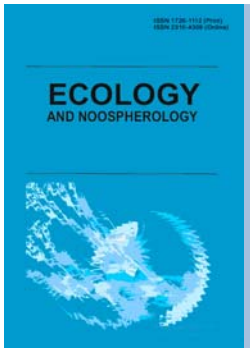

ECOLOGY
AND NOOSPHEROLOGY

ISSN 1726-1112 (Print)
ISSN 2310-4309 (Online)
Ecol. Noospher., 35(1), 66–71
doi: 10.15421/032411

«Lace Miracle», lichens as an indicator of the ecological situation using the example of Turkey Creek, Florida

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Article info

Received 23.04.2024
Received in revised form 24.05.2024
Accepted 29.05.2024

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Poleva, J. L., Polev, M. D. (2024). «Lace Miracle», lichens as an indicator of the ecological situation using the example of Turkey Creek, Florida. Ecology and Noospherology, 35(1), 66–71. doi:10.15421/032411

In this article, we took a walk-exploration of a piece of paradise called Turkey Creek in the center of Florida. Enjoying the spring period of the awakening of nature, accompanied by a multitude of birds and other unique sounds of the inhabitants of Turkey Creek, we paid special attention to the diversity of lichens, which, as bioindicators, react and reflect the state and quality of the environment. Lichens are very sensitive to air pollution and die when there is a high content of carbon monoxide, sulfur compounds, nitrogen and fluorine. The degree of sensitivity varies among species, so they can be used as living indicators of environmental cleanliness. Based on the composition of lichens, the concentration of various pollutants in the air can be quantified using developed scales and formulas. Lichens are a unique group of lower plants. Lichens combine two organisms with opposite properties: an alga (usually green), which creates organic matter through the process of photosynthesis, and a fungus that consumes this substance. Lichens are characterized by fairly high tolerance to climatic factors and sensitivity to environmental pollutants and are widely used as environmental indicators. Lichens contain many macro- and microelements, organic acids, hormones and enzymes. Vitamins are produced by lichens in very small quantities. Lichens produce specific substances that are not found in other organisms (lichen starch, lichen acids, etc.). Lichens have the ability to extract various elements from the environment and accumulate in their thallus. The number of currently known lichen substances exceeds 250, of which 75 are found only in lichens. Lichens are indicators of the environmental situation. Our goal is to find out whether recreational load affects the state of the environment in people's recreation areas. We carried out our study of the state of the environment in the state of Florida in the Turkey Creek natural park. This territory was chosen because the natural complexes of the area are characterized by high environment-forming, environmental, and recreational significance. In the last decade, the anthropogenic load on ecosystems associated with the recreational use of the territory has been increasing. It is worth familiarizing yourself with the types of lichens that were seen in the study area.

Keywords: Turkey Creek; biomonitoring; bioindicators; bottom fauna; lichens; ecology; biodiversity.

The article is dedicated to the memory of Lidiya Nikitichna Goritsyna, senior researcher at the Environmental Protection Laboratory of the Research Institute of Large-Dimensional Tires, Dnipro, Ukraine

Introduction

The problem of environmental pollution is one of the global problems of modern civilization. Due to the development of industry and transport, a large quantity of harmful emissions enters the biosphere. There is practically no place on Earth where pollutants do not enter in one concentration or another (Poleva, 2024). Among them, sulfur dioxide, carbon monoxide, hydrogen sulfide, ammonia, as well as soot, ash, and solid particles have a large share. When studying the degree of environmental pollution by industrial facilities, the reaction of biological organisms to pollutants is important. The unique properties of lichens have made it possible to use them for a general assessment of the degree of atmospheric pollution. On the basis of this, a special direction of indicator ecology began to develop, lichen indication (Poleva et al., 2024).

Biodiversity has both fascinated and puzzled biologists. In aquatic ecosystems, the biodiversity puzzle can be particularly troublesome, such as the «paradox of the plankton» (Poleva, 2024). Competition theory predicts that, at equilibrium, the

number of coexisting species cannot exceed the number of limiting resources. For phytoplankton, only a few resources are potentially limiting: nitrogen, phosphorus, silicon, iron, light, inorganic carbon, and sometimes a few trace metals or vitamins. However, in natural waters dozens of phytoplankton species coexist (Poleva, 2024; Bajdak et al., 2021).

Global monitoring experience has developed a number of requirements for bioindicators. It is not possible to find any organism or group of organisms that meet all these requirements, so a variety of groups are used for monitoring – from microorganisms to fish and mammals. When monitoring freshwater ecosystems, macrozoobenthos animals are a favorite subject (Bajdak et al., 2021; Poleva, 2020). They satisfy many requirements for bioindicators, including: widespread occurrence, sufficiently high numbers, relatively large sizes, ease of collection and processing, a combination of being confined to a specific biotope with a certain mobility, and a long enough life span to accumulate pollutants over a long period. Benthic organisms, as a rule, are not economically valuable or unique objects; therefore, their removal from a reservoir for research purposes does not damage its ecosystem (Poleva, 2020).

Methods of bioindication and biomonitoring, such as studying benthic fauna, or sensing air purity with the help of lichens, are important and necessary as a complement to long-term, multifaceted and complex research options. An instant assessment of the environmental situation can serve as a good «assistant» for formulating a plan for more detailed and global studies and observations, and also saves resources and reagents necessary for the use of expensive equipment (Poleva, 2024).

Plants are used as very sensitive tools for prediction and recognition of environmental stresses. In recent time, due to industrialization and urbanization the problem of contamination of water and water pollution has intensified (Batiuk et al., 1992; Joanna, 2006). Marine plants provide valuable information to predict the status of oceanic environment, as they are immobile and rapidly obtain equilibrium with their natural surroundings. The presence or absence of some specific plants or other vegetation provides ample information about environmental health. Lichens generally found on the trunks of trees and rocks are composed of algae and fungi both. They react to ecological changes in forests, including changes in the structure of the forest, air quality, and climate. Environmental stress can be indicated by the disappearance of lichen in forests, as caused by changes such as increases in the level of sulfur dioxide (SO_2), pollutants of sulfur and nitrogen (N_2) (Walsh, 1978; Peterson, 1986; Reynolds, 1984).

In many water bodies, such as, seas, lakes, streams, and swamps, significant biological production is carried out by plankton. Planktons are composed of organisms with chlorophyll (i.e. phytoplankton and animals such as zooplanktons). These planktons consist of communities that float along currents and tides, yet they fuse and cycle important quantities of energy that is then passed on to higher trophic levels (Reynolds, 1984).

Plankton also plays an important role in biological deterioration organic matter; but if plankton populations are too large this creates other problems in managing the water body. Fish at this critical stage of ecological process play an important role by grazing the planktons. The two roles played by fish are very crucial as they help in maintaining the proper balance of planktons in the pond and convert the nutrient available in wastewater into a form which is consumable by humans (Khatri et al., 2015; Holt et al., 2010; Pradhan et al., 2008; Chakrabortty et al., Carignan et al., 2001).

Lichens were chosen as the object of global biological monitoring because they are distributed throughout the globe and because their response to external influences is very strong, and their own variability is insignificant compared to other organisms. Lichens react sensitively to the nature and composition of the substrate on which they grow, to microclimatic conditions and air composition. Due to the extreme «longevity» of lichens, they can be used to date the age of various objects based on measurements of their thalli – ranging from several decades to several millennia.

Materials and methods

Ecological monitoring of the environment is one of the important and promising methods for monitoring anthropogenic impact on the natural habitat of living organisms. In organizing such monitoring, lichens have long proven themselves to be the most informative, economical object. Many experiments have established the ability of lichens to accumulate heavy metals. Moreover, each type of lichen has selectivity in relation to individual elements. All these features of lichens are a unique basis for the use of this group of plants to address issues of the quality of the ecological state of the natural environment and assess the technogenic load in ecosystems.

The sensitivity of lichens to air pollution is determined by:

• symbiotic nature;

• large absorption surface (all substances, including gaseous and dissolved pollutants in water, are absorbed by the entire surface of the thallus);

• high hydrophilicity;

• habitat (sediment flowing down the trunk contains significantly higher concentrations of pollutants than sediments in open areas);

• life expectancy.

The question arises – «why lichens»? The answer is simple and clear. The object of our research is a striking example of a favorable ecological situation, in terms of quantity, occupied area and biodiversity, without resorting to expensive research we can give an environmental assessment of this territory.

Using lichens, we easily organized a biomonitoring system – without using long-term observations, we analyzed the Turkey Creek test object based on a theoretical basis and visual observations.

Results and discussion

As part of the Brevard County Environmentally Endangered Lands (EEL) program and the East Florida section of the Great Florida Birding Trail, Turkey Creek Sanctuary is 130 acres of wonder, biodiversity and natural resources.

Established in 1981, the Sanctuary offers a 1.85 mile boardwalk passing through hydric (wet) hammock, mesic (moist) hammock, and sand pine scrub communities, and 1.5 miles of jogging trails through native forest, both excellent for viewing a multitude of wild life (Fig. 1).

Fig. 1. The peaceful picture of harmony and splendor of Turkey Creek

Sand Pine Ridge

Located 20–25 feet above Turkey Creek is the sand pine ridge. This classic scrub area is found only in Florida and is named for its dominant tree, the sand pine (*Pinuc clausa*). Sand Pines and other desert (xeric) adapted plants flourish in the sugary sands of Ancient Atlantic Ocean dunes. Since they usually occupy a high dry site, the dune areas are much sought after as construction or agricultural sites. Vegetation in the area is sparse as the soil lacks many nutrients. Rain water drains rapidly and is filtered as it percolates through the soil. Some of Palm Bay's well fields are located in this area and provide drinking water. Most of the plants are wax-coated or have succulent leaves to aid in water retention.

Scrub and American Turkey oak (*Quercus laevis*), Bitter Melon (*Momordica charantia*), Muscadine (*Vitis rotundifolia*), Peppevine (*Nekemias arborea*), and large flower rosemary are the dominant flora. Up in the pines, air plants such as Spanish Moss (*Tillandsia usneoides*) and Ballmoss (*Tillandsia recurvata*) thrive.

Birds such as Great Crested Flycatcher (*Myiarchus crinitus*), northern Cardinal (*Cardinalis cardinalis*), Blue Jay (*Cyanocitta cristata*), Ovenbird (*Seiurus aurocapilla*), and American Redstart (Setophaga ruticilla) nest here. Habitat exist for the Eastern Ratsnake (*Pantherophis alleghaniensis*), Rough Greensnake (*Opheodrys aestivus*), Gopher tortoise (*Gopherus polyphemus*), False Map Turtle (*Graptemys pseudogeographica*), Eastern Gray Squirrel (*Sciurus carolinensis*), Common Raccoon (*Procyon lotor*), Nine-banded Armadillo (*Dasypus novemcinctus*), and the endangered Florida mouse. Many insects, butterflies (*Black Swallowtail, Eastern Tiger Swallowtail, Tawny Emperor, Red Admiral, Question Mark*) and spiders flourish.

Transition Zone (Ecotone)

This narrow zone where the sand pine scrub and wet hammock merge contains plants of both the Sand Pine Ridge and Wet Hammock communities. Note that the foliage becomes more scrub-like and stunted as you walk uphill.

Wet Hammock

This Hammock is located on the banks of Turkey Creek, a major tributary of the Indian river Lagoon. The creek mouth forms a bay surrounded by palms from which our (Palm Bay) city was named. Beginning at the Melbourne Tillman drainage District Canal dam. The creek drains 100 square miles of land.

The mature forest surrounding the creek is known as the «hydric», or wet hammock. The word «hammock» is thought to be of Indian origin meaning «a shady place», and is an island of vegetation surrounded by a sea of different types of vegetation. Beneath the wet hammock is a unique geological rock strata called «Anastasia Formation». Perched on this limestone rock is a bed of fossil bones over 250,000 years old. This is overlaid by rich organic soil which is increased by the natural creek overflow. Turkey Creek is «black water creek» whose dark water color results from natural leaching of tannic acids from decomposing leaves.

Describing the flora and fauna of Turkey Creek, I would like to draw attention to similar characteristics of another climatic zone and no less significant and unique natural park as Samara Plavni. The creation of reservoirs in river valleys for the accumulation of fresh water has been and remains an important issue throughout the world. This process has both positive and negative consequences for people and nature. Significant changes in the regime of rivers and their valleys, flooding of meadows and forests, flooding of soils and changes in the composition of flora and fauna of adjacent territories are taking place. In this article, we consider the restoration of the biodiversity of a site of disturbed lands after the creation of one of the first reservoirs in Europe – the Dnieper (Zaporozhe) on the river Dnieper, which has existed since 1933. The territory of the Samara floodplains was formed on the floodplain of the mouth of the Samara River, as a result of which the territories of various forest, meadow and bog biotopes were flooded. For almost 90 years, new biotopes have been formed, and plant and animal species, especially waterfowl, have been renewed and enriched. In the further existence of this complex under conditions of climate change and anthropogenic pressure, the question arose of preserving this territory. To control the conservation of biodiversity, it is necessary to apply various management methods, one of which is the creation of nature reserves (Baranovski et al., 2021).

Flora of Turkey Creek includes: Sand Pine (*Pinus Clausa*), Coontie (*Zamia integrifolia*), Shiny blueberry (*Vaccinium myrsinites*) and Malberry (*Ardisia escallonioides*) or cabbage palm (*Florida's state tree*). Understory trees such as Chapman's Oak (*Quercus chapmanii*), Southern Live Oak (*Quercus virginiana*), and Swamp Laurel Oak (*Quercus laurifolia*) here. Shrubs such Wild Olive (*Cartrema floridana*), American Trumpet Vine (*Campsis radicans*), and beauty berry abound. Ballmoss (*Tillandsia recurvata*), Spanish moss (*Tillandsia usneoides*), shoestring fern, Monk Orchid (*Eulophia maculate*) and the parasitic Painted Leaf (*Euphorbia cyathophora*) to limbs. Many species of lichens, ferns (*Mariana Maiden Fern, Swamp Shield-fern, Golden Polypody, Resurrection Fern, Fishbone fern*) and vines flourish. Virginia creeper, smilax grape and poison ivy vines are common.

Animals include river otter *(Lontra canadensis)*, water turtles (*Trachemys scripta, Graptemys ouachitensis*), alligator (*Alidator mississippiensis*), manatee (*Trichechus manatus latirostris*), frogs (*Limnaoedus) ocularis, Acris gryllus dorsalis, Acris gryllus, Acris crepitans crepitans)*, lizards (*Anolis sagrei, Anolis carolinensis*) and snakes (*Nerodia taxispilota, Diadophis punctatus, Opheodrys aestivus, Panttherophis alleghaniensis, Coluber constrictor*). Several species of both fresh and salt water fish such as mullet, bass (*Micropterus salmoides*), Atlantic Tarpon (*Megalops atlanticus*), Bluedill (*Lepomis macrochirus*), Common snook (*Centropomus undemalis*), Blue-spotted Sunfish (*Enneacanthus gloriosus*), and Florida Gar (*Lepisosteus platyrhincus*) inhabit the creek. The diversity of the creek is very different in comparison with the biodiversity of freshwater reservoirs of the steppe zone of Ukraine (Kobiakov et al., 2021).

Among the birds favoring this habitat are Red-bellied (*Melanerpes carolinus*), Downy Woodpecker (*Dryobates pubescens*), Black Vulture (*Coragyps atratuz*), Green Heron (*Butorides virescens*), Short-tailed Hawk (*Buteo brachyurus*), Summer Tanager (*Piranga rubra*), Ovenbird (*Seiurus aurocapilla*), Northern Parula (*Setophaga americana*), Yellow-throated Warbler (*Setophaga dominica*), Blue Jay (*Cyanocitta cristata*), Great Crested Flycatcher (*Myiarchus crinitus*), Black-and-White Warbler (*Mniotilta varia*) and Little Blue Heron (*Egretta caerulea*). The area is an important stopping off place on the Atlantic flyway for migratory birds. The rare white pelican winters at the mouth of Turkey Creek.

Having made a detailed review of the biological diversity of Turkey Creek, we will detail and dwell on the "heroes" of our review-excursion – Lichens, as unique indicators of a harmonious and pristine ecological atmosphere in the sanctuary park area of Turkey Creek.

There are three main morphological types of lichen thalli:

- scale (found mainly on rocky substrates and on tree bark);
- leafy (found on various types substrate);
- bushy (found on tree branches (dangling thalli) or on the soil (erect thalli).

There are transitional forms between them, for example, species of the genus Cladonia have primary thallus of leafy type and secondary - bushy. Different species may have greater expressed either primary or secondary thallus. Hypohymnia swollen and Parmelia furrowed are gray in color and grow on tree trunks and branches. They occur very often. The branches of the hypohymnia really look swollen. In parmelia they are flat, grooved and look a bit like crumpled gray paper. Cladonias are amazing lichens in the form of cups and intricately curved stems. They settled on stumps, fallen rotting trees, or directly on the ground. Cladonia are very diverse.

Xanthoria parietina – leafy thallus, in the form of a blade sockets, most often occurring type thallus. Different examples of lichens can be seen in photos 3, 4, 5 and 6.

Fig. 3. One variant of lichen in Turkey Creek Sanctuary

Cryptothecia striata

This species is found in xeric to hydric hardwood forests. This species is a white crustose lichen, with a white margin and slight greenish blue interior. This is one of the most common large crustose lichens. Thallus corticolous, rarely saxicolous, delimited by a distinct byssoid prothallus of white, radiating hyphae; thallus surface cottony, ecorticate, greenish gray to grayish white, with storage beige, lacking soredia; medulla white, densely filled with minute colorless granules and sparse calcium oxalate crystals (insoluble in KOH, forming colorless, needle-shaped crystals in 25% H_2SO_4); ascigerous areas developing in the thallus center as small, byssoid dots that soon merge into distinctly radiating striae, rarely not forming striae, but merging into large pustular outgrowths (not true soredia); asci bitunicate-fissitunicate, broadly pyriform to globose, with a short stalk, a moderately thickened wall (ca. 4–6 µm).

Fig. 4. Another lichen variant in Turkey Creek Sanctuary

Canoparmelia caroliniana

This species is common in upland mesic and xeric hardwood and Pinus forests and occasionally in the hydric forest. This species has isidia. The upper surface is strongly maculate while the lower surface is blackish brown to black. However, the margin of the lower side (closer to the lobe tips) is pale brown. Looking at the photos, one is bound to notice that along with two types of lichen, adjacent to and complementing the picturesque «still life», the Turkey Creek Sanctuary grows Ballmoss (*Tillandsia recurvata*). Like Spanish moss (*Tillandsia usneoides*), Ballmoss is an epiphyte and belongs to family *Bromeliaceae*. Ballmoss, or an air plant, is not a true moss but rather is a small flowering plant. It is neither a pathogen nor a parasite. Ballmoss uses trees or plants as surfaces to grow on but does not derive any nutrients or water from them. Ballmoss is a true plant and can prepare its own food by using Water vapors and nutrient from the environment.

Fig. 5. Christmas Lichen – Turkey Creek Sanctuary

Herpothallon rubrocinta (syn: Cryptothecia rubrocincta)

In Turkey Creek, this species is found occasionally. This is a crustose lichen with white edges and bright red. These are isidia-like structures that are red. The common name of this distinct lichen is Christmas lichen. Thallus corticolous, rarely saxicolous or foliicolous, delimited by a distinct byssoid prothallus of carmine red, radiating hyphae; thallus surface grayish to greenish white, ecorticate, dense, cottony, felt-like, in the center covered by carmine red, granular pseudisidia; medulla white, in parts filled with carmine red granules and sparse calcium oxalate crystals (insoluble in KOH, forming colorless, needle-shaped crystals in 25% H_2SO_4); asci and pycnidia not observed. Distribution and ecology: Cosmopolitan; by far the most common Herpothallon species in Galapagos, often very abundant and sometimes forming thalli of several decimeters across; common in the humid and upper transition zone, rarely also in the dry zone, on a wide variety of both native and introduced tree species, rarely also on rock; both in sunny, exposed and ±shaded and sheltered habitats.

Powder-puff or Reindeer Lichen (Cladonia sp.) – this small gray lichen may look like moss, but it's not – in fact. Lichen isn't even a plant (Fig. 6). It is a fungus living in a mutualistic relationship with algae or cyanobacteria. Lichens are some of the first living things to grow on exposed rock surfaces, making them important in helping to establish new plant communities after disturbances such as rocksides. This lichen has a highly brached, leafless growth pattern known as fruticose. Fruticose lichens survive well during extremely dry periods. Members of the diverse Cladonia group grow in many habitats in a wide range of climates, and some species of this group are a critical food sourse for reindeer and caribou. One rare species, Cladonia perforate is endermic to Florida.

Reindeer Moss, *Cladonia* spp., includes several species of lichen that can be found growing on the ground throughout Florida in undisturbed, dry upland habitats. It is typically abundant in areas that have not been exposed to fire for many years. Lichens are not a single species, but are actually a mutualism between a fungus and a blue-green algae. In this relationship, the fungus provides structural support for the

blue-green algae, while the algae make food through photosynthesis. It is colored gray to green with sponge-like masses lacking roots, it may be found in oak leaf litter in scrubby flatwoods on well drained soils. The Cladonia genus occurs as far north as the arctic tundra where it provides food for reindeer during frozen winter months. There are nine species of *Cladonia* in Florida, including *C. evansii*, the powderpuff lichens (photos 7, 10).

Fig. 6. Turkey Creek Sanctuary

Therefore, the prevalence and diversity of lichens in the Turkey Creek suggest that the air quality is relatively good, providing a healthy environment for visitors and wildlife (Fig. 8 and 9).

Fig. 7. Powder Puff lichens Turkey Creek Sanctuary

However, the presence of some lichen species that thrive in disturbed habitats indicates that certain parts of the Turkey Creek are experiencing environmental stress, possibly due to human activity or climate change. Therefore, there is a need for ongoing monitoring and conservation efforts to protect and preserve the lichen population and, by extension, the overall ecosystem health of the Florida Sanctuary park – Turkey Creek.

Fig. 8. Peaceful & Picturesque Atmosphere Turkey Creek Sanctuary

Fig. 9. Lichens on Oak-Tree Turkey Creek Sanctuary

Fig. 10. Lichens as art in nature-Turkey Creek Sanctuary

After extensive observation and research, it can be concluded that lichens in the Turkey Creek play a pivotal role in the ecosystem. These composite organisms, consisting of a fungus and an alga or cyanobacteria, exhibit a remarkable adaptation to their environment, thriving in varied conditions, from tree barks to rocks.

Lichens contribute significantly to the biodiversity of the Turkey Creek, providing food and habitat for a variety of invertebrates. They also play a crucial role in nutrient cycling, particularly nitrogen and phosphorus, thus enhancing soil fertility. Furthermore, lichens contribute to the formation of soil by breaking down rocks through biochemical weathering.

Interestingly, lichens are also an excellent bioindicator of air quality, as they are sensitive to pollutants, especially sulphur dioxide. Walking, enjoying, looking at and exploring the splendor and virginity of Turkey Creek, you involuntarily make comparisons with places in Ukraine that evoke similar feelings. One of these unique places is Lake Sukorivshchina (Ukraine), (Poleva et al., 2023).

Conclusion

The many-fold advantages of Bioindicators have outweighed their restrictions. The bioindicator is helpful, objective, straightforward, and reproducible. Bioindicators can be utilized at various scales, from the cell to the environmental level, for assessing the changes taking place in a specific biological community. Planktonic monitors unite biological, physical, chemical factors, and are utilized as an important part for evaluating health status of water bodies. The conclusion can be drawn that bioindication and biomonitoring have become promising methods for studying the impacts of external factors on an ecosystem and its development and for differentiating polluted and unpolluted areas (Poleva et al., 2024).

Lichens can be useful as biosensors, helping to assess the overall health of a forest and aiding in land management planning. Some have also been used in perfumes, dyes and medications. Increasing human knowledge of them can have value beyond just basic science. Being adapted to extremely unfavorable conditions, lichens are found wherever life is possible. They tolerate very low temperatures, going further north than any plants, and they also thrive in the humid environment of the tropical forest. However, a limiting factor for their spread is atmospheric air pollution, in particular industrial and exhaust gases - even a small admixture of sulfur dioxide is harmful to them. Therefore, lichens are rightly called indicators of clean air.

In conclusion, I would like to say that bioindication and biomonitoring are components of ecomonitoring, based on the use of living organisms in order to identify changes in the quality of the environment that occur under the influence of natural and anthropogenic factors. I would like to instill the skills of conducting bioindication research in students and in the future apply the acquired knowledge and observations when carrying out scientific research and also in carrying out various environmental measures (Poleva et al., 2024).

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