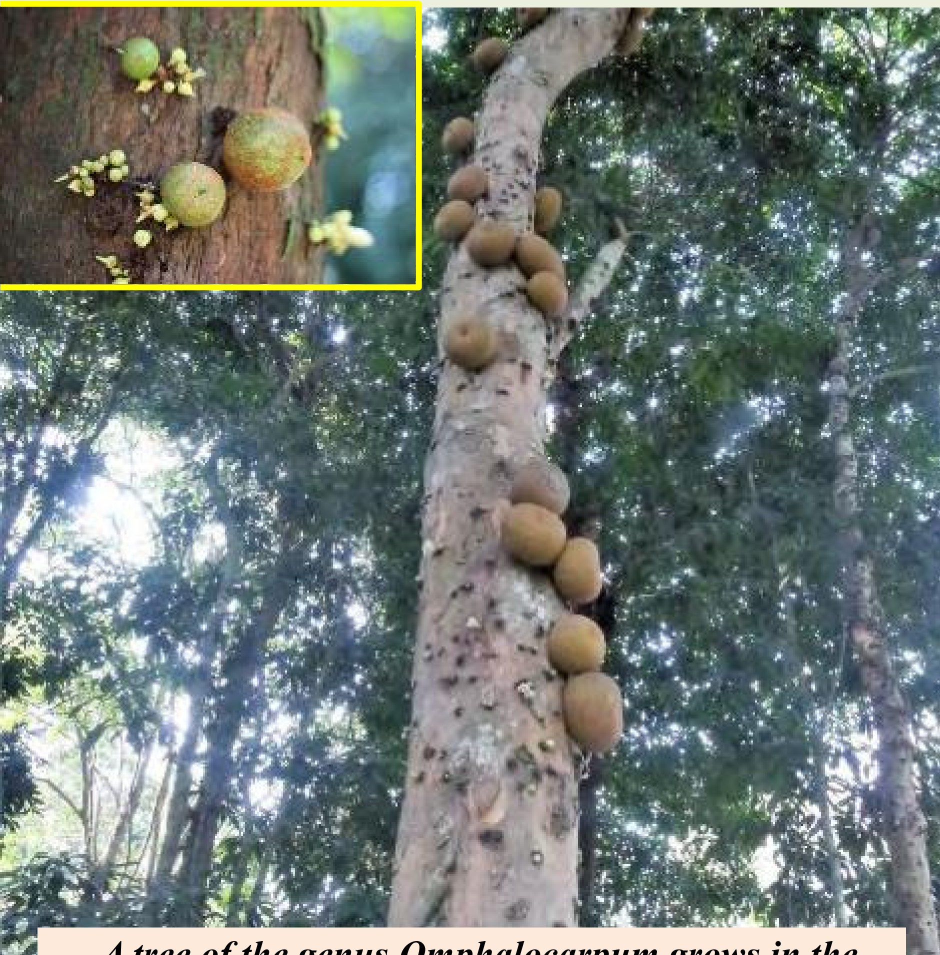
ECOLOGY FOR EVERYONE

SCIENCES NEEDED TO TACKLE PROBLEMS OF HUMAN SURVIVAL: ECOLOGY OF BIOSYSTEMS AND HISTORICAL ECOLOGY, BASIC CONCEPTS – KEYSTONE SPECIES



A tree of the genus Omphalocarpum grows in the rainforests of Congo. Mass killing of elephants by poachers is deadly for this and other trees because it is only elephants who disperse their seeds.
Photo by: David Beaune.

Fruit and sprouts

BASIC CONCEPTS OF ECOLOGY OF BIOSYSTEMS: KEYSTONE SPECIES

At the current level of knowledge, among the entire diversity of terrestrial and aquatic FLORA and FAUNA, researchers focus on species and groups of species that make most significant and diverse changes to the environment creating habitats needed for the sustainable existence of other (subordinate) species.

Different terms have been used for the most powerful environmental modifiers, e.g. **EDIFICATORS** (from the French *aedificator* meaning "builder"), **ECOSYSTEM ENGINEERS, KEYSTONE SPECIES** *(Braun-Blauquet, Pavillard, 1925; The mosaic-cycle concept…1991; Crain, Bertness, 2006).*

'Keystone species' is the term that is used most frequently. No names for less significant environmental modifiers have been proposed yet; in this text they are called **subordinate species**.

KEYSTONE SPECIES change both the habitat of the population in general and its parts most significantly (as compared to other species of the same trophic level) during the flows of their generations. This results in changes of the hydrological, temperature and light regimes; micro- and mesorelief; soil cover structure and other parameters of ecosystems.

HETEROGENEITY OF HABITATS OF KEYSTONE SPECIES POPULATIONS is the factor which determines the possibility of co-existence of ecologically and biologically different subordinate species in these habitats, which results in stable high biodiversity.

PALEOBOTANIST AND PALEOZOOLOGIST ON KEYSTONE SPECIES

One can lay it down as an axiom that in forests with any flora trees have been powerful environment modifiers (edificators) of forest communities due to their long life and large size, i. e. from the appearance of the forest type of vegetation on the Earth the principles of structure in all the forests were the same. "The role of environment modifiers of other trophic groups is less apparent and until recently has not been a subject of discussion in the literature". *(Krishtofovich, 1946)*

"The external appearance of prehistoric forest territories differed significantly from the modern appearance of rainforests and forests of moderate areas". "Prehistoric forests had a mosaic structure, with sparse tree canopy, high diversity and high density of large mammals…" "It was the largest animals who were…the factors improving the environment of various species. This can be seen when considering the structure of paleotropical forests which is analogous to that of prehistoric forests" *(Puchkov, 1992)*.

It was not until the mid-20th century when botanists started to understand the importance of large herbivorous animals in maintaining the composition and structure of prehistoric forests. Since the mid-late 20th century, as a result of the rapid development of historical ecology and generalization of written sources, ideas about the defining role of herbivorous animals in maintaining a stable structure and species diversity of natural forests have emerged (Vera, 2000).

Comparing data on the role of keystone plant species (trees) and animals species (large herbivores) enables the reconstruction of the composition and structure of prehistoric forests; understanding the reasons for the differences between the forests of modern protected areas and natural forests, and the development of methods of restoration in the modern conditions.

GAP MOSAIC CONCEPT – THE CONCEPT OF THE MOSAIC OF GAP RENEWAL, PIT-AND-MOUND AND WINDTHROW TOPOGRAPHY IN NATURAL FORESTS DEVELOPING WITHOUT HUMAN IMPACT

Studies of forests developing without human impact (felling, burning, grazing in the forest) or natural disasters (windfalls, avalanches, etc.) have revealed their common features (*Watt, 1925; Richards, 1961; Korotkov, 1991; Yaroshenko et al., 2001*). These are breaks in the forest canopy (**"gaps"**) resulting from the death of trees from old age and from local damage by woodboring insects, wood-decay fungi, viruses, etc. (**"gap mosaic"** ***or*** **"mosaic of ontogenetic parcels").** The light regime of gaps determines the species composition of the undergrowth: light-loving species predominate in large gaps, whereas shade-tolerant tree species predominate in small ones.

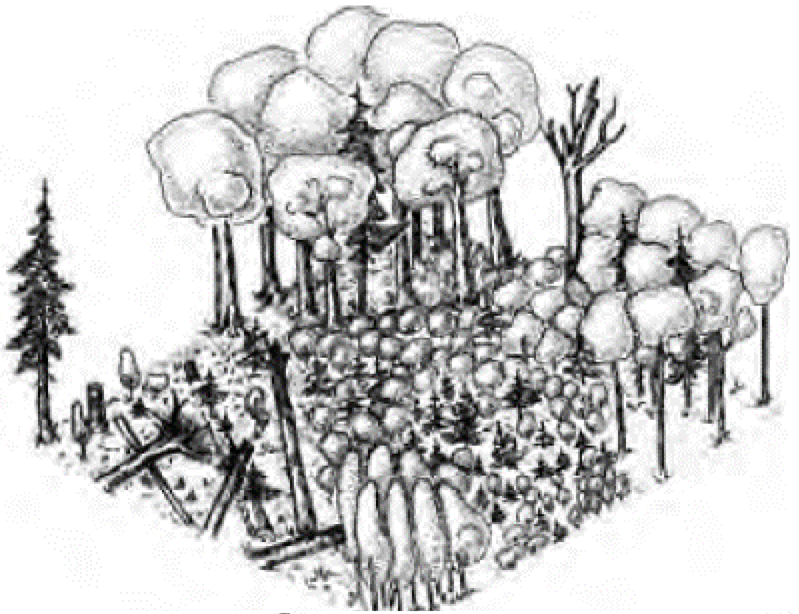
The formation of gaps in the forest canopy is also accompanied by the formation of a mosaic of microsites of two types:

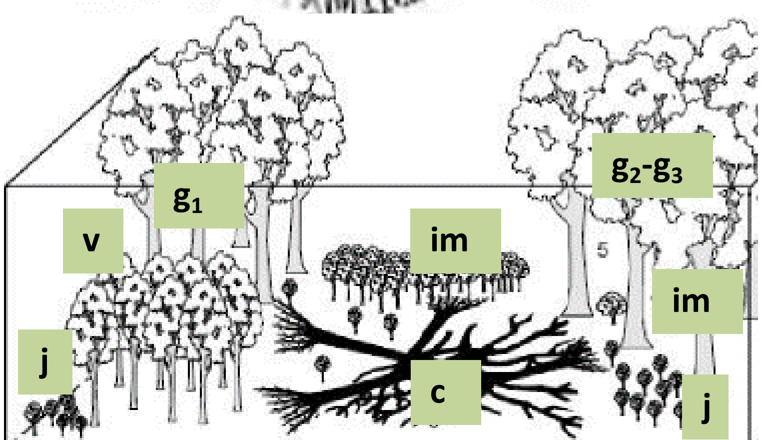
1. mound-and-pit and
2. windthrow complexes.

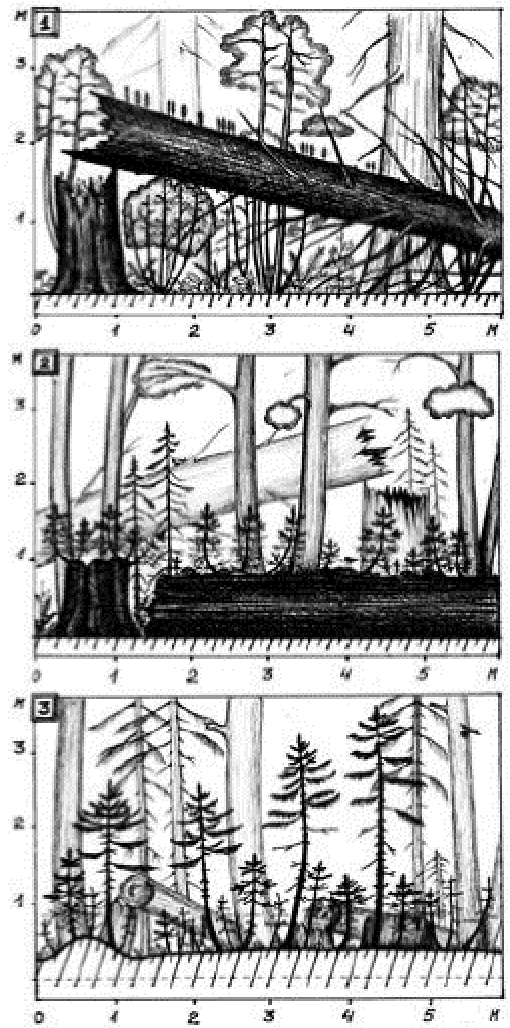
Mosaic of the first type is formed if a falling tree turns out a lump of earth; a three-part complex is formed consisting of a pit, a mound (a lump of earth on the roots) and a tree trunk (a fallen log). Mosaic of the second type is formed if a falling tree breaks at the base of the trunk; a two-part complex is formed consisting of a stump and a tree trunk *(Karpachevsky, Stroganova, 1981; Skvortsova et al., 1983; Aleinikov, Bovkunov, 2011).*

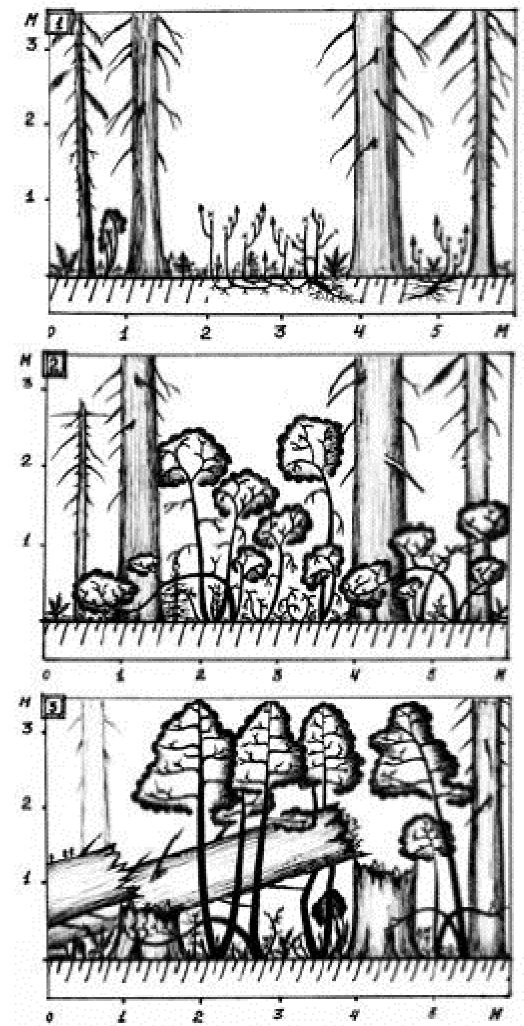
Different elements of both types of mosaics determine the heterogeneity of the microecotope environment: soil moisture and aeration, differences in temperature, and so on. Significant differences in microecotope environment in the same forest significantly increase its level of biodiversity.

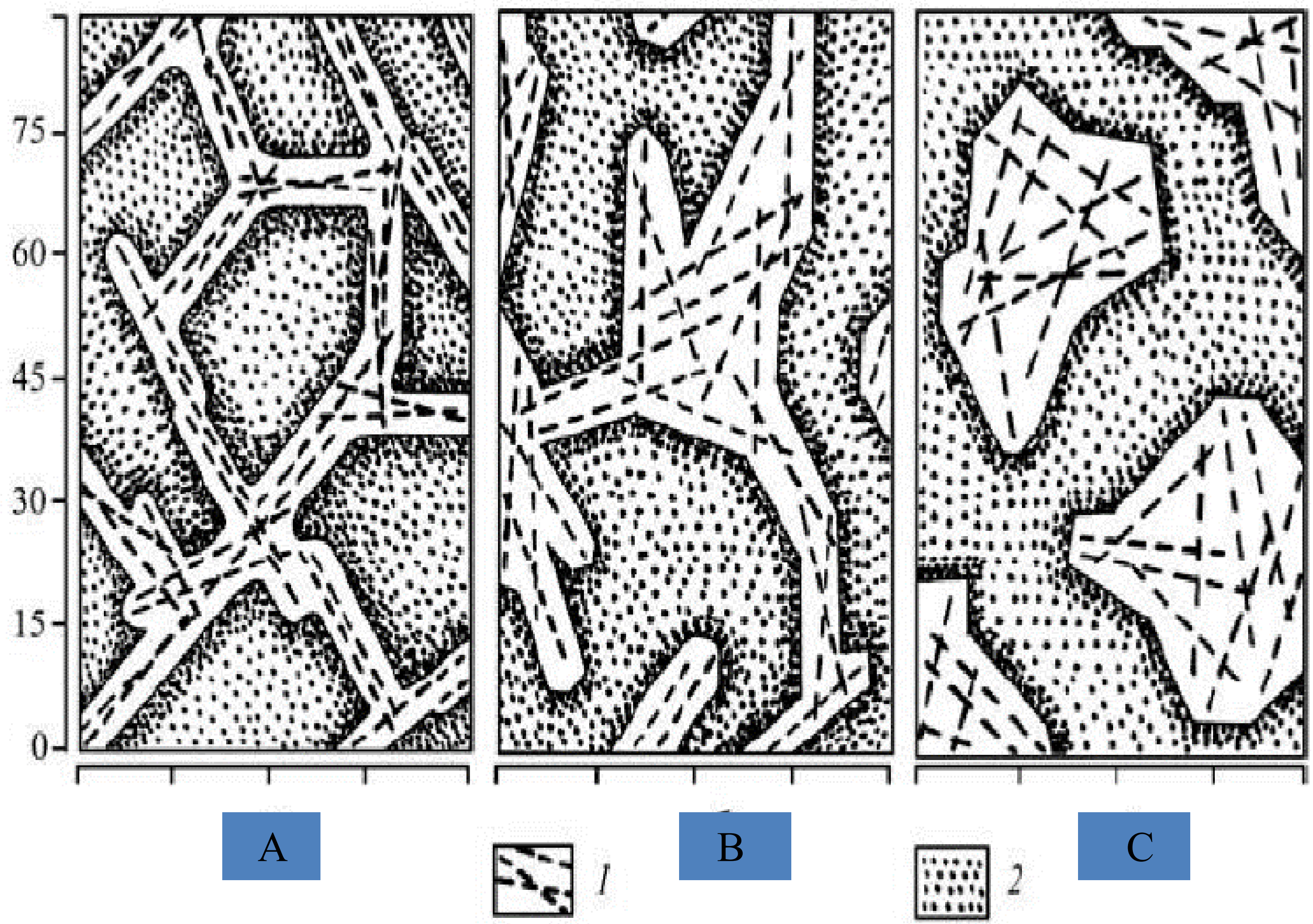
Because of the different lifespan of species, groups of trees at different stages of development (youth, maturity, and old age) live together in forests. All stages of life of trees and their destruction after death are a necessary element of a stable life of the populations of trees of all types (*Korotkov*, 1991).





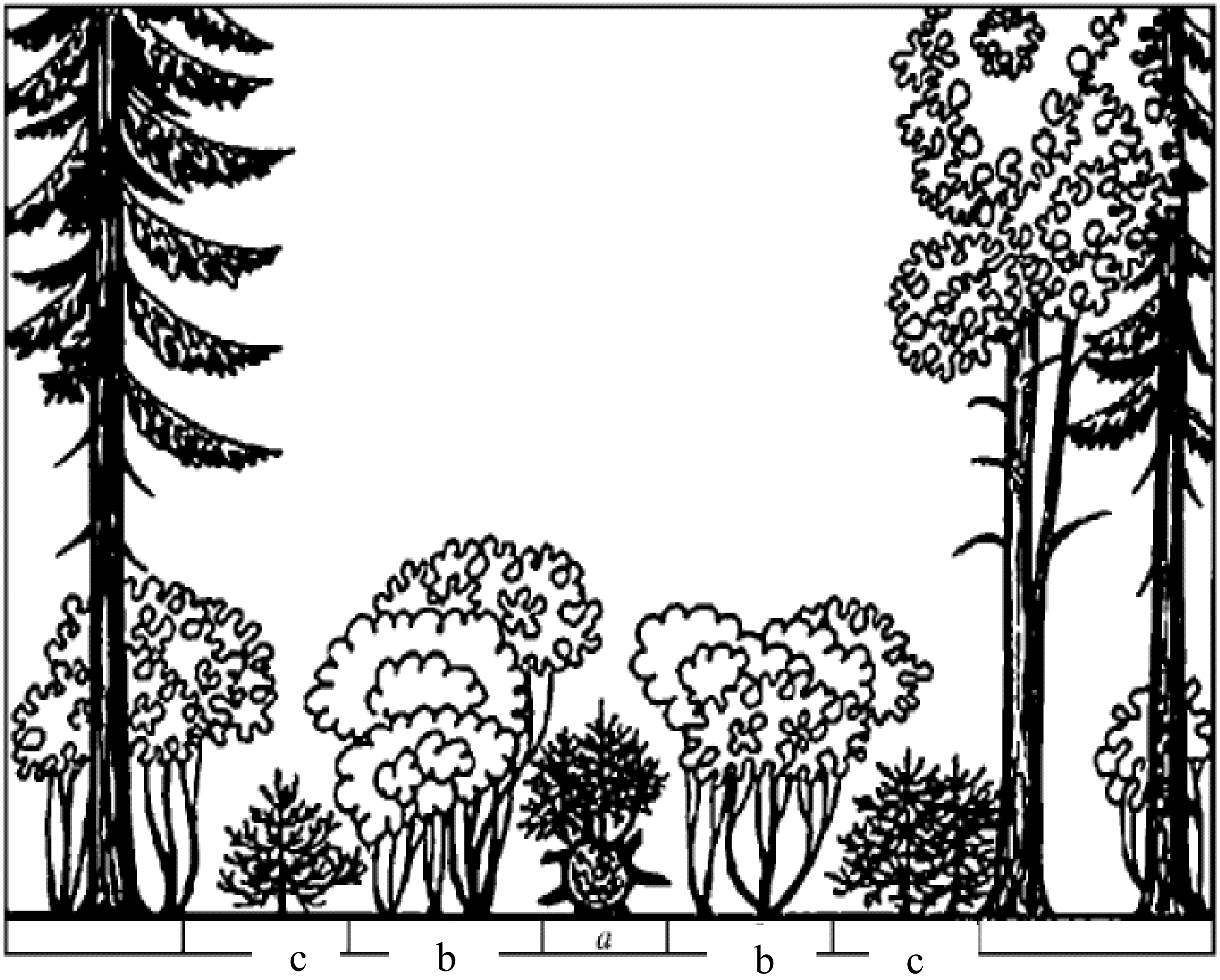






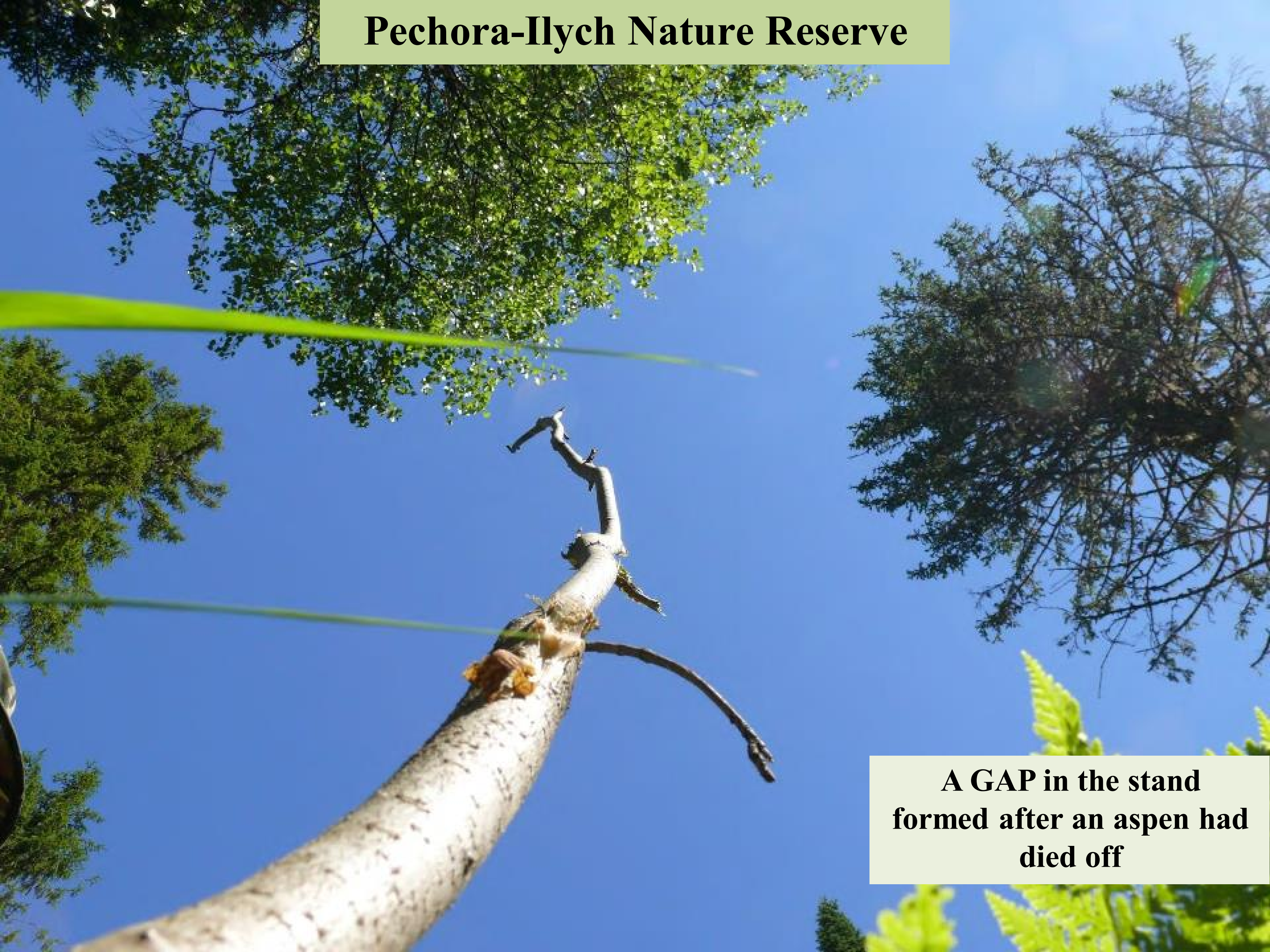
Size and configuration of the gaps in: ***a*** **– dark coniferous,** ***b*** **– dark coniferous-broad-leaved,** ***c*** **– broad-leaved forests of European Russia**

1 **- gaps, 2 - closed parts of the canopy** **(**Eastern European forests.., *2004***)**



The structure of the gap resulting from a fall of a large spruce.
Gap elements: a – central (fallen log); b – near-trunk (coppice linden);c – peripheral – spruce undergrowth (Eastern European forests, *2004*).

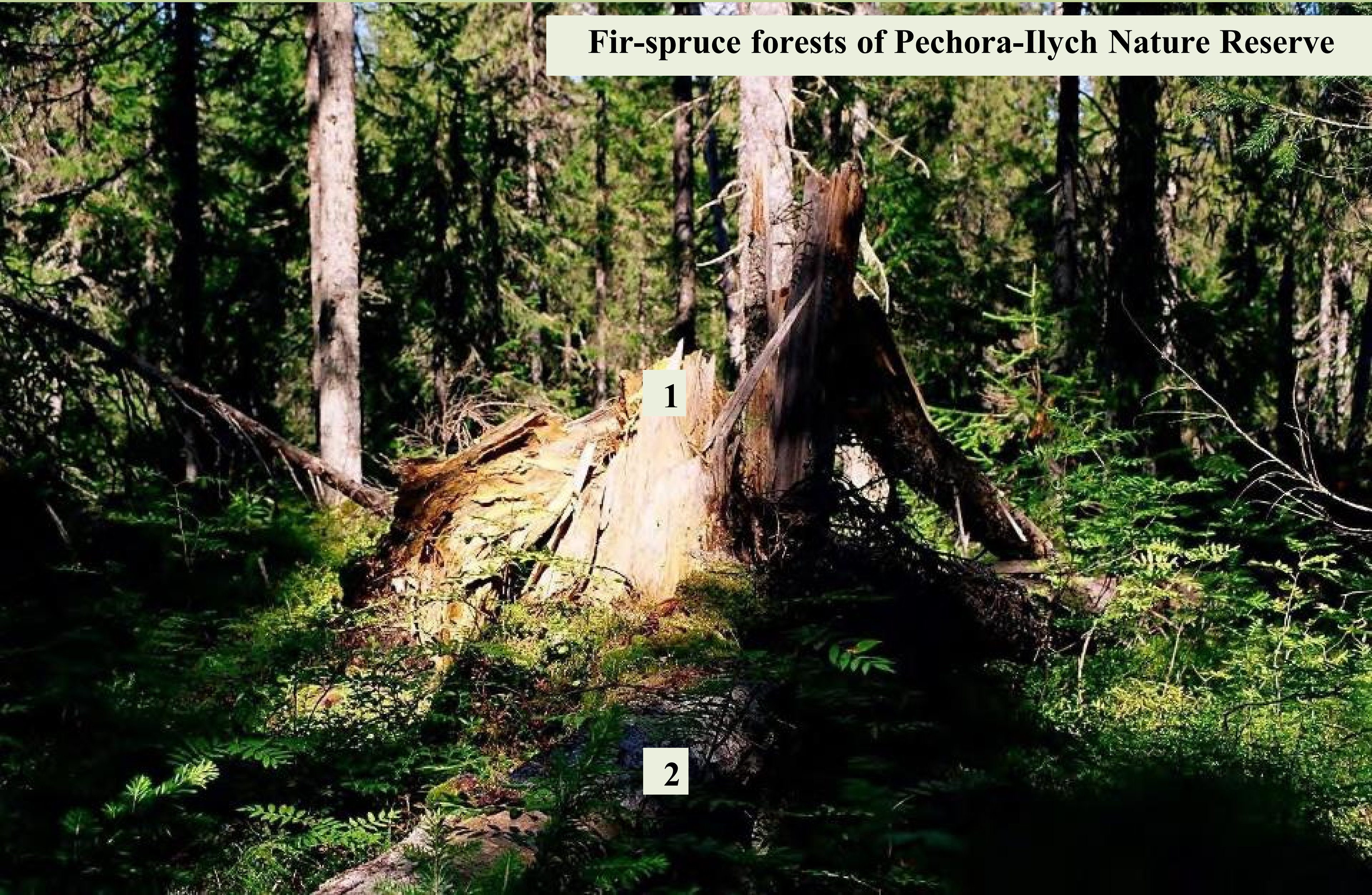
Pechora-Ilych Nature Reserve



A GAP in the stand formed after an aspen had died off

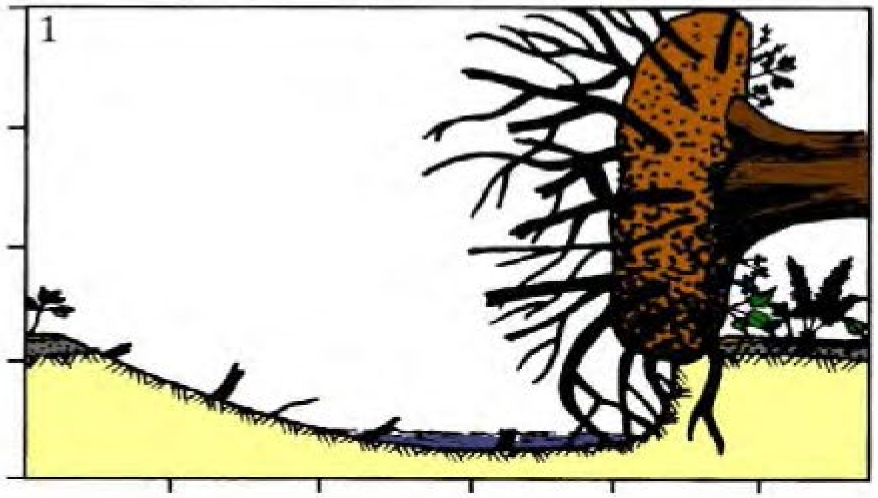
ELEMENTS OF THE THREE-PART COMPLEX: MOUND (1), PIT (2), TRUNK – FALLEN LOG (3)

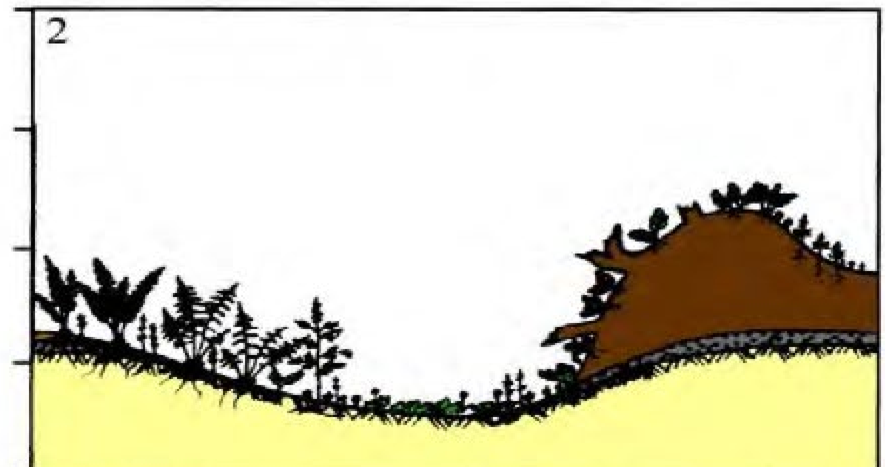
ELEMENTS OF THE TWO-PART COMPLEX: STUMP (1) AND FALLEN LOG (2)

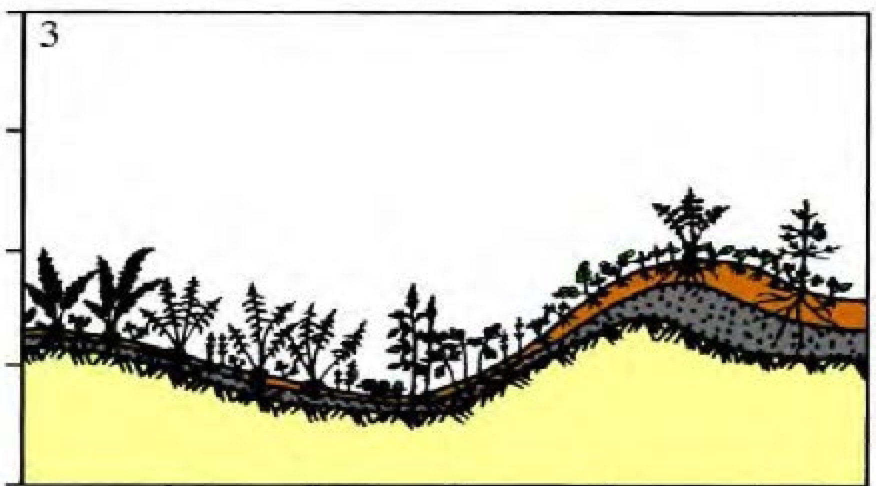


FALLEN TREES (DEADWOOD) SLOW DOWN THE SPEED OF WATER FLOWS IN STREAMS, INCREASING THE RESERVE OF MOISTURE IN THE SOIL

STAGES OF TRANSFORMATION OF A MOUND AND A PIT:
the rate of transformation of microsites depends on the degree of preservation of soil biota. Constant fires in forests slow this process down, preventing the restoration of soil fertility.



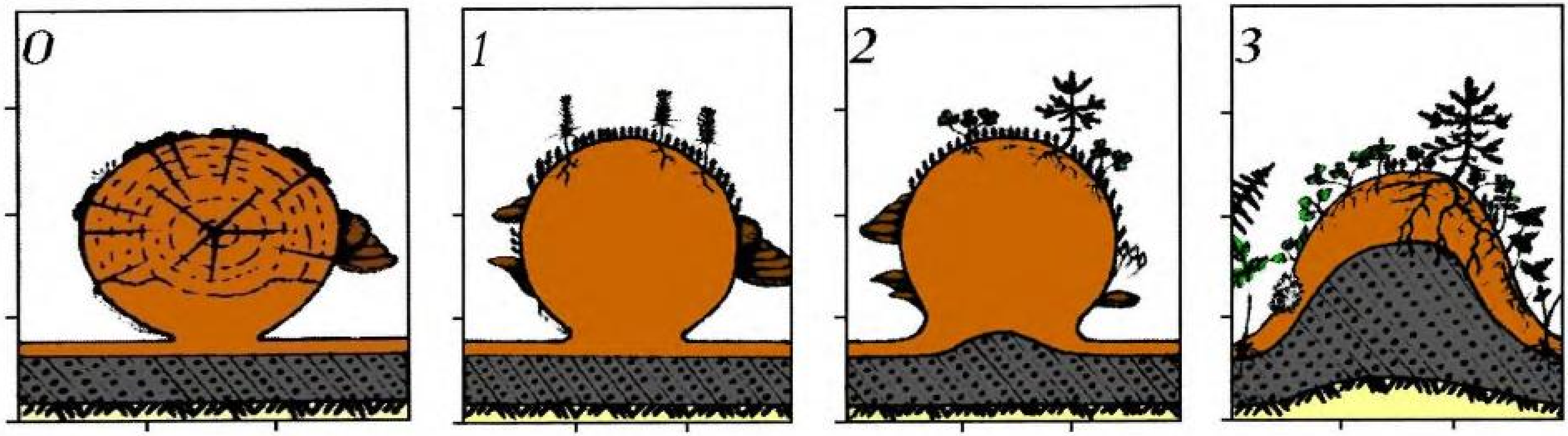




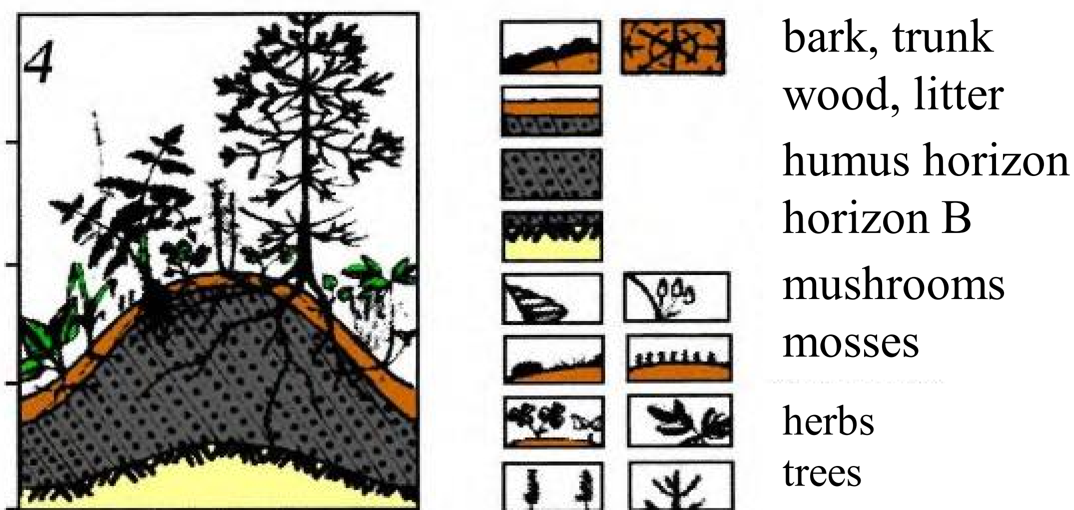
Stage	Start and end of the stage, years
1	0–20(30)
2	20(30)–120(130)
3	80(100)–200(500)

STAGES OF DECAY OF SPRUCE DEADWOOD

(Spirin, Shirokov, 2002)



Stage	Start and end of the stage, years
0	0–10(15)
1	10(15)–15(20)
2	15(20)–20(25)
3	20(25)–25(30)
4	25(30)–70(80)



CRUSTACEOUS (1) AND FRUTICOSE (2) LICHENS ON THE FALLEN NORWAY MAPLE TREE. BROAD-LEAVED FORESTS OF TEBERDINSKY RESERVE

TRUNK OF A TREE AFTER DEATH (FALLEN LOG) – BECAME A HABITAT FOR WOOD SORREL, FIR-SPRUCE FORESTS OF TEBERDINSKY NATURE RESERVE

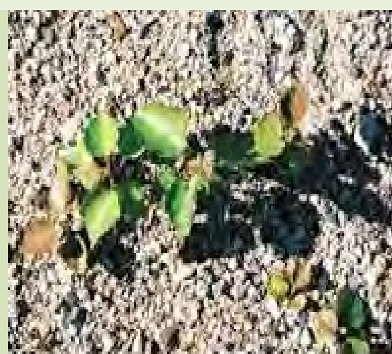
IS IT ENOUGH TO KNOW THE GAP-MOSAIC CONCEPT TO RECONSTRUCT THE NATURAL COMPOSITION AND STRUCTURE OF MODERN FORESTS?

Common birch

Siberian larch

Common oak

The species of trees and shrubs that do not renew in closed-canopy forests due to being light-loving at a young age: birch, aspen, larch, grey alder, oaks, apple tree, pear, sweet cherry, hazel, etc. Light is indispensable for their seedlings and young trees to grow successfully.



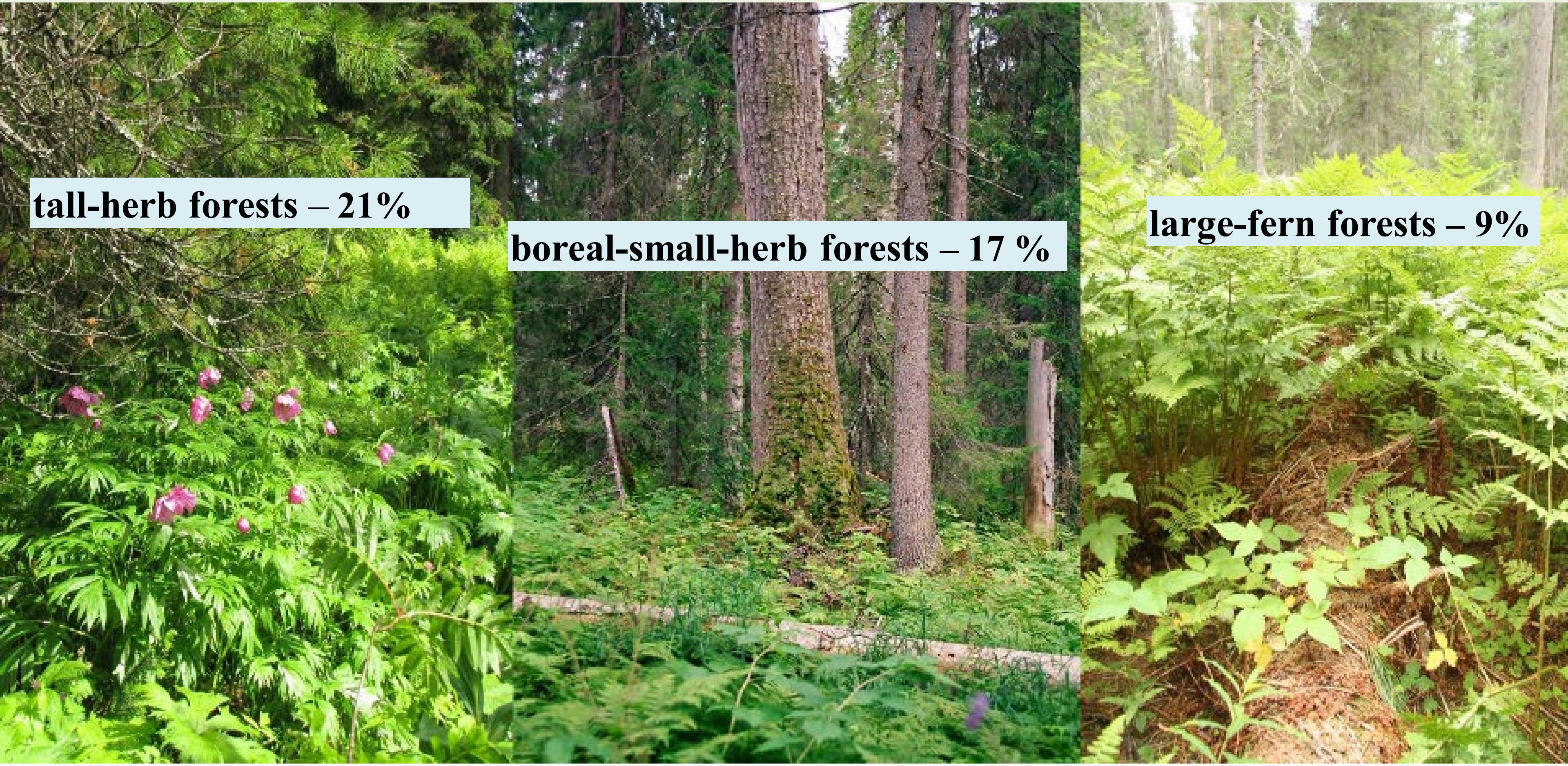
Birch – j

Larch – im_1

Oak – im_2

LOSS OF FLORAL DIVERSITY IN DARK CONIFEROUS FORESTS
Pechora-Ilych Nature Reserve

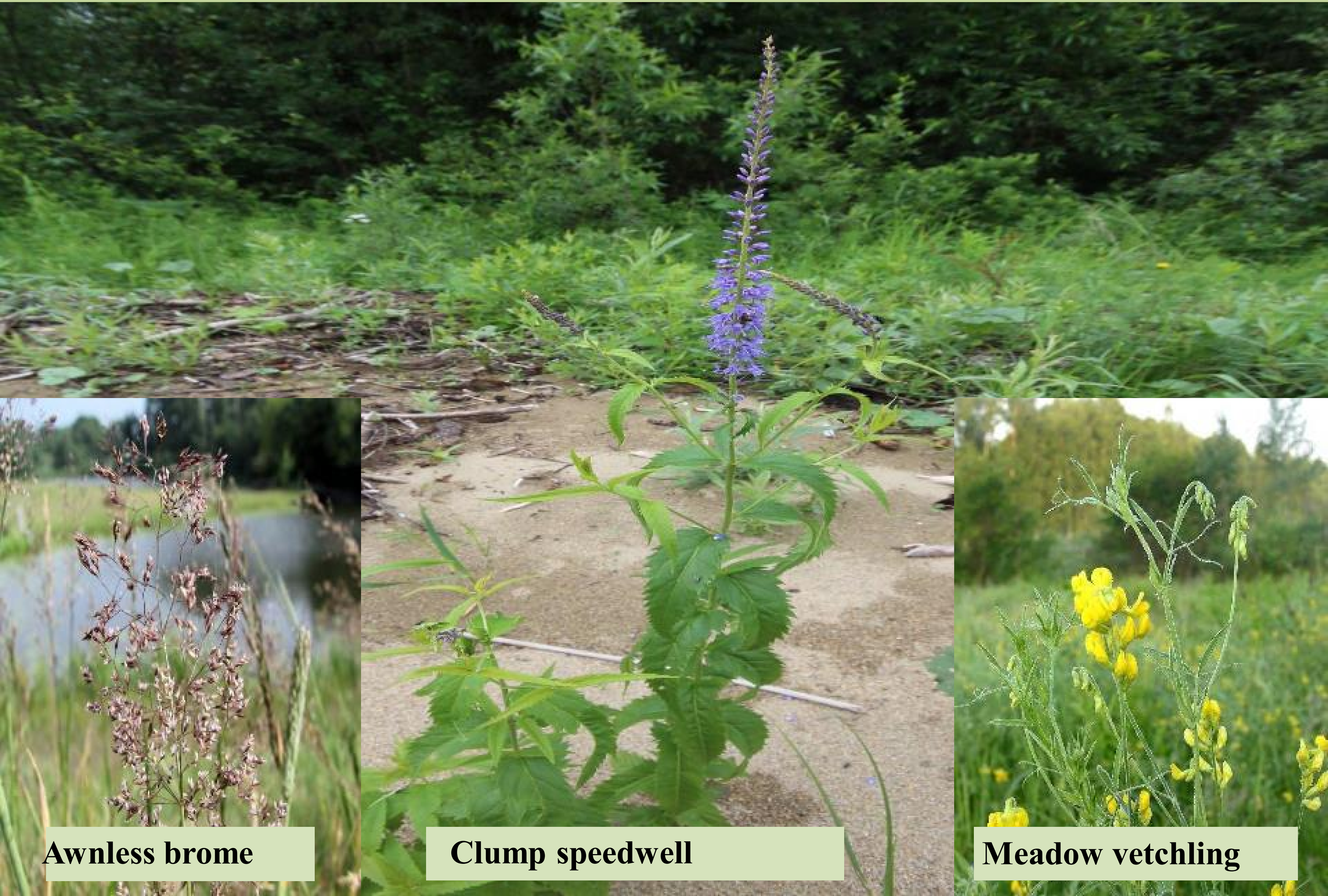
The share of light-loving species of grasses and dwarf shrubs in the reserve's forests of their total number in the reserve:



As the closed forest canopy is restored after felling, species diversity decreases, and light-loving herb species disappear. The number of pollinating insects and other inhabitants of forest clearings decreases. The main reason is the absence of large phytophagous animals.

MEADOW SPECIES THAT SURVIVE ONLY IN OPEN AREAS IN DARK CONIFEROUS FORESTS

Pechora-Ilych Nature Reserve, Bolshaya Porozhnyaya river, shoal stretch



NATURAL (1) AND COMMERCIAL (2) FORESTS

Moist conditions, light spots

Dry and dark

BIOLOGICAL PROPERTIES AND ECOLOGICAL

Natural forests: no fellings during the life of 2–4 or more generations of trees

1. **Composition** includes all tree species of this territory; their ontogenetic population spectra are fully-fledged; the species diversity of shrubs and herbs, landliving and soil animals is maximal.
2. **Structure**: multilayered due to renewal gaps in the tree stand, closed-canopy groups of young, mature and old trees, and microsites (mound, pits, stumps, fallen logs) with diverse inhabitants. Such structure provides the greatest biodiversity and soil richness.
3. **Ecological advantages:** structural diversity of habitats of different size and age lets precipitation and light reach the forest cover, therefore the undergrowth develops well in gaps; stable humidity in the woodland in general reduces the risk of fires.
4. **Environmental problems:** loss of light-loving tree, shrub and herb species, loss of small vertebrates and invertebrates as well as representatives of other kingdoms because of lacking keystone species, i. e. trees and large herbivorous vertebrates.

Commercial forests: 1st generation trees are felled when mature

1. **Composition** includes only 1–2 tree species of the entire spectrum of the territory, ontogenetic population spectra are not fully-fledged; low biological diversity.
2. **Structure**: one-layered, the tree canopy is even, microsites are hard to define. The ground cover is not diverse, species richness is minimal, soils are poor in mineral elements.
3. **Environmental problems:** lack of structural variety of the canopy: one-layered structure and closure (no gaps corresponding to the pits in the ground cover) prevent the water from saturating the entire forest cover as the largest part of precipitation gets caught in the crowns and is evaporated. The soil gets less moisture than in gap-mosaic conditions. Since there are no renewal gaps, the undergrowth does not get enough light for its stable development, and therefore is often characterized by low vitality.

THE SYSTEM OF GROUP-SELECTION OR GAP (HOLLOWS) FELLING IS ONE OF THE WAYS TO RESTORE THE NATURAL FEATURES OF FORESTS

Realizing the importance of preserving the composition and structure of natural forests, at the beginning of the 20th century (before the spread of the *gap-mosaic* concept) Russian scientists proposed a system of group-selective or gap felling (*Nesterov*, 1950**;** *Pogrebnyak,* 1968; *Melekhov*, 1989).

From the point of view of modern forest ecology, this system should include:

1) Hollows

a) with a felled stand, left for natural renewal;

b) for sowing seeds or planting trees seedlings of that are economically valuable and previously inhabited this territory, but were destroyed in the course of nature management (for example, Siberian cedar in Vologda Oblast).

2) Non-felled plots

a) of mature forests that can later be felled

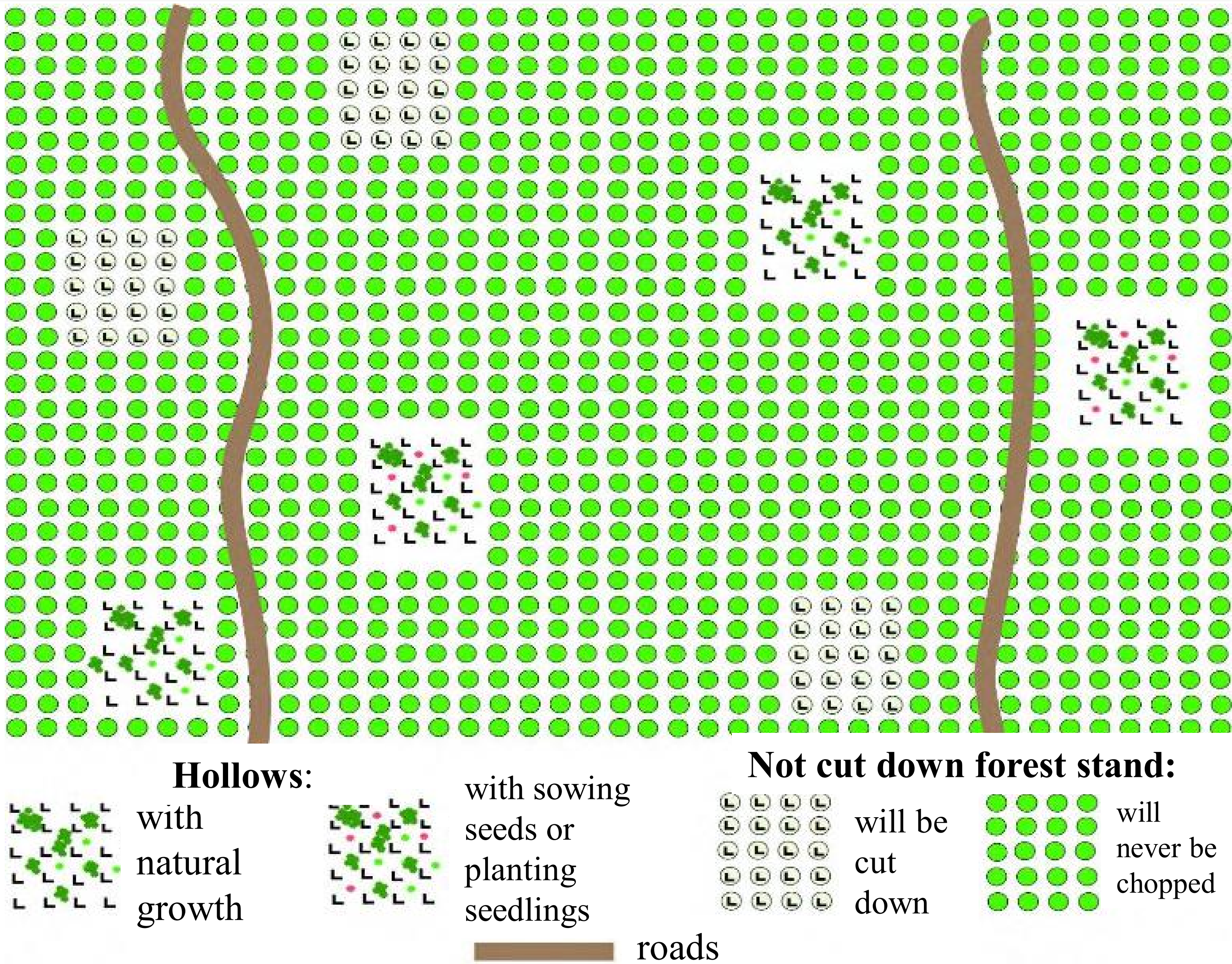
b) of forests that are naturally decaying due to old age and will never be cut down; these are microrefugiums of the biological diversity of creatures of all species that can only live in natural forests.

V. G. Nesterov* (1950): *"In terms of forestry, gap felling is always customized and takes into account all the details of the forest biology and environmental conditions, thus ensuring, as a rule, successful natural renewal. During such fellings, the soil is always forested and is used for permanent timber production. The forest under this felling system constantly performs its soil- and water-protecting functions, excludes soil erosion and water balance disturbance…"

A. Yu. Yaroshenko* (2004) "*Group-selection felling ensures the constancy of the forest environment during the entire felling cycle, largely imitates the natural gap mosaic of stands due to a group selection of trees, and preserves the full age structure of the stand due to felling of adult and old trees over a large period of time."

ELEMENTS OF GAP FELLINGS

Parameters of the hollows:
1) size
2) density
3) type
to be determined after the examination of the wooded area by forest ecology specialists and approval of the reconstruction plan by Forestry organizations .

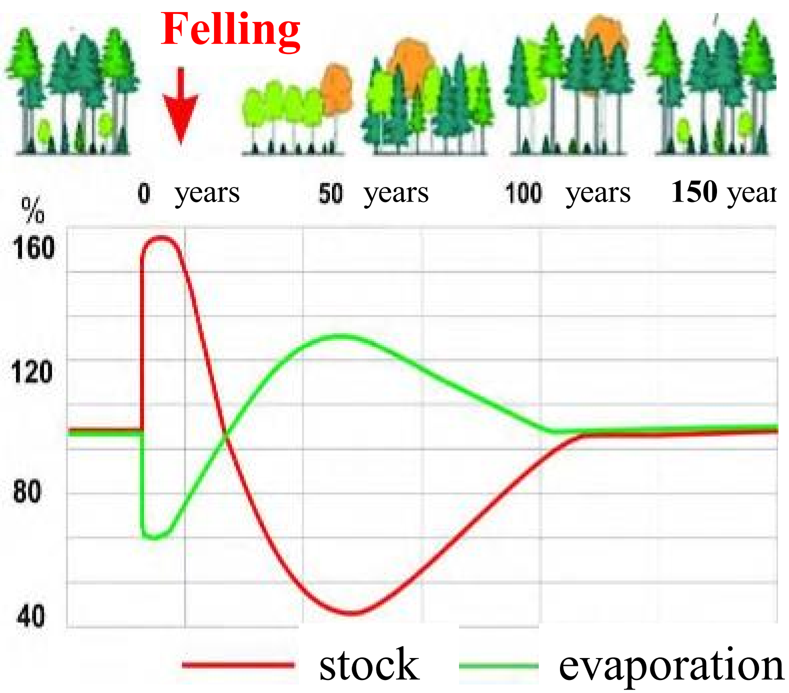


EXPERIMENTAL FELLINGS: THE SABINSKY FORESTRY, THE REPUBLIC OF TATARSTAN

In 1989–1990 and in 2004–2005, two group-gap-selection renewal and improvement fellings were performed; mixed spruce-fir-deciduous plantation is formed, spruce bear fruit (*Krasnobayeva, Akhmetzyanov, 2015*)

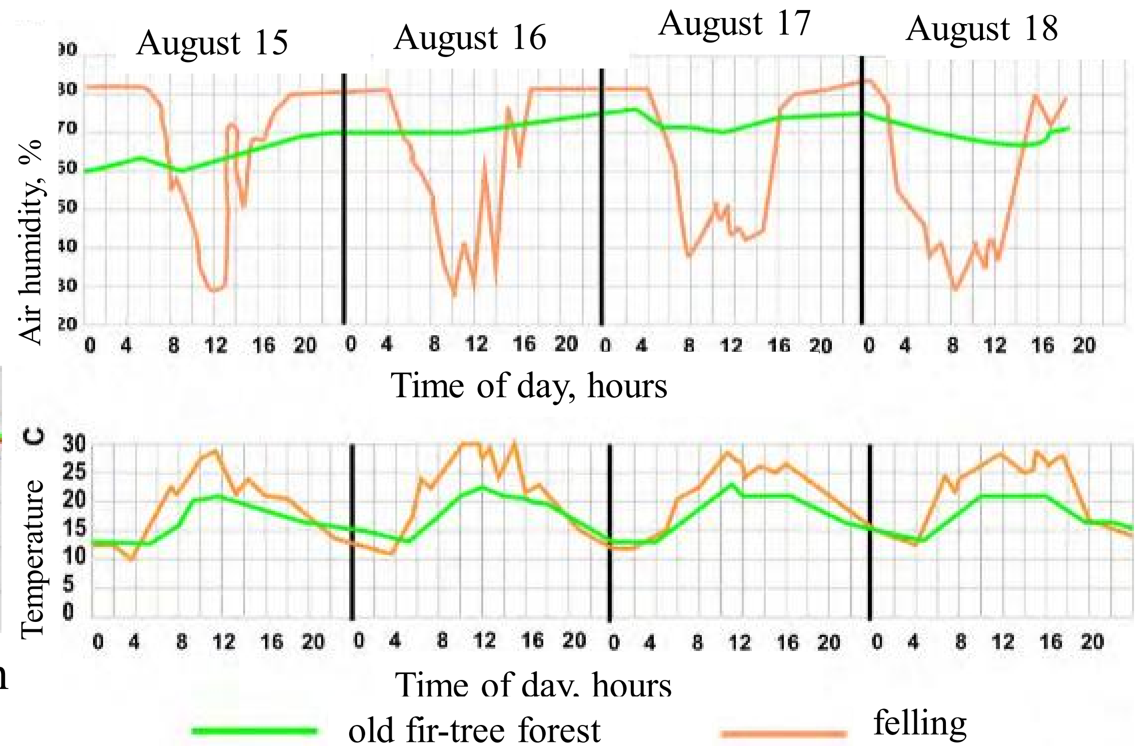
HYDROLOGICAL (RUNOFF AND EVAPORATION), TEMPERATURE AND HUMIDITY FEATURES IN NATURAL FORESTS AND IN FORESTS AFTER FELLINGS (data provided by A. A. Aleinikov)

Effect of felling on runoff and evaporation



Krestovsky, 1987

Effect of felling on temperature and humidity



Zubareva, 1967

Stable hydrological regime is restored during 100 or more years after felling; before that, drying or waterlogging of the soil can lead to the death of the undergrowth of all or some tree species, as well as to the depauperization of the earthworm population, which leads to soil impoverishment. Sharp daily fluctuations in air humidity and temperature on the surface of the soil adversely affect the growth and development of undergrowth of trees and reduce the variety of grasses and small animals, both vertebrates and invertebrates.

One of the possible (used in developed countries) ways of conserving natural resources is the introduction of a system of gap felling in forest management

The introduction of a **system of gap or group-selection felling** in forestry is of great importance for the restoration of ecosystem functions of forests at the local and regional levels.

The proposed methods of management to some extent imitate the system of natural renewal gaps and microsite system. This enables the following functions:

1) optimized use of precipitation: much more moisture is absorbed by gaps in the forest canopy, pits of pit-and-mound complexes and decaying deadwood than by closed and aligned canopy of commercial forests;

2) optimized use of PAR: gaps in the forest canopy are the main habitats where the undergrowth can get enough light for normal development; within the same forest, trees with different light needs survive and develop in gaps of different sizes;

3) maintenance of ecological and species diversity: mosaic of renewal gaps and microsites determines the possibility of survival of undergrowth of trees with different needs in PAR, humidity and soil richness, both already existing in the forest, and lost due to the previous tendency toward single-crop economy;

4) maintaining the stability of forests: due to various humidity and light conditions within a single forest, multi-species stands may form, which prevents the development of outbreaks of fungal and bacterial infections and mass reproduction of woodboring insects.

As they are ageing and decaying, non-felled areas of mature forests as well as natural deadwood to some extent implement all these functions and **serve as refugiums (shelters) for the biologically diverse plants, animals and representatives of other kingdoms of the NATURE.**

URGENT MEASURES TO RESTORE ECOSYSTEM FUNCTIONS OF FORESTS AT THE LOCAL AND REGIONAL LEVELS

1. Protection of forests from fires.
2. Restoration of forests on the land unsuitable for agriculture.
3. Replacement of clear-cutting with "gap" (group-selection) felling with mandatory conservation of forest areas where the natural gap-mosaic and mound-and-pit complexes will develop.
4. Restoration of herbivorous animals who are natural inhabitants of the local forests.
5. Afforestation of watercourses by planting natural types of trees and shrubs: black and grey alder, aspen, tree and shrub willows, viburnum, etc. to regulate the water regime and form food resources for beavers.
6. Conservation or restoration of the populations of beavers as "natural firefighters": the ponds, boggy forests and low-lying swamps they create significantly reduce the spread of fire to large areas.
7. Conservation of in-forest clearings for mowing and moderate grazing of livestock or wild animals to increase biodiversity, including valuable medicinal plants and pollinating insects, as well as to create favourable conditions for the development of light-loving species of trees and shrubs on the edges of the forest.

ECOLOGY FOR EVERYONE

SCIENCES NEEDED TO TACKLE HUMAN SURVIVAL PROBLEMS: ECOLOGY OF BIOSYSTEMS AND HISTORICAL ECOLOGY, BASIC CONCEPTS – KEYSTONE SPECIES. PART II

Gaps in rainforests occur at the sites of fallen trees... and the paths of elephants, if they still exist.

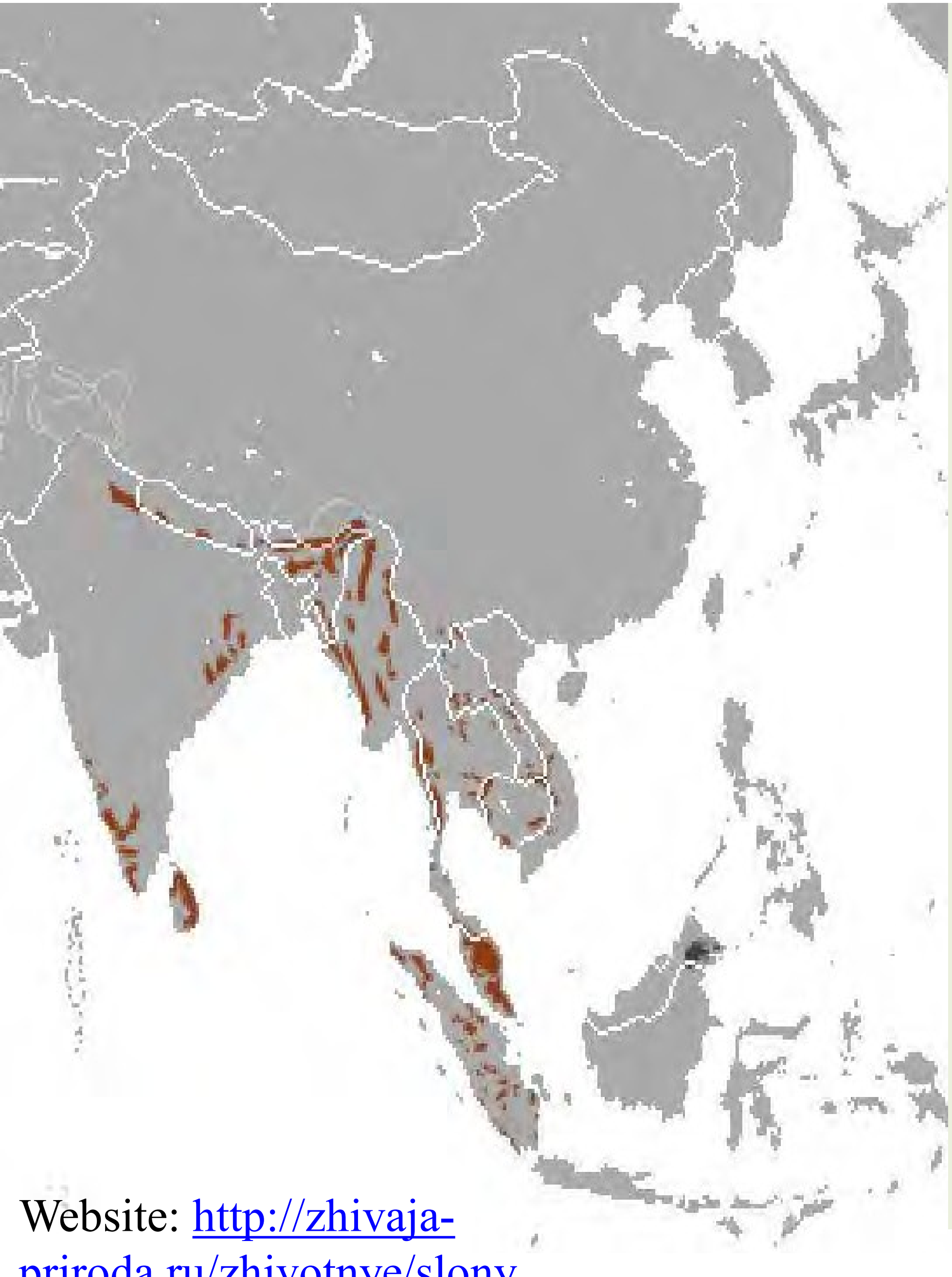
KEYSTONE SPECIES: AFRICAN ELEPHANT – HOPE FOR SURVIVAL

Historical habitat of the elephant in Africa stretches from the coast of the Mediterranean sea to the south of the continent.

Between the 1930s and 1940s, there were over 3–5 million elephants on the continent; their population began to decline significantly since 1950. In the 1980s, 100,000 elephants were killed. In some regions, up to 80% of elephants were exterminated. In Kenya, the number of elephants decreased by 85% between 1973 and 1989. Currently, due to strict conservation measures, the extermination of elephants has decreased, but the illegal trade in ivory still is a real threat to the African elephant.

At the same time, a new problem arises: rapid growth of population and expansion of farmland are rapidly reducing the natural habitat of elephants, i. e. forests and savannas. A new conflict between man and elephant is emerging. Website http://zhivaja-priroda.ru/zhivotnye/slony

KEYSTONE SPECIES: ASIAN ELEPHANT – FEARS AND HOPES FOR SURVIVAL



Currently, ASIAN ELEPHANTS are found only from India to Vietnam, with a tiny population in the southwest of the Yunnan province of China. Over the past 3–3.5 thousand years, the range of the Asian elephant has decreased from 17 million km^2 to 400 thousand km^2. The lamentable fate: over the last five thousand years, at least two subspecies of elephants have disappeared in Asia.

First real steps to save elephants were made 137 years ago. In 1872, the colonial authorities of India in Madras issued the first official order for the protection of these animals. Elephants are now protected in the national parks and reserves in Asia and Africa, and in China, a small group of elephants from the population of North Vietnam is protected by a government decree of the highest category. It is estimated that at the beginning of the 20th century there were over 100,000 individuals of the Asian elephant. And over the past 60–75 years, the population has reduced by at least 50%.

However, even after the ban on hunting elephants, only according to official data, up to 30 tons of tusks are exported from this continent every year.

Website: http://zhivaja-priroda.ru/zhivotnye/slony

PRESERVED SPECIES OF HERBIVOROUS ANIMALS OF NORTHERN EURASIA


Red deer


Reindeer


Elk


Roe

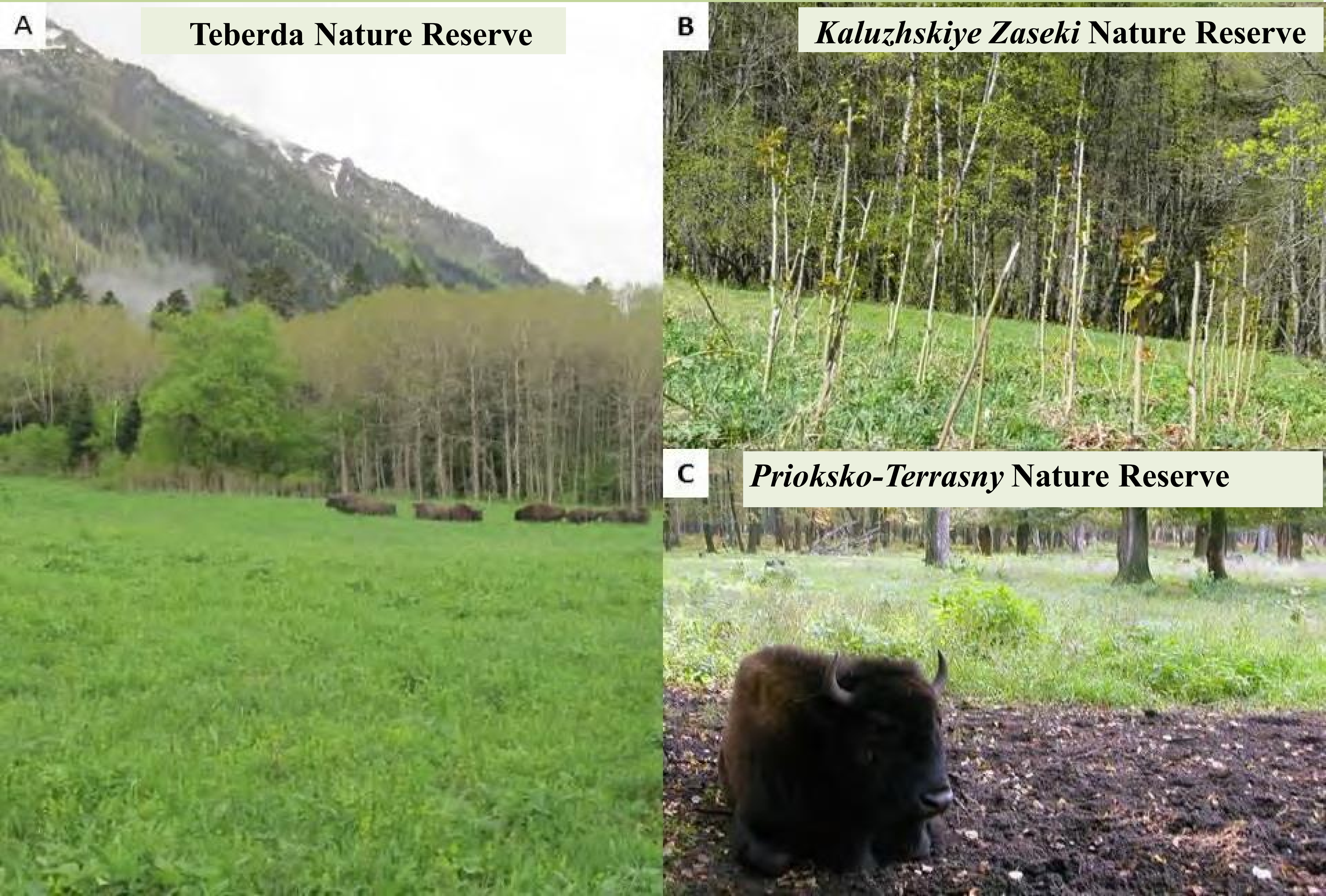

Wild boar

BISON – A RESTORED KEYSTONE VERTEBRATE SPECIES OF NORTHERN EURASIA

BISON RANGE IN THE MIDDLE HOLOCENE: FROM THE ATLANTIC COAST IN THE WEST TO WESTERN SIBERIA IN THE EAST AND TRANSCAUCASIA IN THE SOUTH. At the beginning of the 20th century, the bison was preserved in the Bialowieza Forest and in the Caucasus. By 1927, it was completely exterminated in the Caucasus. 48 BISONS FROM ZOOS AND WILD BEAST SHOWS FORMED THE BASIS FOR THE SPECIES RESTORATION. IN RUSSIA, THE NUMBER OF BISONS IN FREE-LIVING GROUPS IS 450 INDIVIDUALS (*Shevchenko, 2016*)

HABITATS MAINTAINED BY THE BISON:

A – meadow-forest complex, B – a clearing with biting marks on asps, C - bare ground



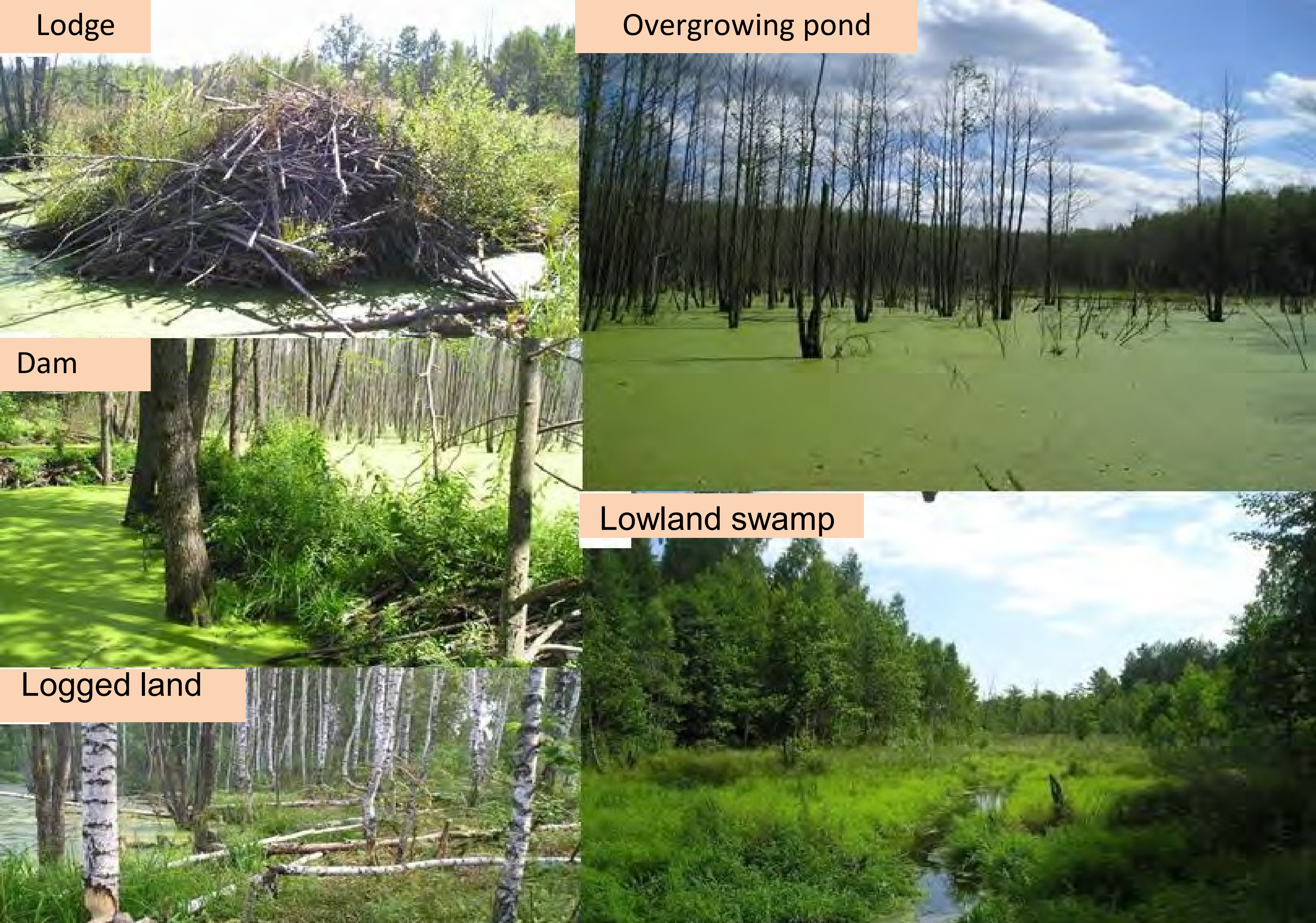
THE MOST POWERFUL MODERN KEYSTONE SPECIES OF MODERN INVERTEBRATE PHYTOPHAGES OF NORTHERN EURASIA

IN THE MIDDLE AND PART OF THE LATE HOLOCENE, THE RIVER BEAVER INHABITED THE MAJORITY OF THE TERRITORY OF NORTHERN EURASIA. In Russia, the northernmost beaver finds are described on the northern coast of the Kola Peninsula, on Vaygach, and in the lower reaches of the Yenisei (about 70° north latitude), and in the south of Yamal. Before the 19th century, beavers lived near lake Baikal and along the tributaries of the Lena and Anadyr rivers. There are pockets of the common beaver in the upper reaches of the Yenisei, in the Baikal region, in Kamchatka, etc. It inhabitates Mongolia and Northwest China. In Europe, the beaver lives in Scandinavia, in the lower reaches of the Rhone, in the Elbe and Vistula basins (*Kalyakin, Turubanova, 2001).*

BEAVER AND GAP-MOSAIC: FORMATION OF GAPS

BEAVERS GNAW AT THE BASE OF TREES (UP TO 15 TRUNKS) NEAR WATER BODIES

Gap diameter up to 50 m^2 *(Aleinikov A. A., 2010)*

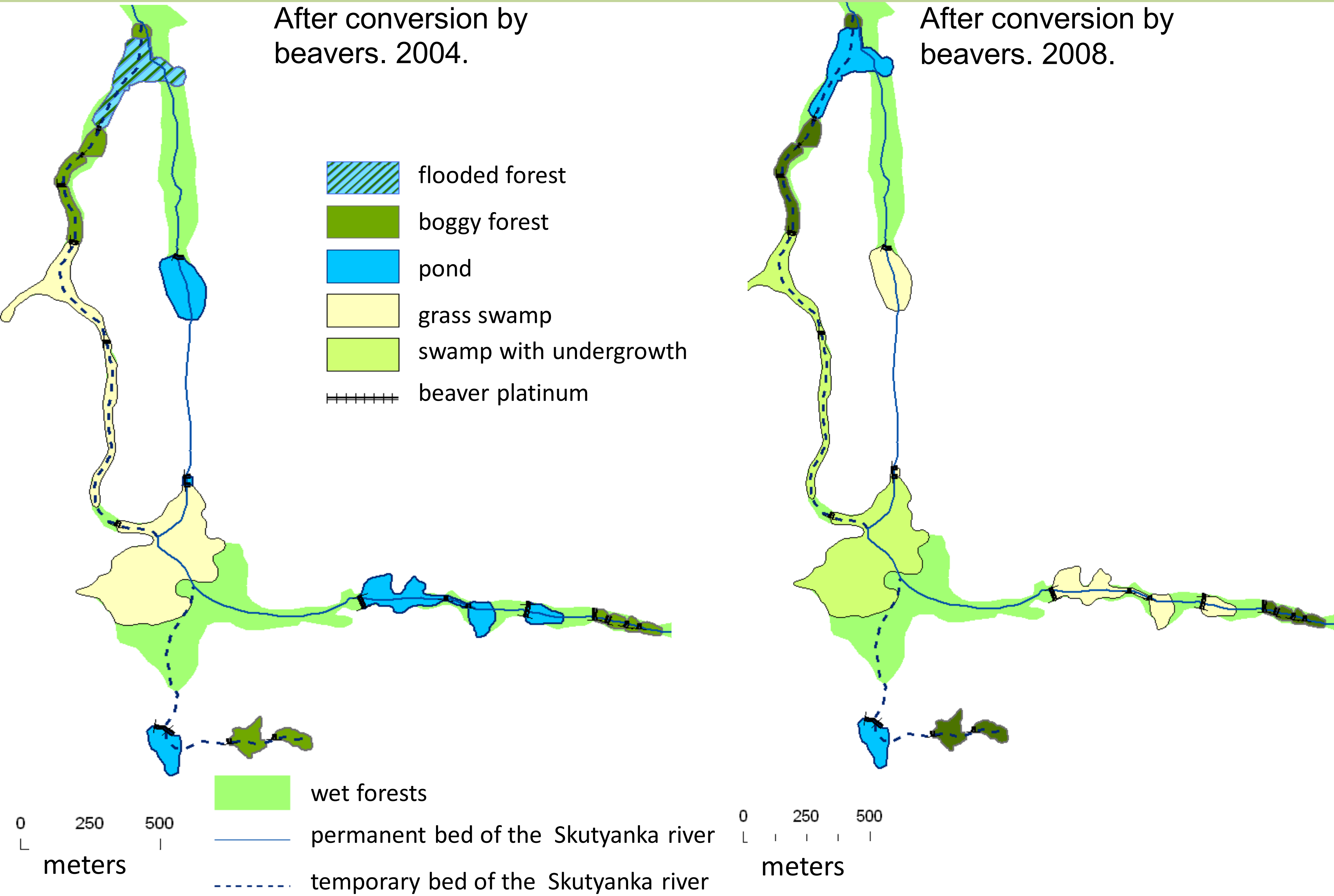


Habitats created by the beaver (Aleinikov, 2010)

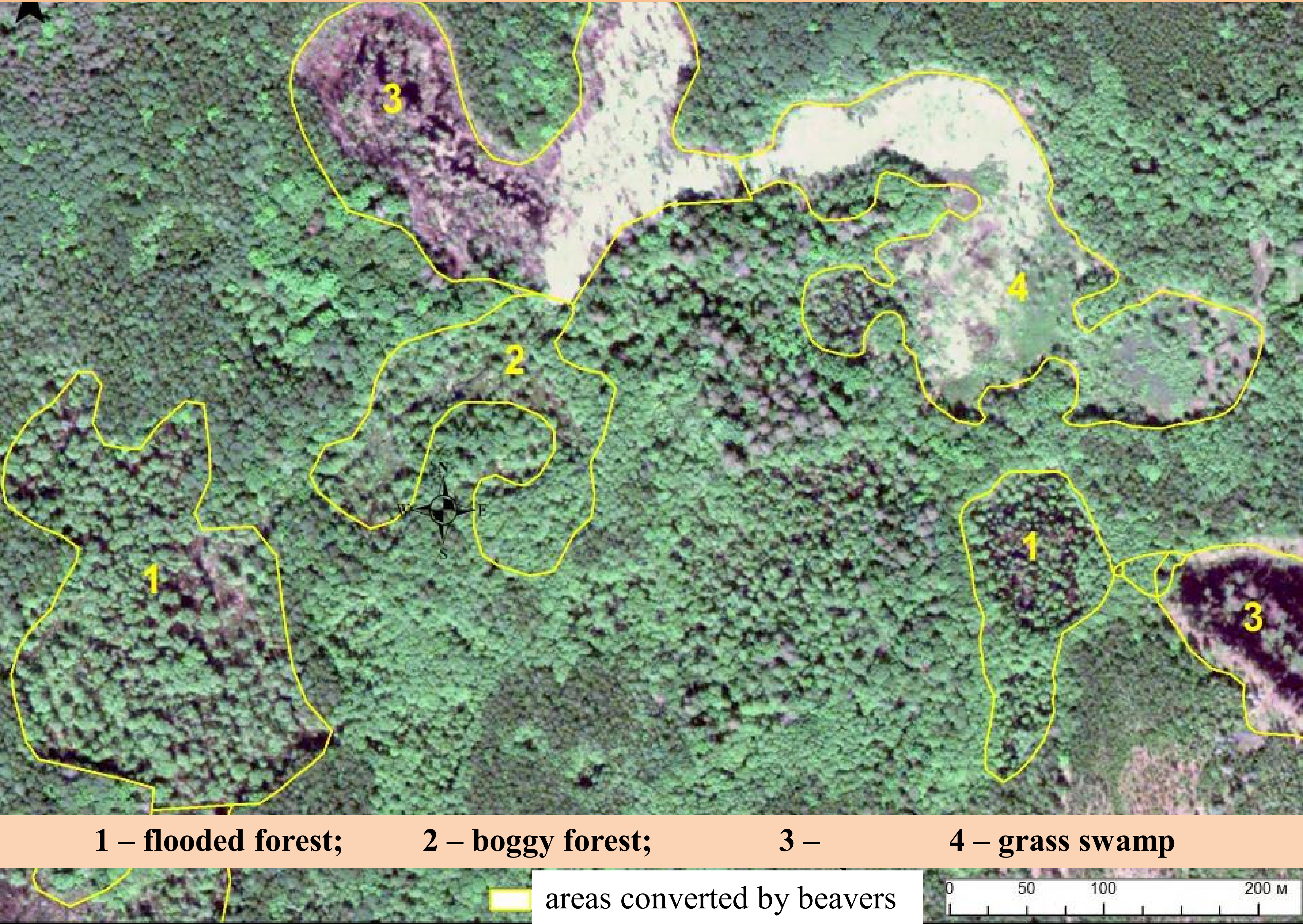
POND WITH AN AREA OF 5.8 ha CREATED BY THE EUROPEAN BEAVER, "Bryansk forest" reserve (A. A. Aleinikov)

The cascade of beaver dams on rivers entraps meltwater and storm water, reduces the probability of floods during high water, reduces bottom and coastal erosion, shortens the period of summer water shortage, and contributes to the restoration of the system of springs and streams destroyed as a result of human activity. Forests inhabited by beavers are less prone to fires. Beaver ponds are inhabited by waterfowl, amphibians, fish and many other animals. The slow flow of water through the pond contributes to the deposition of small particles of humus, silt and sand, that is, to the renewal and formation of floodplain soils, leading to an increase in the biocapacity of the territory. Permanent relocation of dam sites and feeding on aquatic and semi-aquatic plants (water lilies, yellow water lilies, cattails, reeds, iris, etc.) prevents the eutrophication of water bodies, i. e. the accumulation of biogenic elements in the water.
(*Evstigneev O. I., Belyakov, 1997; Zavyalov, 2005, Aleinikov, 2010*).

THE SYSTEM OF HABITATS CREATED BY THE EUROPEAN BEAVER "Bryansk Forest" Reserve (Aleinikov, 2010)



ELEMENTS OF THE BEAVER LANDSCAPE "Bryansk Forest" reserve (A. A. Aleinikov)



1 – flooded forest; 2 – boggy forest; 3 – 4 – grass swamp

FRAGMENT OF THE BEAVER LANDSCAPE (photo from the Internet)

DEGRADATION OF NATURE MAKES THE HUMANITY THINK ABOUT ACTIVE WAYS TO RESTORE IT

According to B. Grzimek (*Grzimek, 2010*), in 1600, between 60 and 100 million beavers lived in North America. In the 17—19th centuries, in America, to the South, East and West of the Great lakes, a dramatic "beaver rush" took place; it was the beaver lands that became one of the causes of the Seven Years' War(1756–1763). Before the arrival of Europeans in North America, Indian hunting was an example of ecological wisdom: just as many animals as were needed were hunted; it was forbidden to kill females and young animals; hunting season was strictly observed. In some protected areas, any hunting was completely forbidden.

The negative consequences of the extermination of beavers: droughts and impoverishment of the landscape – forced the authorities of the United States and Canada in 1955 to also begin measures to restore their numbers. As a result, the beaver was not only saved from destruction, but also became numerous again. It inhabited the territory from the subarctic water bodies of Alaska and Northern Canada to the water bodies of desert Nevada and hot Florida. About 10 years later, in most of the United States and Canada, the beaver has again become a mass-hunting species.

In our country, in 1934, work began on the expansion of beavers. At the first stage, the only source of breeding material was the Voronezh reserve, from which more than 700 beavers were taken in 1934 - 1947. At the second stage, starting in 1948, beavers were also exported from the reserves of Belarus. The recovery was successful, and the rodent population was increasing rapidly. In 1961, beaver hunting was allowed in our country.

Currently there are about 250 thousand beavers on the territory of the former USSR (*Skalon, 1961; River beaver, 2000)*.

HABITATS OF KEYSTONE SPECIES OF MODERN FOREST COVER IN NORTHERN EURASIA ARE THE BASIS OF MODEL RECONSTRUCTION OF NATURAL ECOSYSTEMS IN THE CURRENT CLIMATE

microsites: 1 m^2 – 10 m^2	**mesosites: 100 m^2 –1,000 m^2**	**macrosites: 100,000 m^2 – 100,000m^2**	**megasites: 10 km^2 – 100 km^2**
functional group – trees of various species			
mounds, pits, stumps, deadwood, and under-crown and inter-crown spaces	gap-mosaic elements: clusters of young (im, v), generative (g), senile (s) trees	the set of elementary populations of all species within automorphic, transit or accumulative landscapes	
functional group – river beaver			
lodges, burrows, dams, trails	logged lands, ponds, flooded and boggy forests, swamps	the set of habitats of all types in a small river valley within the area of the elementary beaver population	
functional group – large gregarious herbivores: bison			
resting places of animals, digging and lying places	collective trails, stopovers for small groups of animals	near-water and dry clearings, park sparse woodlands, sections of closed forest	the set of habitats of all types in the basin of a small river within the area of an elementary bison population

PRELIMINARY RESULTS OF DATA ANALYSIS ON KEYSTONE SPECIES OF TREES AND HERBIVOROUS VERTEBRATES OF NORTHERN EURASIA

IN THE FORESTS OF BOTH TROPICAL AND TEMPERATE ZONES, THE SUSTAINABLE EXISTENCE OF THE ENTIRE DIVERSITY of SPECIES OF DIFFERENT TROPHIC GROUPS (plants, animals, fungi, etc.) CAN ONLY BE MAINTAINED IF THERE IS A COMPLETE SET OF KEYSTONE SPECIES.

At the same time, the size of territories necessary for the sustainable cycle of generations of herbivores is a lot larger than the size required for a sustainable cycle of tree generations. This requires not only significant areas of protected areas where populations of keystone species of herbivores are being restored or there are conditions for their restoration, but also the necessary landscape diversity.

THE DATA OBTAINED TO DATE ON THE SIZE OF THE AREAS NECESSARY FOR THE EXISTENCE OF ELEMENTARY POPULATIONS OF KEYSTONE SPECIES OF HERBIVORES (beavers and bisons) REQUIRE A REVISION OF THE IDEAS ABOUT THE POTENTIAL APPEARANCE AND SIZE OF ECOSYSTEMS IN THE STATE OF DYNAMICAL BALANCE.

G. Scott. Nature and space// Man and nature: an ecological history / under gen. ed. by D. Alexandrov, F.-J. Bruggemeier, Yu. Laius. – SPb, 2008. Pp. 180–251.

MODERN KEYSTONE SPECIES OF INVERTEBRATES (A. P. Geraskina)

EARTHWORMS TRANSFORM THE SOIL ENVIRONMENT:

they process the plant litter; mechanical destruction and treatment with enzymes increases the availability of litter for microorganisms**;**

they leave castings (granular feces) inside their tunnels and on the soil surface; these are water-stable, hydrophilic structures with high carbon and nitrogen content; as a result, a well-aggregated, nitrogen-rich, **humus horizon of the soil is formed, contributing to soil fertility**;

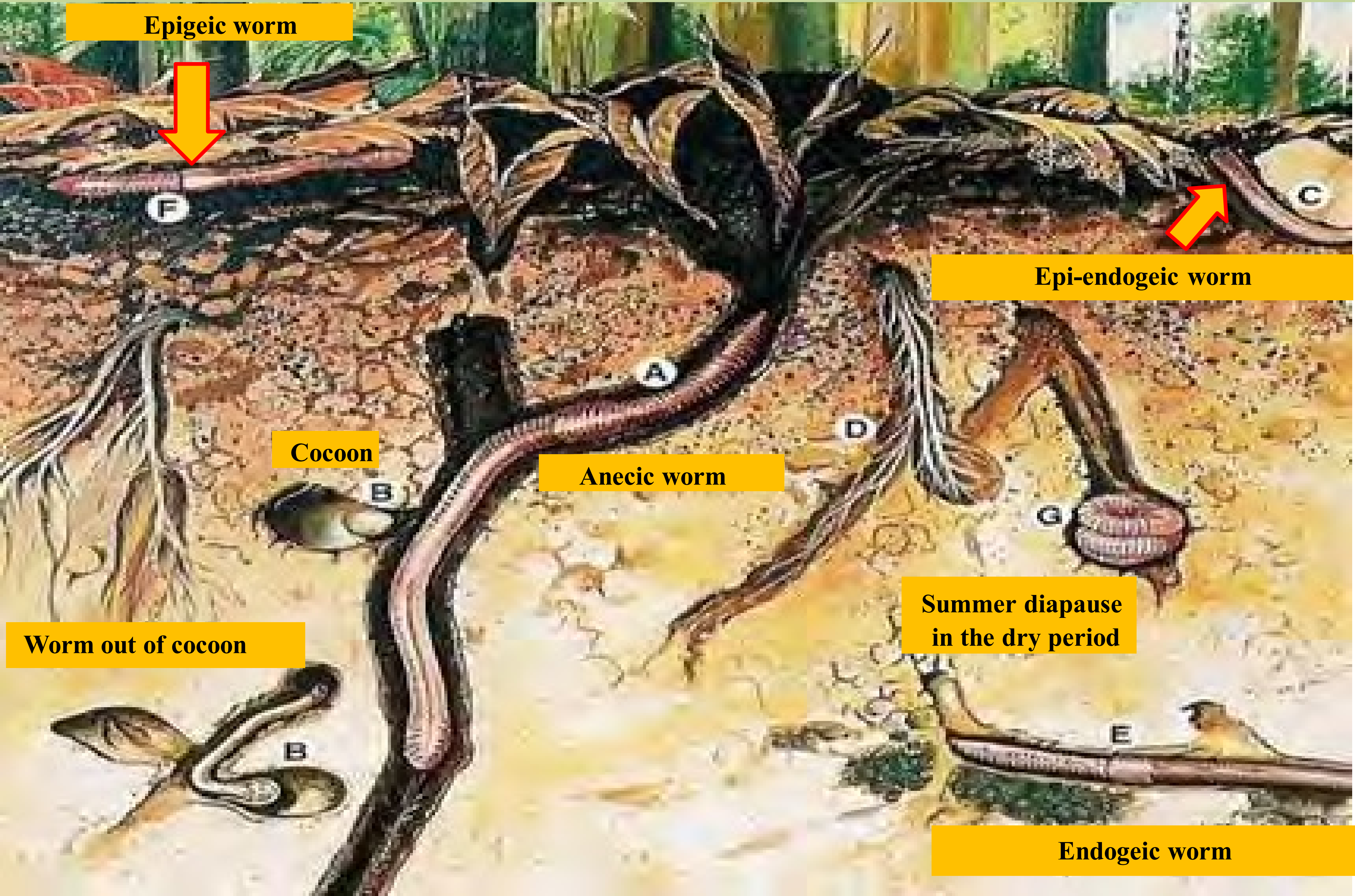
they prevent soil acidification: calciferous glands in the esophagus of worms accumulate calcium ions, which neutralize the acidic contents of their food;

they increase porosity: by forming systems of passages and chambers, they improve the growth of plant roots and the movement of micro- and mesofauna of the soil;

they improve soil aeration and water permeability: they form micro- and mesofauna habitats and increase the available moisture content for plant roots and soil animals *(W. Dunger, K. Voigtlender, 2008).*

FULL-FLEDGED COMPLEX OF EARTHWORMS *W. Dunger, K. Voigtlender. "Leben im Boden", 2008*

PORE SPACE FILLED WITH AIR AND SOLUTIONS OF MINERALS REACHES 60%



REPRESENTATIVES OF DIFFERENT MORPHO-ECOLOGICAL GROUPS OF EARTHWORMS

Apporectodea rosea – endogeic worm

Dendrobaena octaedra – epigeic worm

Eisenia fetida – Epi-endogeic worm

Lumbricus terrestris – anecic worm

Apporectodea caliginosa – endogeic worm

DECOMPOSITION OF PLANT RESIDUES AND SOIL FORMATION

Worms from the soil
dry pasture meadow, Pechora-Ilych Nature Reserve

Earthworm castings,
Krasnodar Krai

Worms on the deadwood

ENVIRONMENT-TRANSFORMING ACTIVITIES OF EARTHWORMS

Earthworms create up to 70% of the pore space of the soil. When burrowing, earthworms contribute to the redistribution of pore space in favour of large pores, where water is less bound by capillary forces and more accessible to plants. In the presence of earthworms, the infiltration capacity of soils increases. On pastures with a high density of earthworms in the soil, up to 100 liters of water can be poured into just one tunnel, and it will not be overflowing, which means that the tunnels largely run into one another. The tunnels are passages for plant roots to grow
freely (Lee, 1985).

MORPHO-ECOLOGICAL GROUPS OF EARTHWORMS

Epigeic worms are small (length: 2–5 cm), have red or purple colour (for protection from UV rays). They inhabit the litter layer. They feed on poorly decomposed plant material and are classified as **primary humus-forming agents.**

Epi-endogeic worms are medium-sized worms (length: 5–15 cm). They live in the litter and in the upper layer of the soil up to 10 cm deep. Only the front part of their body up to the ring is pigmented. They process poorly decomposed plant residues, mix the litter with the upper humus horizon, and are **primary humus-forming agents.**

Endogeic worms are medium-sized (length: 5–15 cm), unpigmented. They live in the mineral layer of the soil, most often up to a depth of 30–40 cm. They feed on soil humus and process the plant material at later stages of plant residue decomposition and are **secondary humus-forming agents.** They actively loosen the soil during horizontal and vertical movements.

Anecic worms are large, 15–30 cm long. Only the front part of their body up to the ring is pigmented. They live in mature soils. They make permanent tunnels in the soil 1 to 8 m deep. They feed on plant residues from the soil surface. Due to their vertical migrations, they mix soil layers. They are **primary humus-forming agents** (*Perel, 1997*).

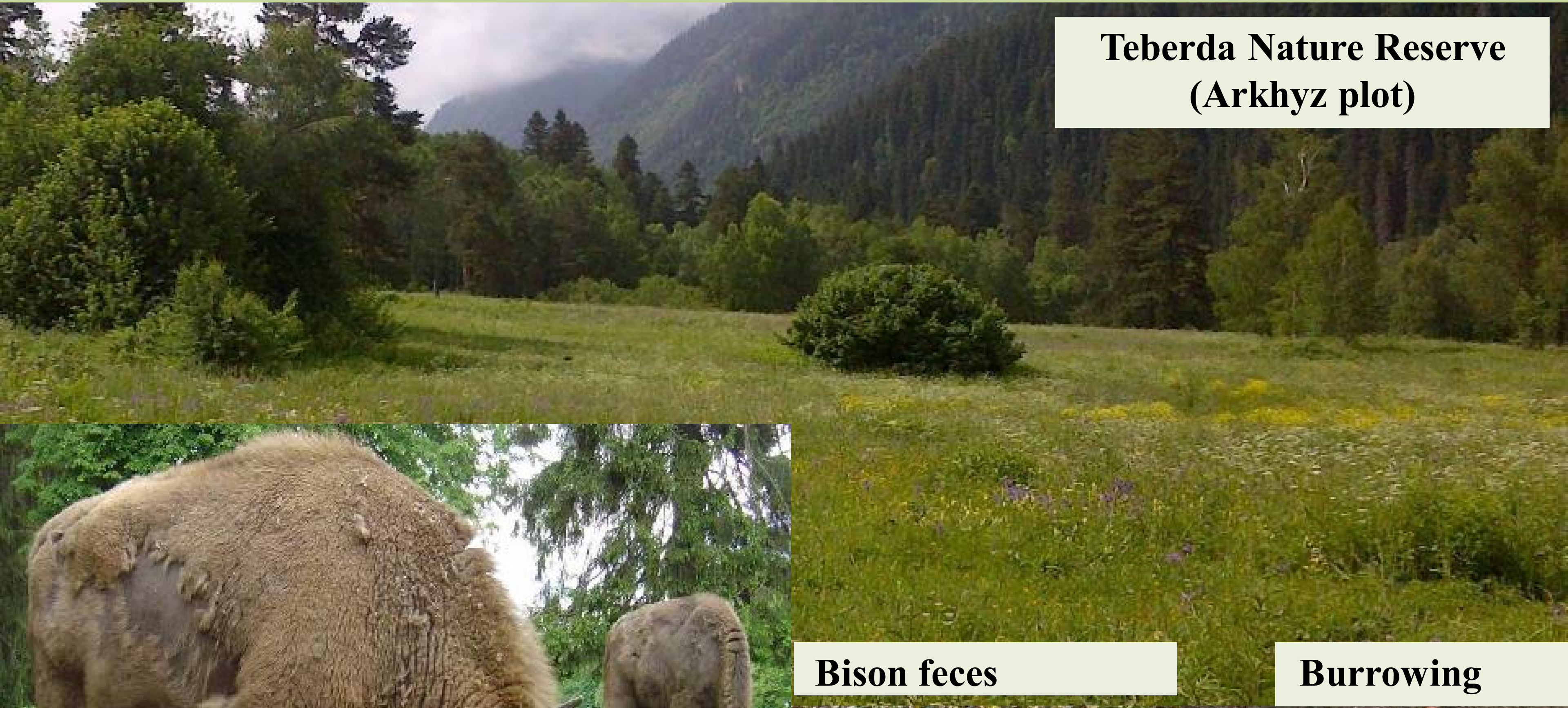
When moving in the thickness of the soil, earthworms permeate it with a network of passages with a diameter of 3 to 7 millimeters. These passages contribute to better soil aeration, penetration of moisture and roots into it. When feeding, a large amount of soil mass passes through their intestines together with decomposing organic matter, releasing the soil in the form of castings. The mass of such castings is several hundred tons per 1 hectare. Castings are the most favourable environment for the reproduction of soil microorganisms: their number increases several times.

Thus, earthworms accelerate the decomposition of organic substances and have an effect on plant productivity. The lifespan of earthworms is 3–5 years, although some species live up to 10 years. Worms have an amazing regenerative ability — they can regenerate lost parts of the body. Earthworms are sensitive to changes in climate and meteorological conditions. Vertical migration of earthworms in the soil profile is often caused by the temperature and humidity of soil, as well as its mechanical composition. The number of earthworms per 1 square meter can range from a few to dozens or hundreds of individuals. With due credit to the outstanding role of worms, it should be said that future farming systems will necessarily take into account the “wormy" question. German grassland farmers claim that on a hectare of good pasture, the weight of livestock should be equal to the mass of earthworms in the soil.

Returning to the main wealth of the mankind, to its progenitor – the soil and seeing it in a poor state, we want the sea signal SOS (save our souls) to sound as loud on land (Tyuryukonov, Kovda).

Bison feces are a valuable food resource and habitat for juvenile earthworms

Their mass, number and species diversity in forests with bison and other large herbivores is much higher than without them.



Teberda Nature Reserve (Arkhyz plot)

Bison feces

Burrowing worm

RESULTS AND PROSPECTS OF STUDYING KEYSTONE SPECIES

Consideration of **keystone species** (trees, vertebrate phytophages and invertebrate saprophages) in terms of the features of their habitat and changes in the environment makes it clear that they constitute a **complex of complementary species**.

Absence of bisons in the forests of Northern Eurasia and of wood bisons from the forests of North America, leads to the disappearance of light-loving species of plants and animals (including insect pollinators), without beavers, the hydrological regime on these territories changes fundamentally: the risk of fires increases, waterfowl and other inhabitants of ponds, swamps, and wet forests disappear; without earthworms, the productivity of vegetation decreases ... **Only together they form the basis for the successful existence of living forest cover in both the northern and southern hemispheres in modern climatic conditions.**

The concept of keystone species (***ecosystem engineers, edificators***) continues to develop successfully and new keystone species will undoubtedly be identified, which are necessary for the sustainable existence of the entire population of meadows, forests, steppes, etc... However, because of the lack of full-scale research of keystone species complexes in general it is impossible to get a clear idea of the potential living cover of a particular territory.

This hinders the development of science-based measures for the conservation and restoration of natural biodiversity of ecosystems and their complexes of different types.

To successfully solve the tasks of preservation and restoration of natural cover and sustainable use of natural resources one should, in the context of local conditions, summarize the data of historical ecology and ecology of biosystems, identify the appropriate set of keystone species and assess the possibility of restoration of their populations or of man-made simulation of their impacts (for example, moderate grazing in the steppes for conservation of biological diversity).

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