why dead wood? (continued)

- A vast number of animal species (called saproxylic or xylobiotic), particularly arthropods, depends on this resource either partially or totally through a spatial link (microhabitat) and/or a trophic link (food chain).

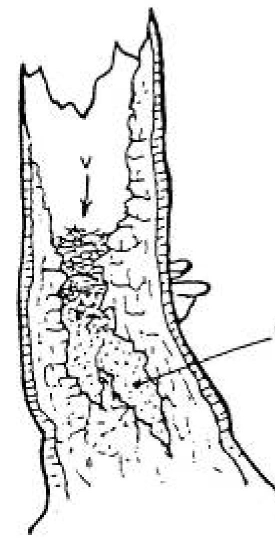
Examples of dead wood structures - microhabitats for of saproxylic fauna



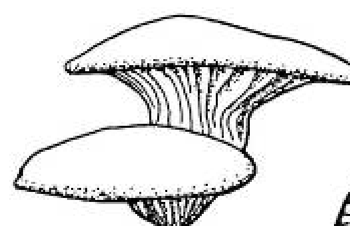
Standing dead trunks



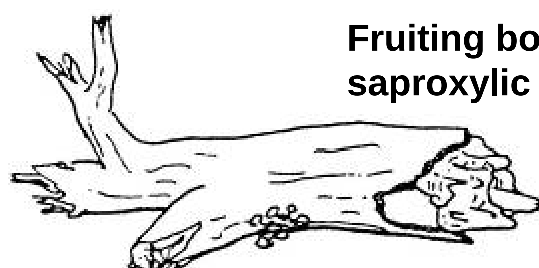
Beetle workings



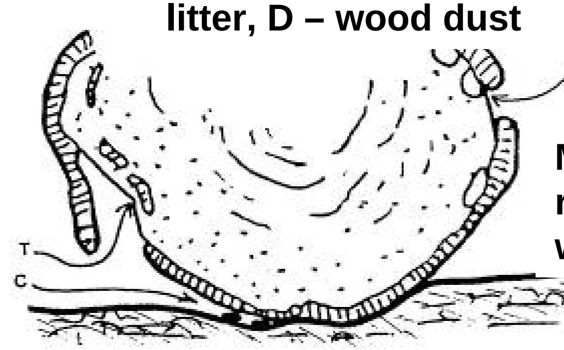
Tree cavity: V – layer of wood fragments and leaf litter, D – wood dust



Fruiting bodies of saproxylic fungi



Fallen trunks and limbs



Moist, rotten wood

Why dead wood? (continued)

- A substantial part of forest biodiversity is thus based on the high structural diversity of dead wood and depends
  - on its amount (dead wood volume),
  - its “quality”,
  - distribution in space (connectivity),
  - distribution in time (ecological continuity; site history)

- Dead wood quality is given by
  - origin of wood (tree species),
  - micro- and mesoclimate of its situation: humidity, temperature (insolation); contact to soil - standing or fallen,
  - size of individual piece of wood (e.g. trunk diameter),
  - stage of decomposition (succession of the saproxylic community),
  - decomposition path (determined by abiotic factors and by initial colonization by saproxylic organisms, particularly specific fungi).

- Dead wood amount and distribution is given by
  - present management of the forest stand and its surroundings
  - site history (type of forest: coppice, wood pasture, …, temporary deforested site – non-forestry land-use; occurrence of forest fires, etc.)

Why dead wood? (continued)

- Traditional forestry has widely eleminated „overmature“ trees, dead wood and the entire phase of forest disintegration from European forests.
- Present forests have often undergone periods of very intensive exploitation (total lack of dead wood, particularly of larger diameters) or grow on sites with interrupted habitat tradition / ecological continuity.
- Many saproxylic species are today rare and endangered, some limited to few “primeval forest” reserves (Primeval Forest Relicts, “Urwaldrelicts”).
- Such species (if not restricted to too few sites!) are suitable indicators of the present naturalness of forests (habitat quality) and their history.
- Of only 15 beetle species listed in Annex II of the EU Habitat Directive, 8 species are saproxylic ones! Of 8 beetle species listed in Annex II of the Berne Convention, 5 are saproxylics!
- Saproxylic organisms are instrumental in wood decomposition – a key process in (natural) forest ecosystems.

Why dead wood? (continued)

The large Hermit Beetle (*Osmoderma eremita*) depends on large tree cavities with dry wood dust its dispersal ability is very low (poor flier).

The tiny weevil *Acalles camelus* (Curculionidae) is mostly found on twigs and branches with fungi in the litter layer; it is missing from forests with interrupted habitat tradition; its dispersal ability is very low (incapable of flight).

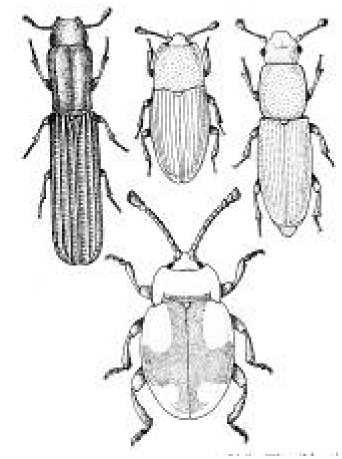
Why arthropods and what arthropods?

- Arthropods, particularly insects, have by far the highest share of all organisms living on Earth: 80 % of all extant animal species (960 000 of ca 1.2 million animals and of ca. 1.4 million extant organisms described). Should the estimates of true species richness (ca 5 – 30 million species) the share of arthropods will even increase.

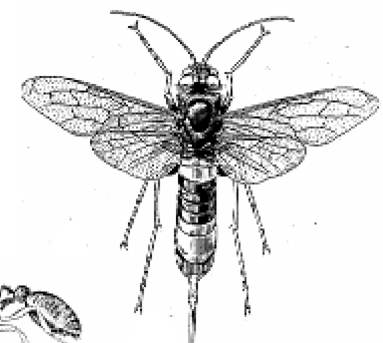
- With ca 350 000 described species beetles (Coleopterea) are the animal taxon of highest species richness, moths and butterflies (Lepidoptera) with ca 150 000 species ranking second.

Why arthropods and what arthropods? (continued)

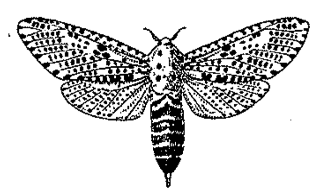
Arthropods living in or on dead wood:

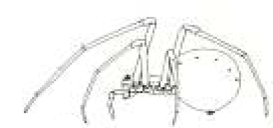


- Many Coleoptera from many families
- Many Diptera: Nematocera and Brachycera
- A considerable number of Hymenoptera
  - Symphyta: Siricidae - xylophages
  - Apocrita: Ichneumonidae - parasitoids
  - Apocrita: Braconidae - parasitoidis
  - Apocrita: Stephanoidea - parasitoids
  - Apocrita: Chalcidoidea - (hyper)parasitoids
  - ants (Apocrita: Formicidae) – polyphages



- Some Lepidoptera
  - Sesiidae
  - Cossidae
  - Tinaeidae
  - Pyralidae
  - Oecophoridae

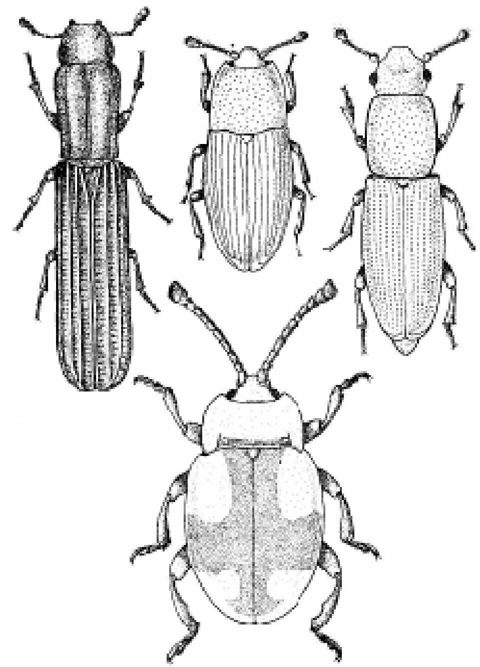




- **Some spiders, many mites** (of other “invertebrates” many nematodes, some snails and slugs; in the last stage typical soil fauna: earthworms, enchytraeids

Why arthropods and what arthropods? (continued)

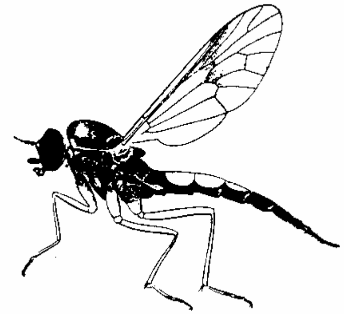
The most studied taxon of saproxylic animals are Coleoptera; for good reasons:



- many species
- ecological (functional) importance
- sufficient taxonomic knowledge, identification rather easy
- sufficient information on autecology and distribution
- sufficient information on level of threat / conservation status

Diptera are of a comparable functional importance:

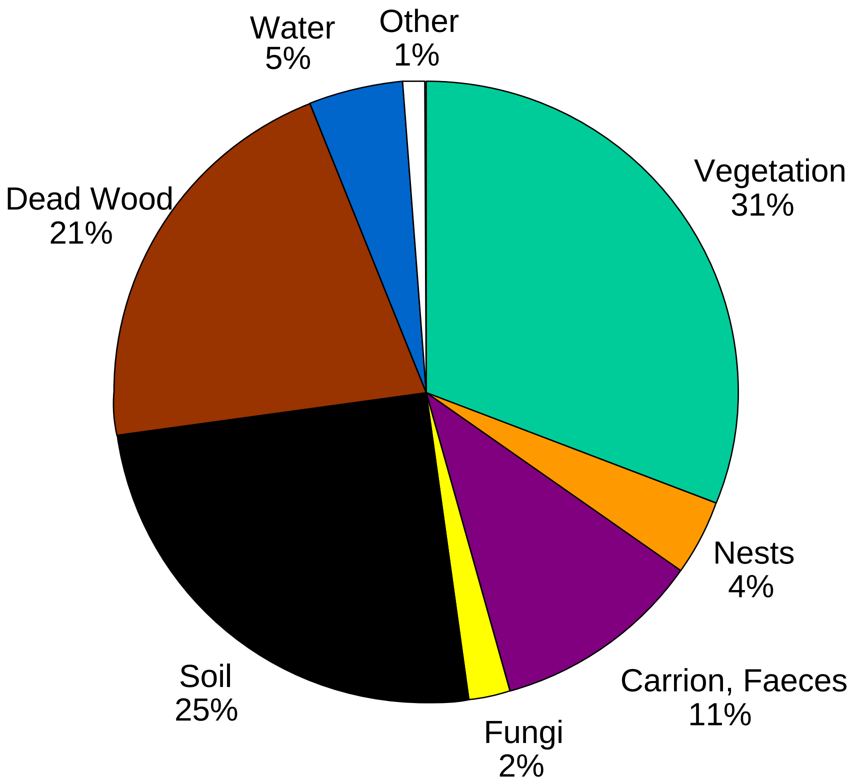
- high abundance (Nematocera)
- many species (Brachycera)



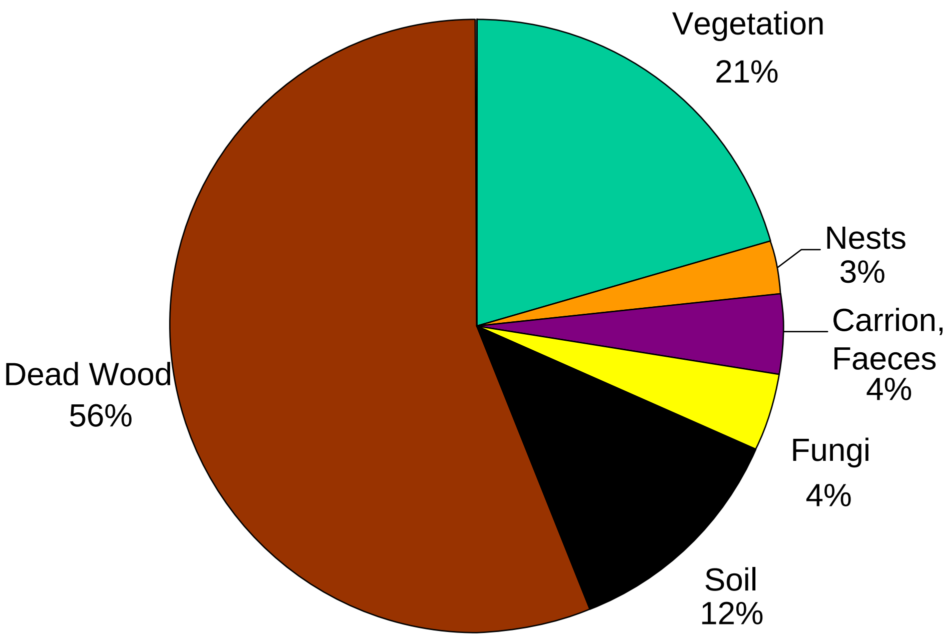
However, taxonomy is difficult for many saproxylic groups of Diptera, information on ecology / level of association with dead wood is insufficient!

Why arthropods and what arthropods? (continued)

The share of saproxylic (xylobiotic) beetles on the total species richness of beetles in Germany (KÖHLER, 2000)



Total beetle fauna of Germany broken down According to (micro-)habitat: 6 477 species (all Central Europe: 8 893 species), of those 1 371 „xylobiotic“ ones



Fauna of **woodland beetle species** in Germany broken down according to (micro-)habitat: 2 340 species, of those 1 316 „xylobiotic“ ones

How to monitor?

- In general, the objective of monitoring organisms is
  - to assess the development of their populations / communities over time,
  - to assess the factors causing the changes observed, and
  - to draw conclusions regarding the past and future management of individual populations and/or communities and their habitats .

- Thus monitoring also requires the collection of potentially relevant data on abiotic factors, human interference (management), etc.

- To come to sound conclusions collected data have to allow meaningful statistical analysis.

- Monitoring does not require to produce a “complete” inventory of all species of the target group (studied assemblage), but it requires the repeated use of one or several standardized methods capable of collecting a reasonable segment of the entire assemblage and providing data allowing for statistics.

How to monitor? (continued)

- A survey aimed at producing an site inventory of species as complete as possible (presenting a valuable information on the conservation value of a site) should use a combination of a number of collecting methods, both trapping techniques and hunting techniques.

Number of saproxylic beetle species recorded by 6 closed ground photo-eclectors with enclosed oak logs, tree photo-eclectors on 3 standing tree trunks, 2 window traps and hand collecting for two years (window traps one year only) at two floodplain forest sites in South Moravia, Czech Republic (Schlaghamerský, 2000).

How to monitor? (continued)

Collecting methods used for saproxylic beetles (and other arthropods):

Hunting techniques:

- beating
- sweeping
- sifting litter / woody debris
- hand-collecting (combined, e.g., with bark peeling)
- canopy fogging

Trapping techniques:

- emergence traps (closed trunk photo-eclectors or modified ground photo-eclectors) used outdoor or indoor (rearing).
- open tree or trunk photo-eclectors
- pitfall traps in tree cavities
- sticky bands (around tree trunks)
- light traps
- Malaise traps } **flight interception traps**
- window traps }

How to monitor? (continued)

- A combination of methods will produce a longer species list but will hardly allow a statistical analysis that would allow to compare different sites and different years (as required for monitoring).

- The result of “hunting” techniques as sweeping and beating, sifting litter and fine woody debris, and hand-collecting (picking individual specimens from particular micro-habitats) is heavily dependent on the experience and personal preferences of the collector. They can be very efficient for site surveys if a specialist is employed (but difficult to standardize).

- Therefore the use of traps seems more appropriate for monitoring schemes.

- The number of traps will always constitute a compromise between statistical requirements and the managable amount of material (cost-time considerations).

- In-between-year differences in beetle populations – reflected by differences in the structure of assemblages found – are high. Thus differences between individual years are different to interpret – “time points” should be probably represented by data of at least two years.

How to monitor? (continued)

Using modified ground photo-eclectors to study saproxylic arthropods (eclector bottom made of gauze – enclosed oak logs, or plaster of Paris – enclosed stumps)

How to monitor? (continued)

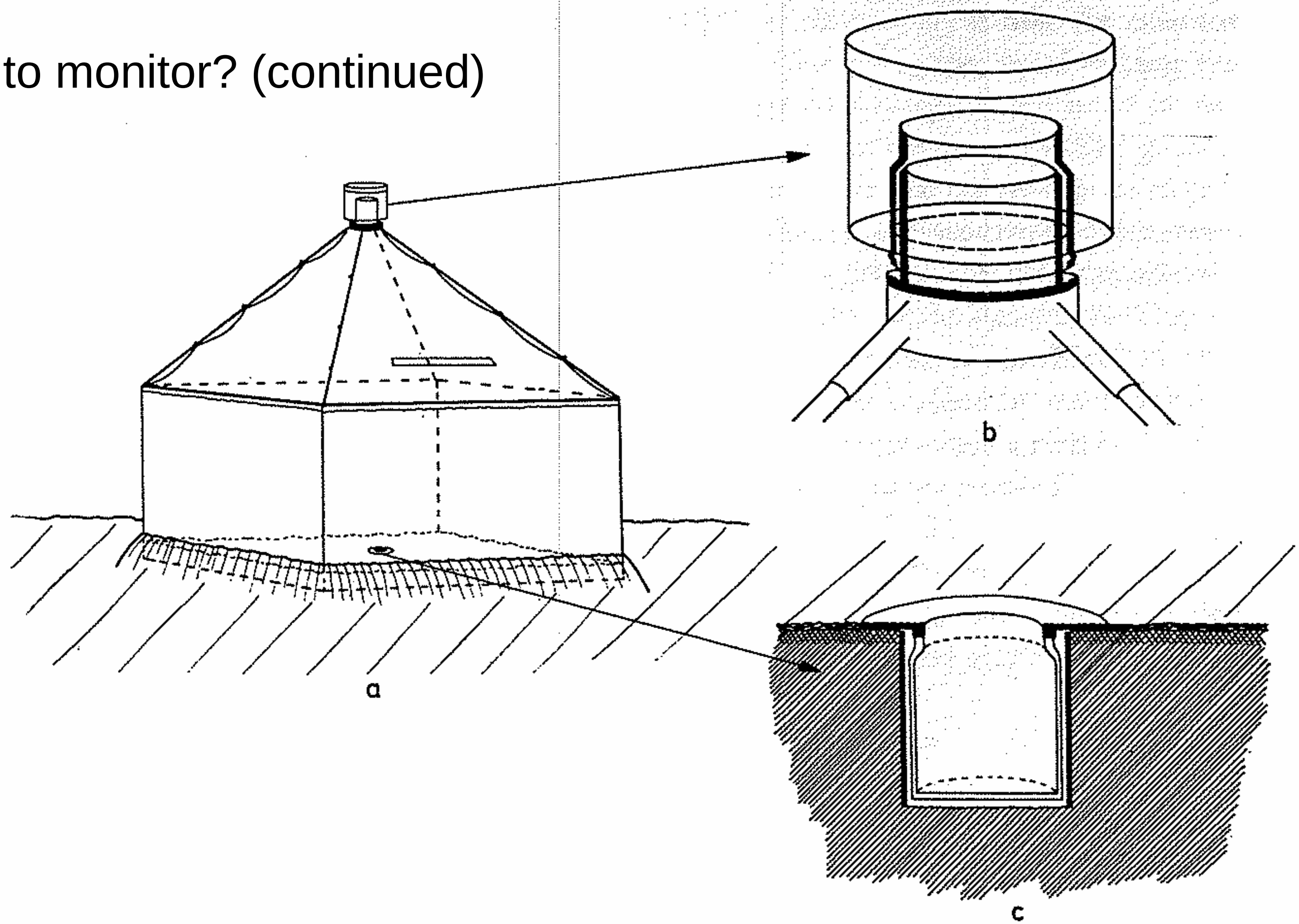
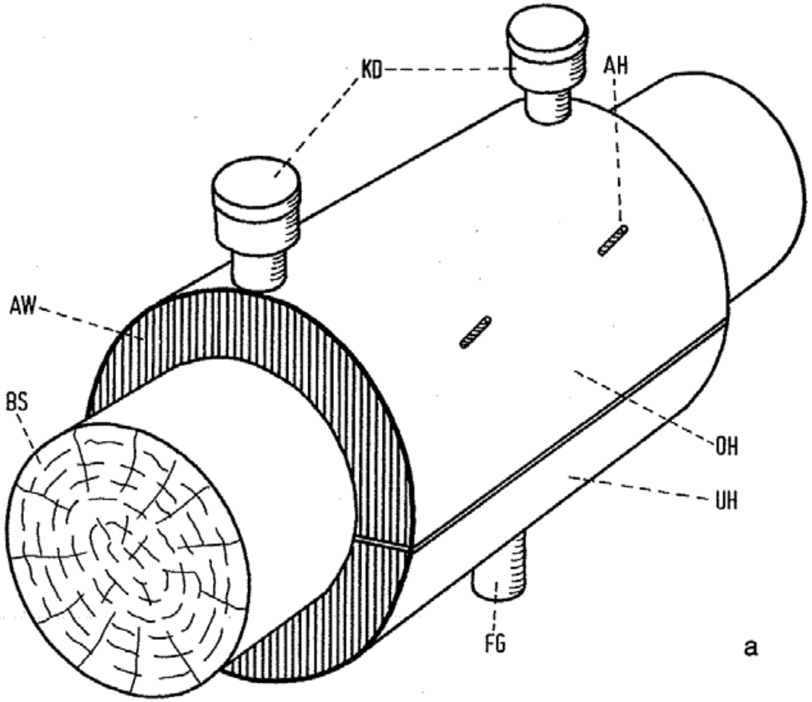


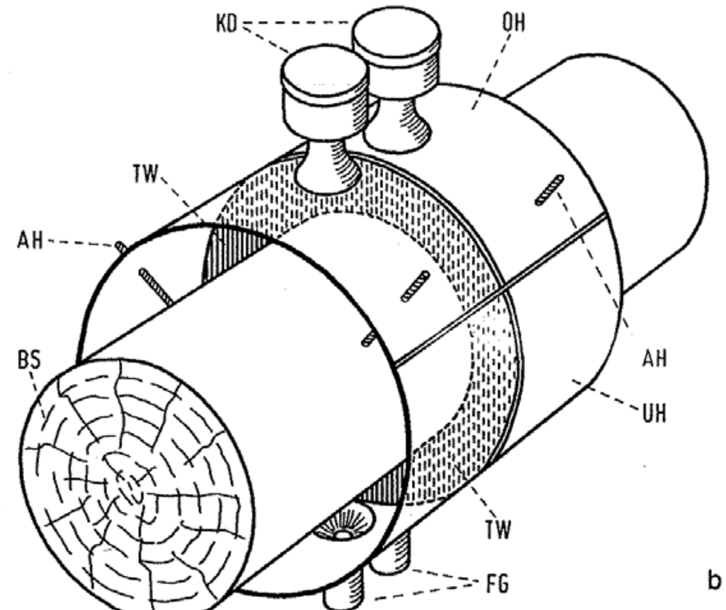
Fig. 1a—c. Ground photo-eclector (emergence trap). a) total view; b) sampling box (light trap) with pipes and upper metal construction; c) pitfall trap (sectional diagram); particulars see text

Funke, W., 1977: Food and energy turnover of leaf-eating insects and their influence on primary production. In: Ellenberg, H. (ed.) Integrated Experimental Ecology

How to monitor? (continued)



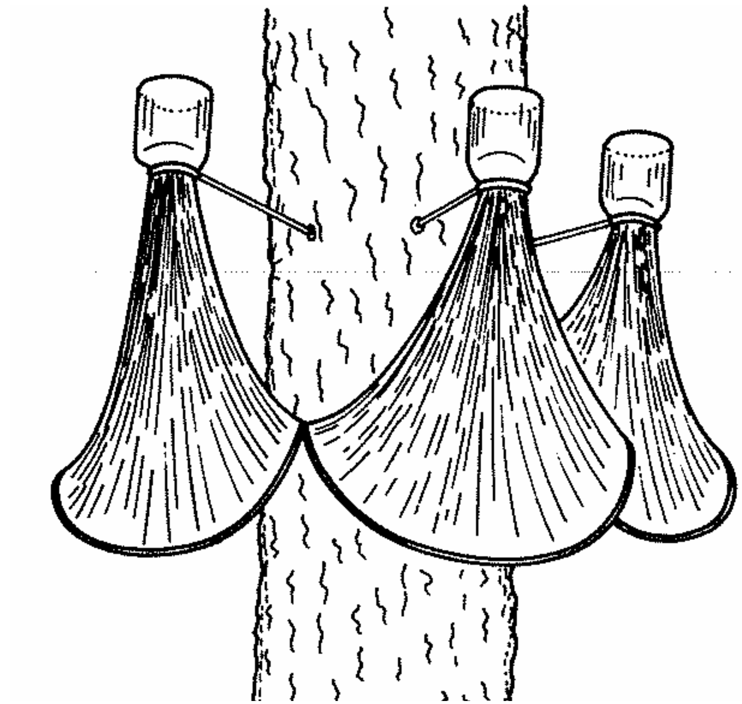
Closed trunk photo-eclector



Open trunk photo-eclector

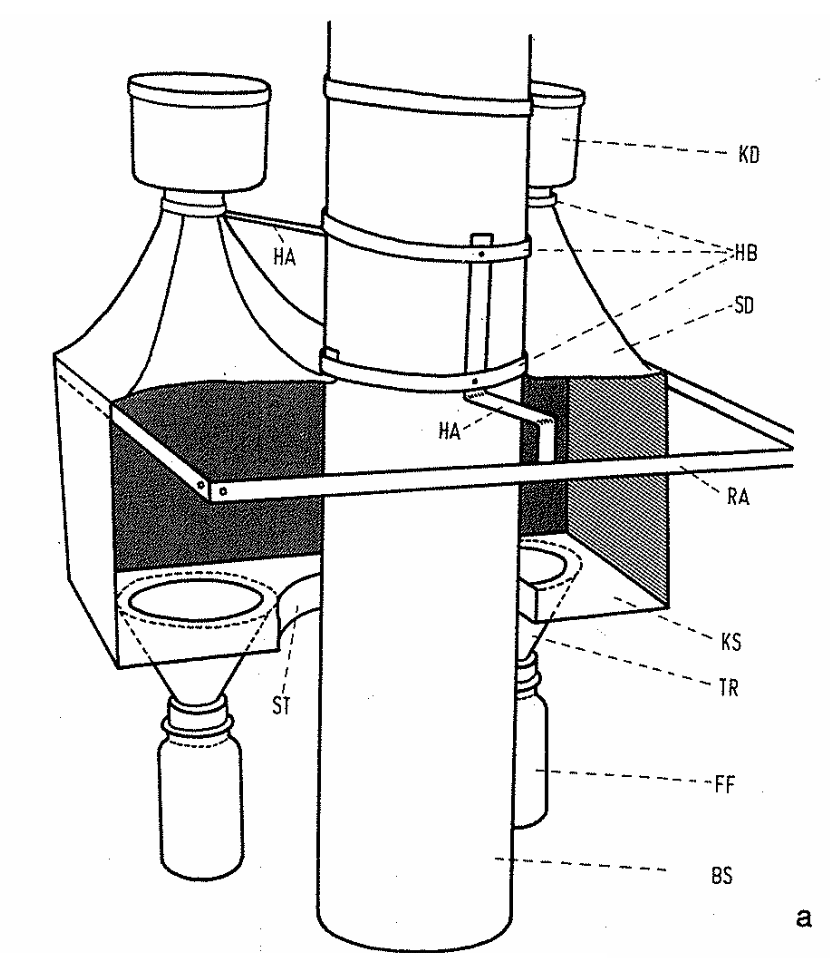
(Product of the Company Behre; in Mühlenberg, 1989)

How to monitor? (continued)

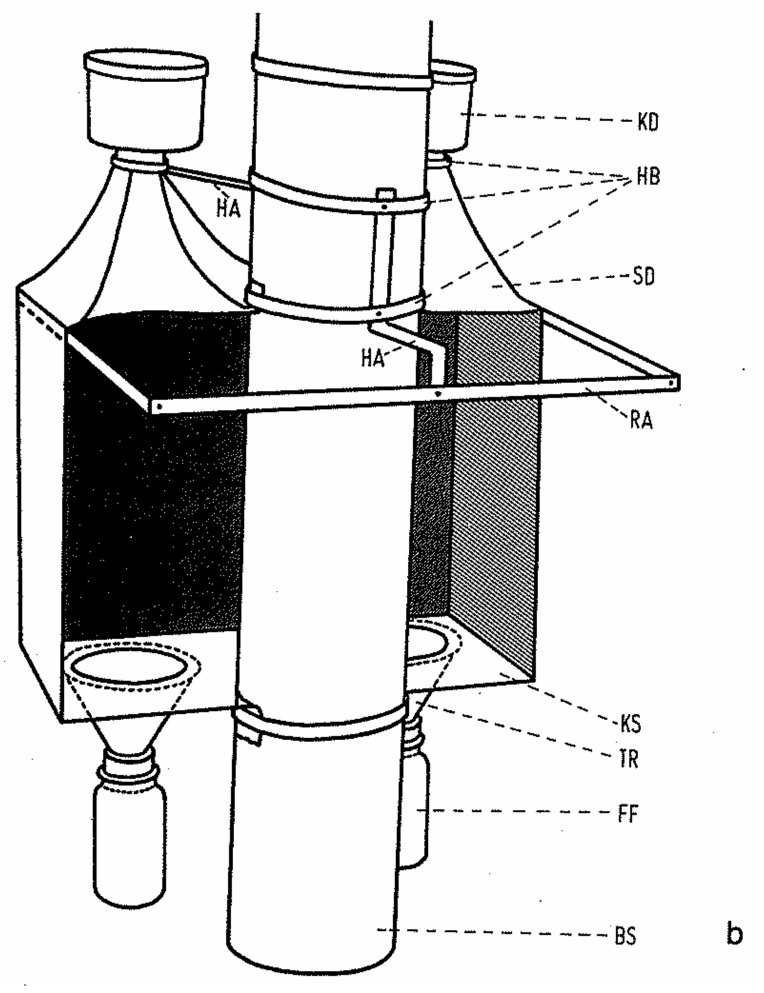


Open tree (= arboreal) photo-eclector (Funke, 1977; in Dykyjová et al.,1989)

How to monitor? (continued)



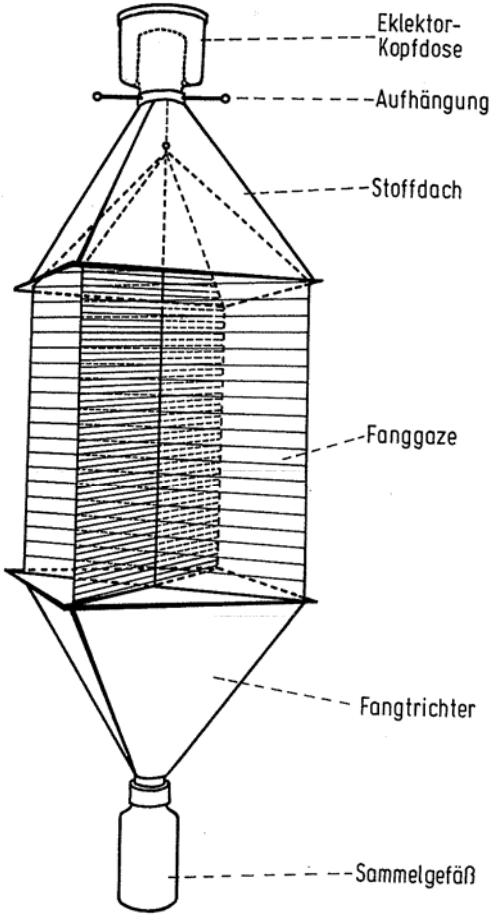
Open tree photo-eclector



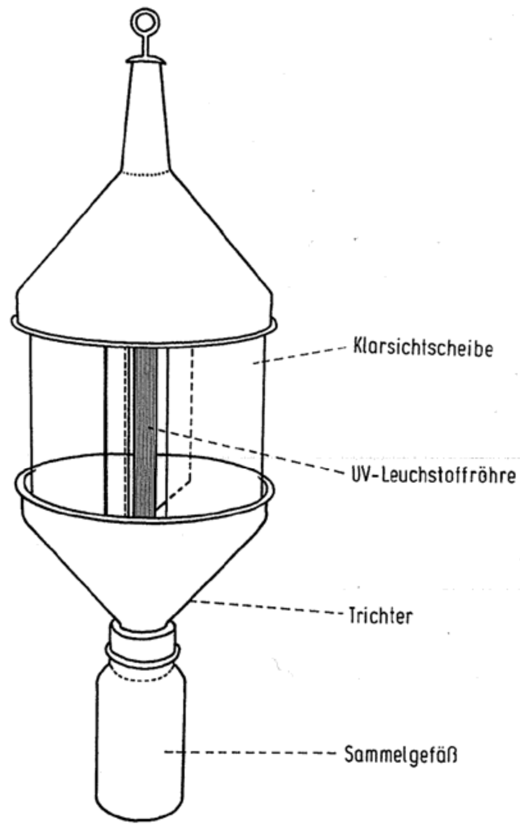
Closed tree photo-eclector

(Product of the Company Behre; in Mühlenberg, 1989)

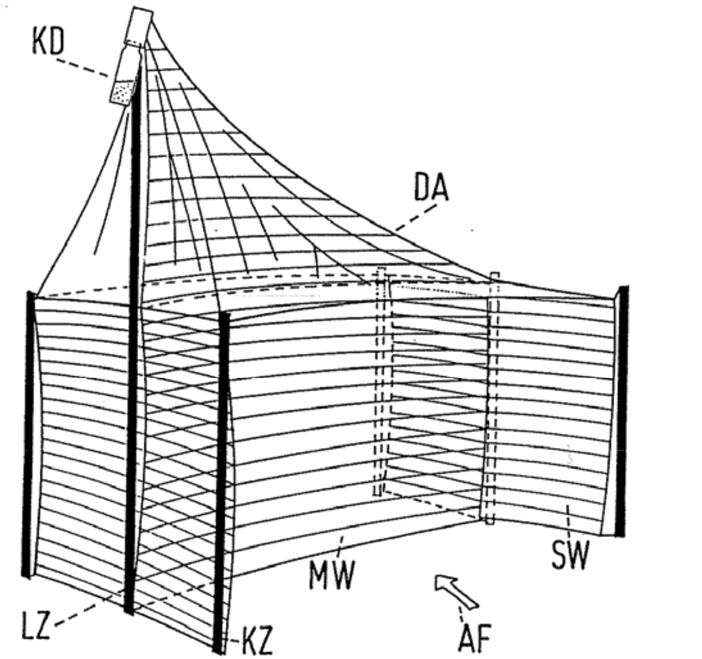
How to monitor? (continued)



Aerial Eclector



Light Trap



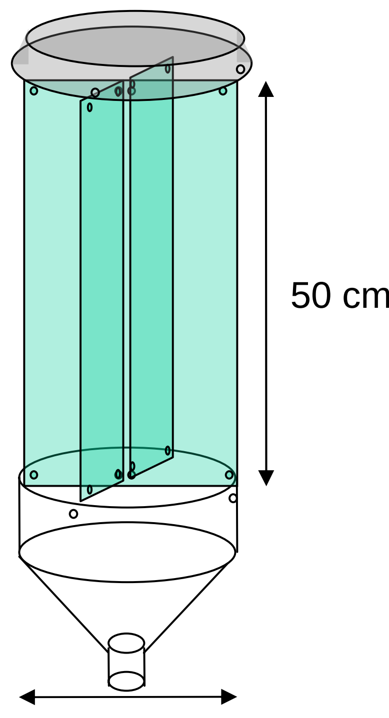
79: Malaise-Falle (Modell Townes) (Behre). – KD – Kopfdose, LZ – lange Zeltstange, KZ – kurze Zeltstange, MW – Mittelwand, SW – Seitenwand, DA – Zeltdach, AF – Anflugrichtung.

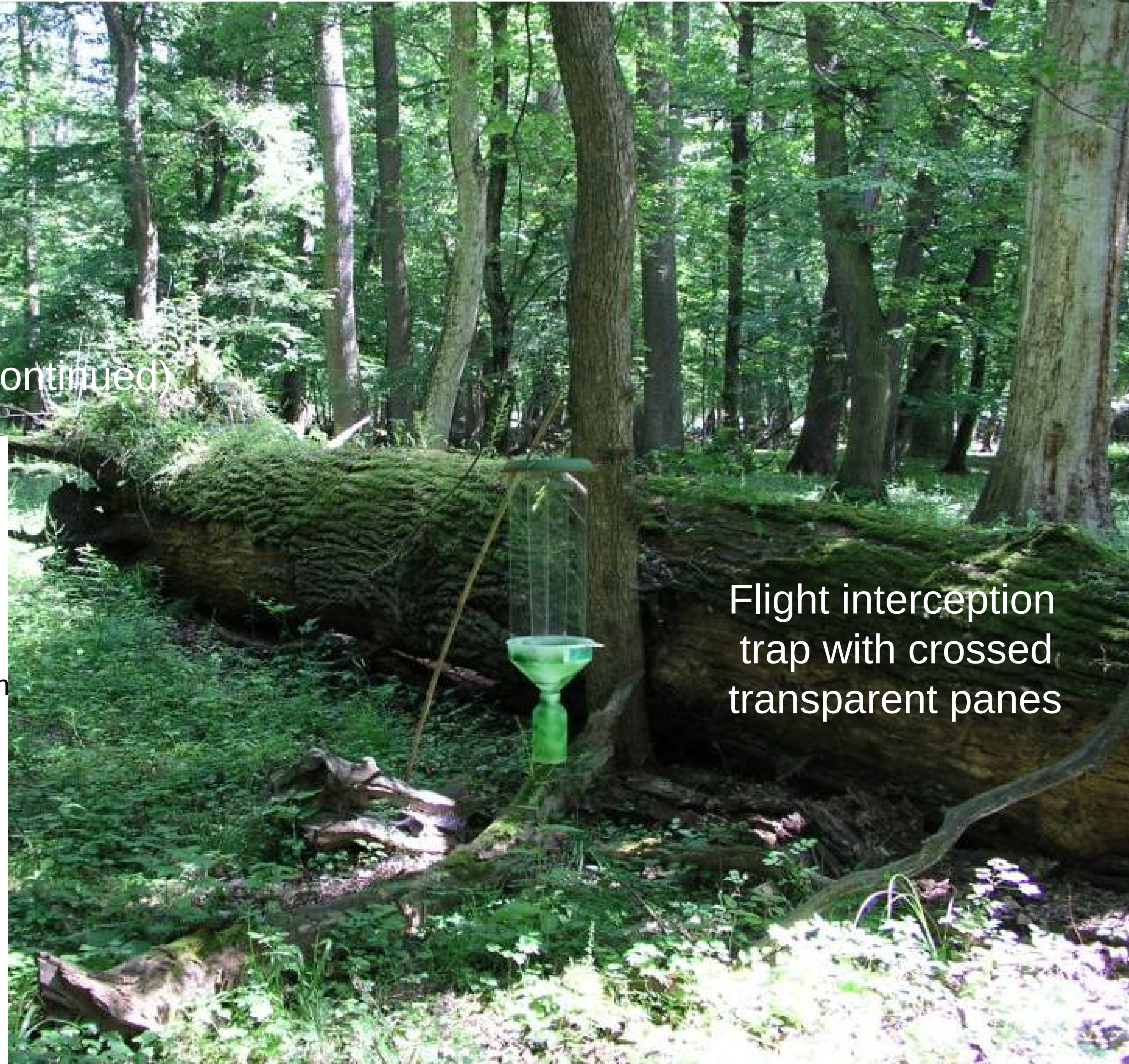
Malaise Trap

How to monitor? (continued)

Window trap of classic design

How to monitor? (continued)





Flight interception trap with crossed transparent panes


How to monitor? (continued)

How to monitor? (continued)

Collecting canopy fauna / studying vertical distribution of flight activity

How to monitor? (continued)

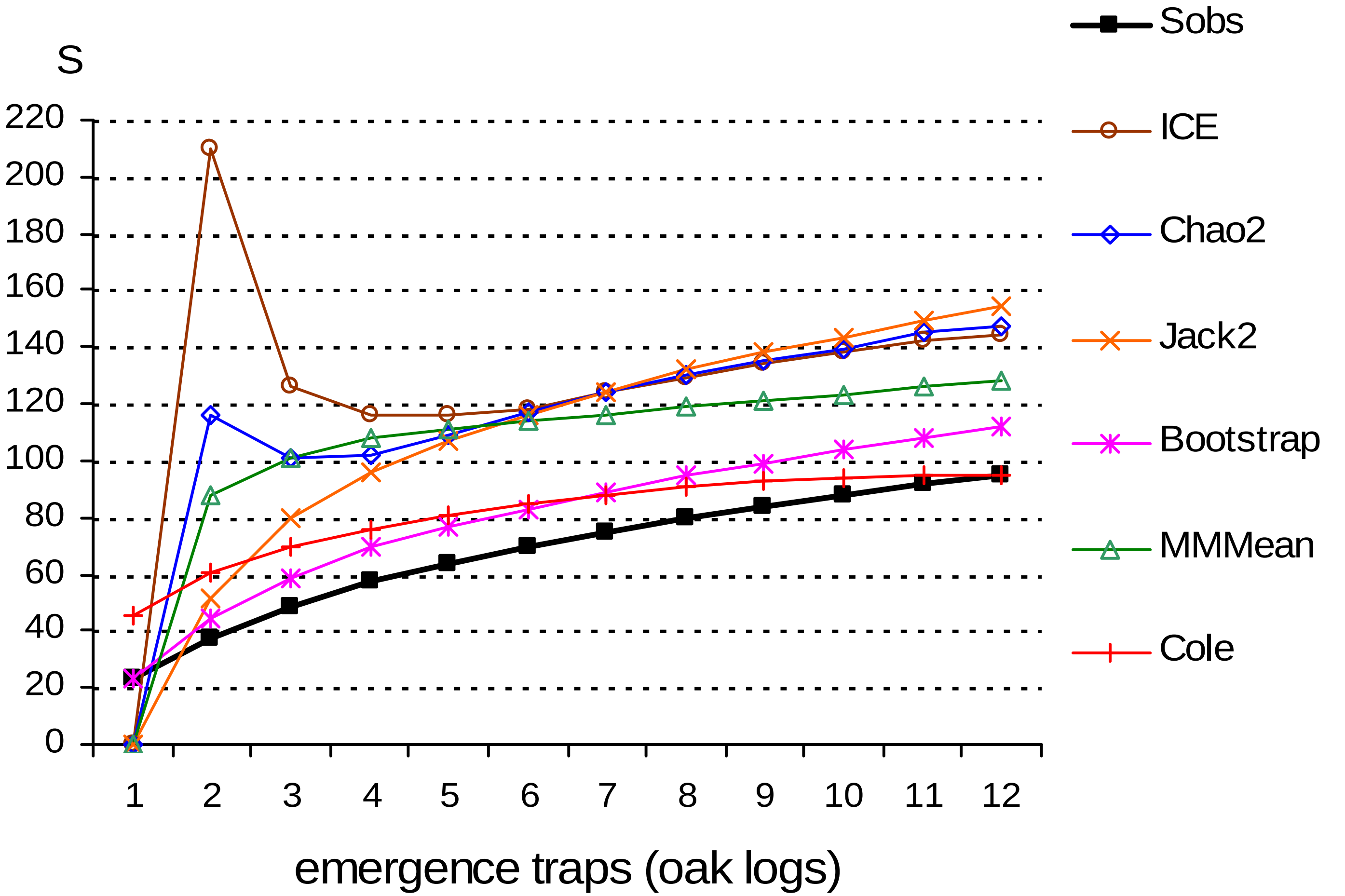
- Advantages of flight interception (window) traps include for instance

  - the non-invasive character – no distruction of micro-habitats (particularly important in reserves)
  - the high proportion of the target group (dead wood beetles) in the catch, i.e. selectivity
  - the suitability for the use in different strata of the forest stand
  - the rather simple construction and operation
  - the high efficiency (cost-benefit ratio)

- Disadvantages of flight interception (window) traps include for instance

  - the need to check, empty and replenish the traps in regular intervals
  - the risk of loss due to vandalism or adverse weather (storm)
  - the fact that they collect species capable of flight only (apterous species and poor fliers – often the most endangered species – are underrepresented)

How to monitor? (continued)



Example of accumulation curves based on observed and estimated species numbers in individual samples (coloured curves based on different estimators, i.e. mathematical algorithms) for saproxylic beetles from 12 oak logs collected by emergence traps (Schlaghamerský, 2000).

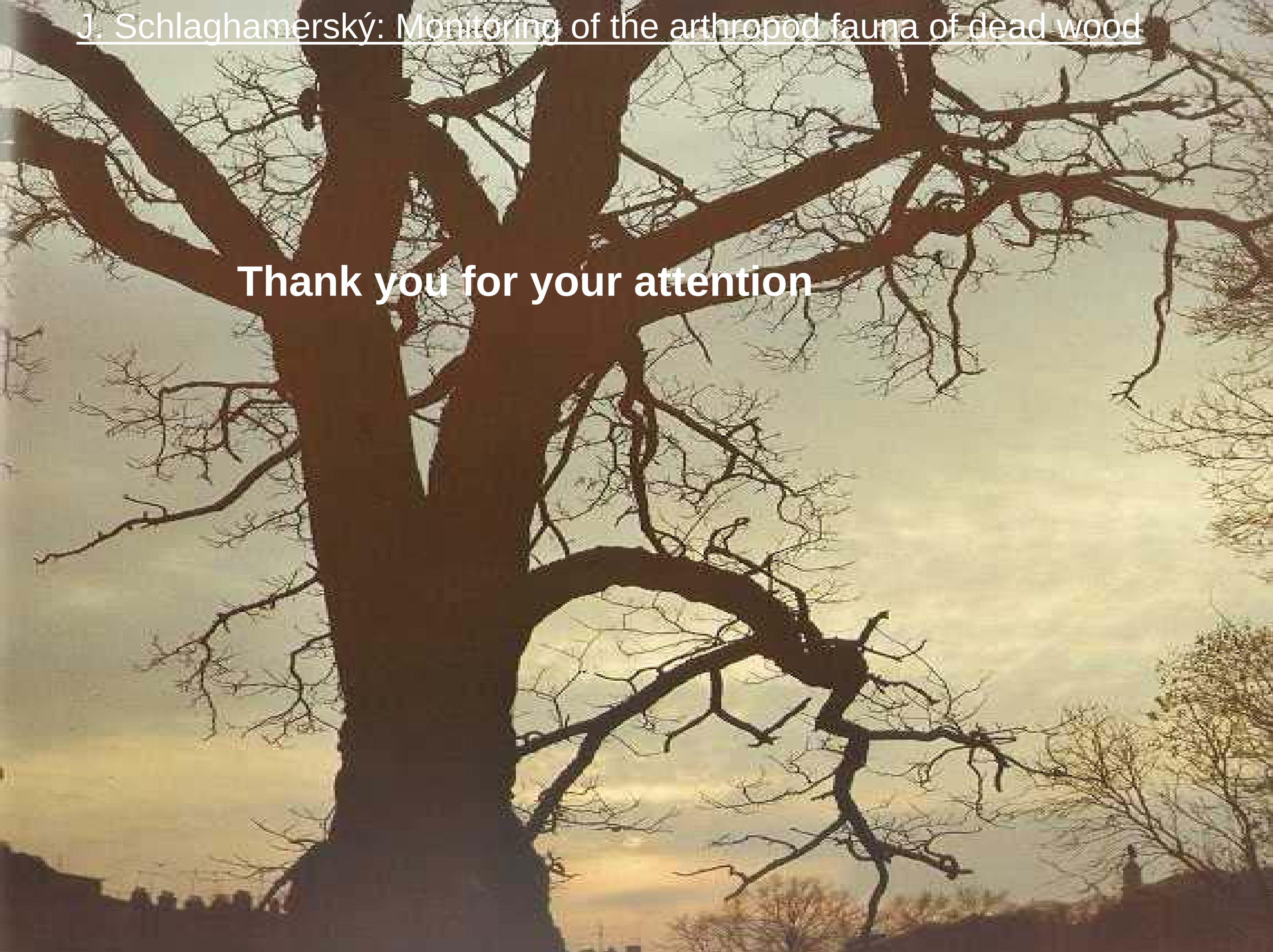
Conclusions

- Emergence traps are rather expensive and can hardly cover all the different types of microhabitat associated with dead wood.

- Many other trap types are very efficient for collecting other insects but less so for beetles (Malaise traps – Diptera, light traps – Lepidoptera).

- Flight interception traps (window traps) seem the most suitable single method for monitoring saproxylic beetles and have become the most frequently used means for this and related purposes (used e.g. in the UK, Fennoscandia, Germany, Switzerland, France, Belgium, Italy, Czechia, and Slovakia).

- Issues of standardization are yet to be resolved if different researchers in different countries are to produce comparable outputs:
  - **size and exact design of traps**
  - **killing and preserving agent (attractive vs non-attractive solutions)**
  - **number of traps required per site**
  - **the way of placing the traps (independent of vs close to “attractive” dead wood structures.**



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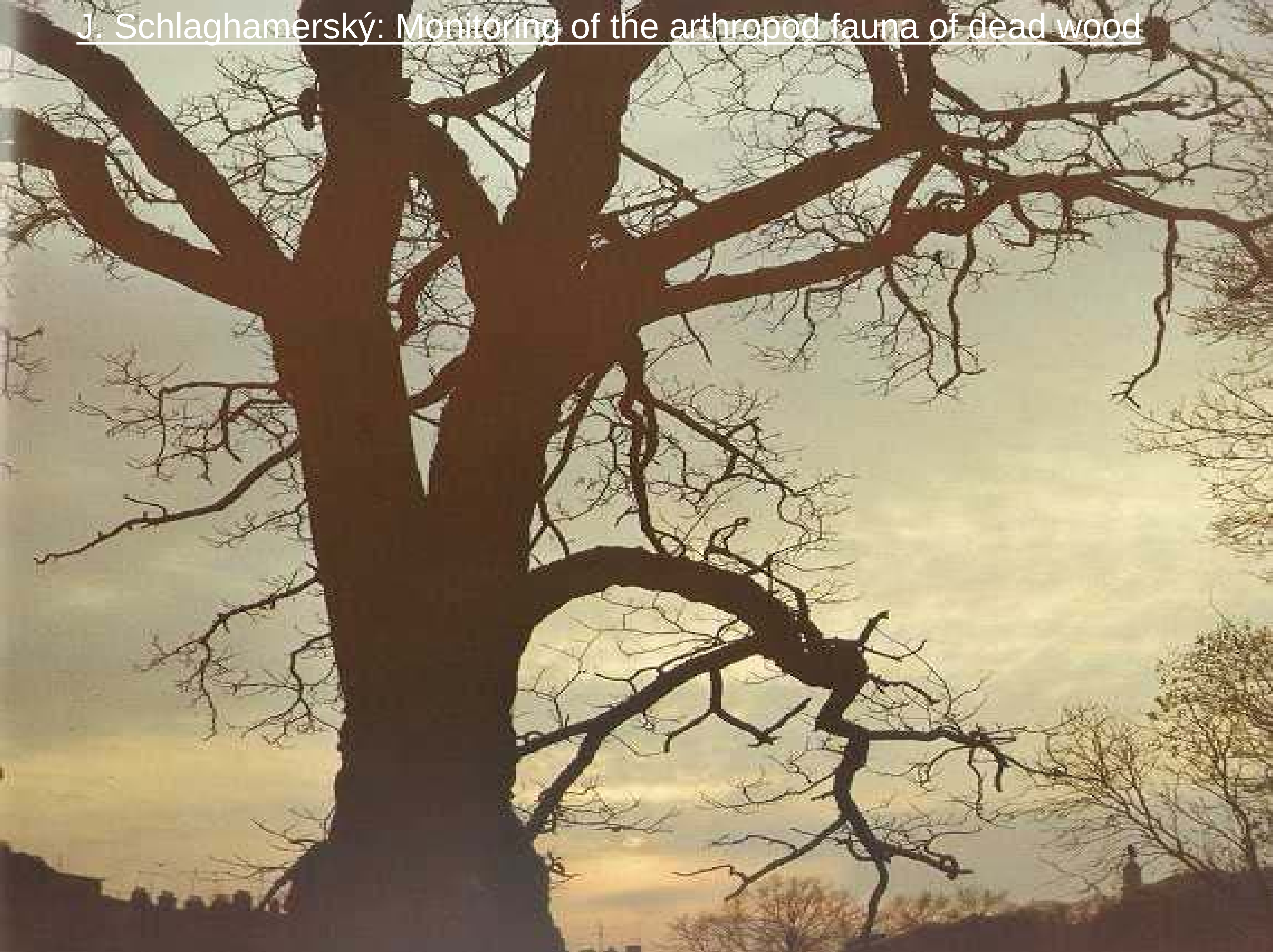

Definition of saproxylic invertebrates / organisms

(more from the point of view of conservation than from a strict scientific, ecological one)

Saproxylic invertebrates (SPEIGHT, 1989):

“Species of invertebrate that are dependent during some part of their life cycle upon the dead or dying wood of moribund or dead trees (standing or fallen), or upon wood-inhabiting fungi, or upon the presence of other saproxylics”

Druhy bezobratlých živočichů, které jsou závislé, během některé části svého vývojového cyklu, na mrtvém nebo odumírajícím dřevu odumírajících nebo mrtvých stromů (stojících nebo padlých), nebo na houbách žijících na dřevě, nebo na přítomnosti jiných saproxylických organismů.

“Primary saproxylics“ initiate the wood decomposition by injuring the tree (mostly phloeophages), “secondary saproxylics“ follow.

Saproxylic organisms (HARDERSEN, MASON, SANDSTRÖM, SCHLAGHAMERSKÝ, SPEIGHT, VALLAURI, 2003):

“Saproxylic organism: A species dependent in some stage of its life cycle on dead wood of senescent trees, or on fallen wood, or on other saproxylic organisms.”

Ecological requirements (and conservation needs) in common have led to a need for a term for animals or even all organisms closely associated with (dependent on) dead wood. Due to the dominance of insect species among the animals involved, this is most apparent in entomological literature:

dead wood beetles / Totholzkäfer (brouci mrtvého dřeva)
saproxylic inverterbrates (organisms,...) / saproxyličtí bezobratlí (saproxylické organismy atd.)
xylobionte Käfer (Wirbellose,...) / xylobiotic beetles (invertebrates,...) / xylobiontní brouci (atd.)
xylophilous Diptera / xylofilní dvoukřídlí

What exactly is “dead wood”?

Most wood tissues of live trees and shrubs is dead tissue – the xylem.
However, this wood is not decomposing (as long as the plant is healthy).
Thus it is generally understood that by saying dead wood we mean dead trees and shrubs or dead parts of these plant.

Xylobiotic means “living in or on wood”.

The term as such does not discriminate between intact (live or dead) and decomposing wood, it does not per se include wood fungi or even tree bark (however, its definitions usually do!).

Saproxylic means “in or on decomposing wood”.

The basis of wood decomposition is the colonization by fungi – their fruiting bodies are associated to decomposing wood as are all other organisms living in the wood (directly or indirectly participating in its decomposition). These organisms form the “saproxylic complex“. However, this term (“saproxylique“) has been originally used only for the phase when soil fauna starts to immigrate into dead wood, i.e. for the transition between wood and soil (SILVESTRI, 1913).

Most animals with a trophic link to decomposig wood or moribund trees are invertebrates. Major vertebrate representatives are the woodpeckers (Aves: Picinae).

A spatial link exists in many invertebrates but also a fair number of vertebrates:

- birds nesting in tree cavities,
- bats (summer colonies),
- dormice, squirrels

These species have specialist predators (e.g. the pine marten)

The definitions' problem with border cases:

- What about species feeding on live tissue (bark, phloem)?

  Where does wood decomposition start, which species is still phytophagous, which already saprophagous (s.l.)?

- What about species feeding on sap runs?

- How strong has the species' dependence on dead wood to be?
  - obligate saproxylic species (developing exclusively here)
  - facultativ saproxylic species (developing also in other substrates)

- Insufficient knowledge of the biology / ecology of species
  - potentially saproxylic species (we assume – e.g. based on known biology of related species – that the species might evolve exclusively or as well in dead wood)

Pouhé fakultativní využívání saproxylických mikrohabitatů jako loviště nebo úkrytu (denního, k přezimování) nestačí (např. mnozí střevlíkovití). I to však představuje důležitou funkci tlejícího dřeva!

Function of invertebrates in wood decomposition:

- initiation of decomposition by opening up the tree bark, allowing access to other invertebrates, fungi and bacteria
- vectors of fungi, mites and nematodes that participate in wood decomposition (partially also regulation of the environment and growth of these organisms)
- comminution of wood, bark, fungal fruiting bodies
- digestion of woody matter (hemicelluloses, cellulose) together with symbiotic microorganisms inside and outside of their own alimentary channel
- regulation of populations of phloeo-, xylo- a mycetophages by zoophages (predators, parasitoids, parasites)
- incorporating woody matter into the soil – speeding up mineralisation

Chrysobothtris affinis (Buprestidae)

Hylis olexai (Eucnemidae)

Calambus bipustulatus (Elateridae)

Ampedus pomorum (Elateridae)

Synchyta humeralis (Colydidae)

Trichoferus pallidus (Cerambycidae)