Assessment environmental safety for mangrove biome

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Summary. Mangrove ecosystem was analyzed from ecological safety point of view. The comparison anthropogenic impact on some mangrove biome in Brazil and Seychelles show that mangrove in Brazil affected by industrial and anthropogenic loading, whereas on Seychelles recreational disturbance and pollution are biggest problems for mangrove. Threats to mangrove ecosystem include: clearing, overharvesting, water reduce, overfishing, coral reefs destruction, pollution, climate change. Analyses of mangrove soil find big transformation ratio soil elements to mobile forms for Fe ($K_{s\text{-}mf}$ =253,81) and Cu (105,45), which is make this metal accessible for other living organisms and return to nutrient cycle. Mangrove systems support a range of species and provide a number of essentials for many different living organisms. The ability myxomycetes *Hemitrichia serpula* accumulate Ca (K_a = 443,69) and Zn (247,41) from environment was discover; Ni (60), Mn (16,04) and Pb (11,94) also show high level elements concentration in compere with their content in soil. Mangroves provide a wide range of goods and ecosystem services with great economic and environmental consequences. Risk for mangrove assess by exceeding the rate of the disappearance and reduces the capacity to function effectively as a viable ecosystem.

Key words: ecological safety, mangrove, anthropogenic load, risk assessment

INTRODUCTION

The ecological values of mangroves in most tropical countries have been qualitatively well documented and recognized. However, there is little quantitative scientific data to back this up, because most of the evidence is observational [9]. Mangrove is unique ecosystem therefore they are often the object of conservation programs, including national biodiversity action plans [14]. Problems of nature protection and environmental safety are closely related. “Environmental safety passports of species” (ESPS) appears universal platform for impersonal evaluating of risk with accounting the interests and tasks of environmental safety and nature protection [10]. ESPS accumulate veracious scientific information about individual species and evaluation of risk probability of real and potential threatens from this organism to environment, humans and other bioobjects [11]. The main purpose of the introduction of passports is to systematize scientific information for determination of effect of evaluated species on the environment, humans and other living organisms. In results analysis of information about organisms being evaluated could be possible to draw conclusions about impact risks to this species and danger effects of this species [12]. But ecosystems analyses may more effectively represent biological diversity as a whole than individual species. It include fundamental abiotic components that are only indirectly included in species assessments. Declines in ecosystem status may be more apparent than extinctions of individual species. For urgent evaluation ecosystem-level assessments may be less time consuming than species-by-species assessments. For balance this discrepancy the combination main information from ESPS can be used together with general information about ecosystem. The International Union for Conservation of Nature (IUCN) setting classification schemes international global standards for documenting extinction risk for species and ecosystems [4].

PURPOSE OF WORK

The objective of this study is to make preliminary risk assessment of mangrove biome using environmental safety passports of species and IUCN classification schemes with considering WWF evaluation. According with this purpose was planed to 1) analyze data about biotic components and abiotic factors of mangrove ecosystems; 2) assess of beneficial use the mangrove by human and their role in the nature; 3) determine potential threatens and risk for this ecosystems; 4) compare anthropogenic load on some mangrove biome in Brazil and Seychelles.

MATERIAL AND METHODS

Research of anthropogenic load on mangrove ecosystems was carried in September 2011 in Pernambuco Brazil and in Seychelles: on Mahé Island in October 2011, Praslin and Curieuse Islands during June and July 2015, La Digue Island in January 2016.

Risk assessment of anthropogenic load on mangrove ecosystems made for determination of quantitative or qualitative estimate of risk related to recognized threats. Quantitative risk assessment requires calculations of two components of risk:

$$R_i = L_i p(L_i), \tag{1}$$

$$R_{total} = \sum_i L_i p(L_i), \tag{2}$$

were R – risk, i – factors of risk, L – the magnitude of the potential loss, p – the probability that the loss will occur. For environmental safety loss is simply a verbal description of the outcome. In that case, the "risk" is expressed as:

$$R_i = p(L_i), \tag{3}$$

Risk assessment of bioobjects for environmental safety involved different dimensions, or plot axes, of a niche represent different biotic and abiotic variables. These factors may include descriptions features of the organism's, habitat, trophic position, geographic range, etc. [20]

Coefficient for transformation soil elements to mobile forms of soil elements calculated by formula:

$$K_{s\text{-}mf} = C_s / C_{mf}, \tag{4}$$

where $K_{s\text{-}mf}$ – ratio for transformation soil elements to mobile forms of mangrove soil elements, C_s – concentration element in soil, C_{mf} – concentration element in mobile forms of soil.

Coefficient of elements accumulation by myxomycetes fruiting body in mangrove calculated with formula:

$$K_a = C_m / C_s, \tag{5}$$

where K_a – ratio of elements accumulation, C_m – concentration element in myxomycetes fruiting body, C_s – concentration element in soil [12].

RESULT OF RESEARCH

Mangroves geographical distribution

Mangroves occur worldwide in the tropics and subtropics between latitudes 25° N and 25° S, but the largest percentage of mangroves is found between the 5° N and 5° S latitudes. The area of mangroves was 137760 km², spanning 118 countries and territories [1]. Approximately 75% of world's mangroves are found in just 15 countries. Asia has the largest amount (42%) of the world's mangroves, followed by Africa (21%), North/Central America (15%), Oceania (12%) and South America (11%) [7].

Mangroves forming components

Mangrove environments created by trees and shrubs species growing in coastal saline or brackish water. About 110 species are considered "mangroves", in the sense of being a tree that grows in such a saline swamp, though only a few are from the mangrove plant genus Rhizophora (Fig. 1). Of the recognized 110 mangrove species, only about 54 species in 20 genera from 16 families constitute the "true mangroves", species that occur almost exclusively in mangrove habitats [7]. Major components of mangroves include 47 species belonging to 10 genus of 6 plant families: Acanthaceae, Arecaceae, Avicenniaceae, Combretaceae, Lythraceae, Rhizophoraceae. Black mangroves conclude 9 species of genus *Avicennia* and two – *Lumnitzera*. 11 species of genus *Laguncularia* called white mangrove. Red mangroves from family Rhizophoraceae include 8 species of genus *Rhizophora*, 6 – *Bruguiera*, 2 – *Ceriops* and *Kandelia*. Monotypic taxa *Nypa fruticans* Wurmb is the only palm considered adapted to the mangrove biome. Mangrove apple present by 5 species of genus *Sonneratia* from family Lythraceae, also *Conocarpus erectus* L. (buttonwood) from family Combretaceae. Minor components of mangroves involved 15 genus from 14 families: 6 species from genus *Barringtonia*, 3 – from *Acrostichum, Heritiera*, 2 – from *Aegialitis, Aegiceras,Bravaisia, Camptostemon, Excoecaria, Pemphis, Xylocarpus* and by one species for genus *Acanthus, Fimbristylis, Osbornia, Pelliciera, Scyphiphora*. The most important feature all this plants that it can thrive in high temperatures and absorbs brackish water. Each species has its own solutions to these problems.

Characteristic of mangroves habitat

A habitat is made up of physical factors such as soil, moisture, range of temperature, and availability of light, etc. Analyses of impacts of abiotic factors from habitat to species vital activity show range of tolerance, optimum, minimum and maximum value of each factor. Mangrove plants require a number of physiological adaptations to overcome the problems of anoxia, high salinity and frequent tidal inundation. The saline conditions tolerated by various mangrove species range from brackish water, through pure seawater (30 to 40 ppt = parts per thousand), to water concentrated by evaporation to over twice the salinity of ocean seawater (up to 90 ppt) [18]. Mangroves exclude salt by having significantly impermeable roots which are highly impregnated with suberin, acting as an ultra-filtration mechanism to exclude sodium salts from the rest of the plant. They can also store salt in cell vacuoles and can secrete salts directly with salt glands at each leaf base.

Mangrove adapted to low oxygen prop above the water level with stilt roots and can then absorb air through pores in their bark (lenticels). They also make specialised root-like structures which stick up out of the soil

Fig. 1. Red mangrove *Rhizophora mangle* L. on island Mahe (Seyshelles)

like straws for breathing (manypneumatophores) which are also covered in lenticels. The roots also contain wide aerenchyma to facilitate transport within the plants.

Because of the limited fresh water available in salty intertidal soils, mangroves limit the amount of water they lose through their leaves. They can restrict the opening of their stomata and also vary the orientation of their leaves to avoid the harsh midday sun and so reduce evaporation from the leaves.

As a result of their intricately entangled above-ground root systems, mangrove communities protect shorelines during storm events by absorbing wave energy and reducing the velocity of water passing through the root barrier. In addition, mangroves protect intertidal sediment along coastlines from eroding away in harsh weather year round [19].

Biotic factors of mangrove ecosystem

Mangroves provide a number of essentials for many different living organisms, including food and shelter for a diverse animal community, living both below and above sea level.

Fungi, bacteria and termites can decay mangrove forests into peat deposits [22]. Termites are an important action on the organic matter is crucial to the chemical stabilization of mangrove peats and decaying for peat formation [22]. In mangrove sediments were collected the fungal strains with the great potentiality to degrade diesel oil, without developing antagonistic activity. These fungi accumulated significantly higher biomass, produced extracellular enzymes and liberated larger volumes of CO_2 [2].

Mangrove crabs (Fig. 2) munch on the mangrove leaves, adding nutritients to the mangal muds for other bottom feeders. Negative crabs influence present as predation to plant seedlings [19]. The unique ecosystem found in the intricate mesh of mangrove roots offers a quiet marine region for young organisms [3]. Algae, barnacles, oysters, sponges, and bryozoans live in areas where roots are permanently submerged. They all require a hard surface for anchoring while they filter feed. Mangroves provide important nurseries for many sandy and muddy-bottom demersal and surface feeding species, shrimps and mud lobstersuse the muddy bottoms as their habitat, including commercial fish and crustaceans, also juvenile coral reef fish [7]. Mangroves supply the existence and health of coral reefs which are dependent on the buffering capacity of these shoreward ecosystems, support the oligotrophic conditions needed by coral reefs to limit overgrowth by algae.

Fig. 2. Mangrove root Latreille crab *Goniopsis cruentata*

Table 1. Content of elements in soil and in *Hemitrichia serpula* plasmodiocarp in Seychelles mangrove

Elements	Concentration in soil, mg/g	Concentration in *Hemitrichia serpula*, mg/g	Accumulation ratio
Al	10895,91	1478,4	0,14
Ca	352,3	156312,9	443,69
Cd	0,024	0,11	4,58
Cu	4,64	15,41	3,32
Fe	956,88	5400	5,64
Mg	2555,17	2376	0,93
Mn	6,77	108,62	16,04
Ni	0,08	4,8	60
Pb	1,14	13,61	11,94
Si	513,65	1169,54	2,28
Zn	1,08	267,2	247,41

Mangrove systems support a range of wildlife species including crocodiles, birds, tigers, deer, monkeys and honey bees [13]. Many animals find shelter either in the roots or branches of mangroves. It serve as rookeries, or nesting areas. Many migratory species depend on mangroves for part of their seasonal migrations.

Some common myxomycetes species live in this ecosystem and playing important role in nutrient cycle. They have ability elements transformation and absorption. For some myxomycetes species the feature heavy toxic metal accumulation discovered (Tab. 1).

In our research discover ability myxomycetes *Hemitrichia serpula* (Scop.) Rostaf. (Fig.3) accumulate some elements from environmental. The highest value of coefficient accumulation by fruiting body (plasmodiocarp) this myxomycetes was for Ca (443,69) and Zn (247,41). Some other elements also show high ratio concentration in compere with their content in soil: for Ni K_a = 60, Mn – 16,04, Pb – 11,94. Thus new bioaccumulation organism was discovering in mangrove ecosystem.

Role in nutrient cycle

The mangrove biome characterized by fine sediments often with high organic content collect in areas protected from high-energy wave action. They contain a complex salt filtration system and complex root system.

Mangrove forests are an important part of the cycling and storage of carbon in tropical coastal ecosystems. Many scientists believe that mangroves are far more efficient at trapping carbon than tropical and temperate forests. They have a staggering ability to se-

Fig. 3. Myxomycetes *Hemitrichia serpula* (Scop.) Rostaf.

quester carbon from the atmosphere, and serve as both a source and repository for nutrients and sediments for other inshore marine habitats, such as seagrass beds and coral reefs. Mangroves have slightly different chemical compositions so the carbon content varies between the species as well between the different tissues of the plant e.g. leaf and roots. This plant becomes peat in good geochemical, sedimentary and tectonic conditions [22].

Anaerobic bacteria liberate nitrogen gas, soluble iron, inorganic phosphates, sulfides and methane, which make the soil much less nutritious. Aerial roots allow mangroves to absorb gases directly from the atmosphere, and other nutrients such as iron, from the inhospitable soil. Mangroves store gases directly inside the roots, processing them even when the roots are submerged during high tide [18].

The fine, anoxic sediments under mangroves act as sinks for a variety of heavy (trace) metals which colloidal particles in the sediments have scavenged from the water. Mangrove removal disturbs these underlying sediments, often creating problems of trace metal contamination of seawater and biota.

Table 2. Compare of elements in soil and in its mobile forms in Seychelles mangrove

Elements	Concentration in soil, mg/g	Concentration in mobile forms of soil, mg/g	Transformation ratio
Al	10895,91	–	–
Ca	352,3	30,47	11,56
Cd	0,024	0,038	0,63
Cu	4,64	0,044	105,45
Fe	956,88	3,77	253,81
Mg	2555,17	617,7	4,14
Mn	6,77	3,87	1,75
Ni	0,08	0,22	0,36
Pb	1,14	0,48	2,38
Si	513,65	–	–
Zn	1,08	1,08	1
Soil pH = 8,76			

Such organic pollutants such as polycyclic aromatic hydrocarbons (PAH), organochlorine pesticides dichlorodiphenyltrichloroethane (DDT), hexachlorobenzene (HCB), polychlorinated biphenyls (PCB) can be accumulated in mangrove sediments [8].

Our research finds big transformation ratio soil elements to mobile forms of soil for Fe ($K_{s\text{-}mf}$ =253,81) and Cu (105,45). Accordingly component of soil in mangrove make this metal accessible for other living organisms, including Fe and Cu to nutrient cycle (Tab. 2).

Beneficial use

Mangrove ecosystems represent natural capital capable of producing a wide range of goods and services for coastal environments and communities and society as a whole. Mangroves provide at least US$1.6 billion each year in ecosystem services [4].The loss of mangroves will have devastating economic and environmental consequences. These ecosystems are not only a vital component in efforts to fight climate change, but they also protect some of the world’s most vulnerable people from extreme weather and provide them with a source of food and income. Some of these outputs, such as timber, are freely exchanged in formal markets. They serve as a nursery for fish and other species that support coastal livelihoods. Up to 75% of the game fish and 90% of the commercial species in some regions are dependent on mangroves for part of their life cycles and on nutrients exported from the mangroves to other ecosystems [6].

Mangroves are vital to coastal communities as they protect them from damage caused by tsunami waves, erosion and storms. Maintaining a healthy mangrove forest sustains natural protection and is less expensive than seawalls and similar erosion control structures, which can increase erosion in front of the structure and at adjacent properties due to coastal currents. It appears that as the sea-level is slowly rising, mangroves are a better alternative to protecting coastlines from eroding than other can made structures, such as seawalls [14, 21].

The tsunami has provided an opportunity to illustrate that healthy mangroves serve as a natural barrier against massive waves – protecting infrastructure developments and saving lives. The IUCN compared the death toll from two villages in Sri Lanka that were hit by the devastating tsunami giant waves. Two people died in the settlement with dense mangrove and scrub forest, while up to 6000 people died in the village without similar vegetation [5]. It proves that mangroves provide a natural wall, which is necessary in high impact natural disasters areas such as this one.

Mangrove root systems slow water flow, facilitating the deposition of sediment. Toxins and nutrients can be bound to sediment particles or within the molecular lattice of clay particles and are removed during sediment deposition. Compared with the expense of constructing a wastewater treatment plant, mangroves are commonly selected as receiving areas of effluent. Increasingly the notion of specifically constructed mangrove wetlands is being adopted and used for treatment of aquaculture and sewage effluents [5].

Threats assesment

The chief threats to mangrove habitat come from: conversion and landuse change and the indirect effects of sediments and chemicals in runoff from catchments degraded by clearing of upland vegetation and intensive agriculture. Many mangroves become degraded through the upstream building of dams, roads and irrigation channels. As new cities are developed, mangrove forests around the world have felt a great impact not only on their ecosystems health, but also their wave-attenuating capacity [22]. Threats to mangrove ecosystem and their habitats include: clearing, overharvesting, water reduce, overfishing, coral reefs destruction, pollution, climate change.

Clearing: Mangrove forests have often been seen as unproductive and smelly, and so cleared to make room for agricultural land, human settlements and infrastructure (such as harbours), and industrial areas. Clearing for tourist developments, shrimp aquaculture, and salt farms has also taken place. This clearing is a major factor behind mangrove loss around the word [17].

Overharvesting: Mangrove trees are used for firewood, construction wood, wood chip and pulp production, charcoal production, and animal fodder. While harvesting has taken place for centuries, in some parts of the world it is no longer sustainable, threatening the future of the forests [17].

Water reduce: Dams and irrigation reduce the amount of water reaching mangrove forests, changing the salinity level of water in the forest. If salinity becomes too high, the mangroves cannot survive. Freshwater diversions can also lead to mangroves drying out. In addition, increased erosion due to land deforestation can massively increase the amount of sediment in rivers. This can overcome the mangrove forest's filtering ability, leading to the forest being smothered [17].

Overfishing: The global overfishing crisis facing the world's oceans has effects far beyond the directly overfished population. The ecological balance of food chains and mangrove fish communities can also be altered [17].

Destruction of coral reefs: Coral reefs provide the first barrier against currents and strong waves. When they are destroyed, the stronger-than-normal waves and currents reaching the coast can undermine the fine sediment in which the mangroves grow. This can prevent seedlings from taking root and wash away nutrients essential for mangrove ecosystems [17].

Pollution: Fertilizers, pesticides, and other toxic man-made chemicals carried by river systems from sources upstream can kill animals living in mangrove forests, while oil pollution can smother mangrove roots and suffocate the trees. Mangroves maintain coastal water quality by abiotic and biotic retention, removal, pollutants, and particulate matter from land-based sources, filtering these materials from water [17].

Climate change: Mangrove forests require stable sea levels for long-term survival. They are therefore extremely sensitive to current rising sea levels caused by global warming and climate change. The Global Mean Sea Level has risen 4 to 8 inches over the past century, almost twice the average rate of 80 years prior [16].

Other factors mangroves have an influence on, include coastal profile, water depth and bottom configuration. The mangrove population has felt both direct and indirect effects due to coastal engineering and human development, resulting in a devastating decline in population. This decline has led to a negative chain of effects in other ecosystems that are dependent on mangrove forest for survival.

Risks evaluation

Mangroves respond to deteriorating conditions with dieback and loss of habitat. Degradation of mangrove habitat by the direct loss or alteration of trees reduces its capacity to function effectively as a viable ecosystem. This in turn endangers the species that depend upon the healthy mangrove ecosystems. More than 35% of the world's mangroves have been destroyed, exceeding the rate of the disappearance of tropical rainforests [17]. The Atlantic and Pacific coasts of Central America, where as many as 40 percent of mangrove species are considered threatened, are particularly affected. The figure is as high as 50% in countries such as India, the Philippines, and Vietnam, while in the Americas. In India and Southeast Asia, where 80% all mangrove area has been lost over the past 60 years [4]. The potential loss of these species is a symptom of widespread destruction and exploitation of mangrove forests. More than one in six mangrove species worldwide are in danger of extinction due to coastal development and other factors, including climate change, logging and agriculture. 11 out of 70 mangrove species (16%) which were assessed will be placed on the IUCN Red List [4]. Countries with very large areas of mangroves have a significant number of protected areas notably Australia (180), Indonesia (64) and Brazil (63).

About 7% of the area occupied by mangrove swamps and forests is located in Brazil, extending along most of its coast [7] and concentrated (70%) between the states of Pará and Maranhão [15]. Despite of active conservation an action, some Brazilian mangroves destroy by industry and have negative pressure of anthropogenic loading, especially when it allocated near favela. In Seychelles industry are not active, but recreational disturbance is very strong, so the biggest impact for mangrove is pollution (Fig. 4). The main problem of the island and costal is a real threat of flooding due to global climate change. Thus general main risks for all mangrove ecosystems are destruction, pollution and climate change.

Fig. 4. Anthropogenic rubbish in mangrove

CONCLUSIONS

1. The most strong nature abiotic factors affecting mangrove biome are high salinity, frequent tidal inundation and anoxia, concerning mangrove developed physiological adaptations for overcome the problems.

2. Analyses of mangrove soil find big transformation ratio soil elements to mobile forms for Fe ($K_{s\text{-}mf}$ =253,81) and Cu (105,45), which is make this metal accessible for other living organisms and return to nutrient cycle.

3. Mangroves provide a number of essentials for many different living organisms such as crabs, fish, coral, algae, lobsters, oysters, barnacles, shrimps, sponges, bryozoans and also bacteria, fungi, termites, myxomycetes; mangrove systems support a range of wild-life species including crocodiles, birds, tigers, deer, monkeys and honey bees.

4. The ability myxomycetes *Hemitrichia serpula* accumulate Ca (K_a = 443,69) and Zn (247,41) from environment was discover; Ni (60), Mn (16,04) and Pb (11,94) also show high level elements concentration in compere with their content in soil.

5. Mangroves provide a wide range of goods and ecosystem services with great economic consequences such us a source of food (fish, crustaceans, etc.) and income outputs (timber); protection from damage caused by tsunami waves, erosion and storms; treatment of aquaculture and sewage effluents from toxins and nutrients of wastewater by bound particles or within the molecular lattice of clay particles and sediment deposition; vital component in efforts fight climate change

6. Threats to mangrove ecosystem include: clearing, overharvesting, water reduce, overfishing, coral reefs destruction, pollution, climate change; risk for mangrove determine by exceeding the rate of the disappearance and reduces the capacity to function effectively as a viable ecosystem.

7. The comparison anthropogenic impact on some mangrove biome in Brazil and Seychelles show that mangrove in Brazil affected by industrial and anthropogenic loading, whereas on Seychelles recreational disturbance and pollution are biggest problems for mangrove.

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Оценка экологической безопасности для мангровых биомов

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Аннотация. Проанализированы мангровые экосистемы с точки зрения экологической безопасности. Сравнение антропогенного воздействия на мангровые биомы в Бразилии и на Сейшельских островах показало, что в Бразилии на некоторые мангровые сообщества влияют промышленные и антропогенные нагрузки, в то время как на Сейшелах самыми большим проблемами мангровых лесов являются рекреационный прессинг и загрязнение. В целом наибольшими угрозами для мангровых экосистем являются вырубка, антропогенный прессинг, изменение водного режима, чрезмерный вылов рыбы, разрушение коралловых рифов, загрязнение окружающей среды, изменение климата. Анализ мангровой почвы выявил высокие значения коэффициентов трансформации подвижных форм почвенных элементов для Fe ($K_{s\text{-}mf}$ = 253,81) и Cu (105,45), поэтому эти металлы доступны для других живых организмов и могут вернуться в круговорот веществ.

Мангровые системы поддерживают целый ряд видов и обеспечивают благоприятные условия для жизнедеятельности многих различных живых организмов. Обнаружена способность миксомицета *Hemitrichia serpula* аккумулировать Ca (K_a = 443,69) и Zn (247,41) из окружающей среды; кроме того, для Ni (60), Mn (16,04) и Pb (11,94) выявлены высокие значения концентраций по сравнению с их содержанием в почве. Мангровые леса обеспечивают широкий спектр экосистемных услуг с большими экономическими и экологическими последствиями. Риск для мангровых биомов оценивается в превышении скорости исчезновения и снижении способности эффективно функционировать под воздействием техногенной нагрузки.

Ключевые слова: экологическая безопасность, мангровые экосистемы, техногенная нагрузка, оценка риска.