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THE ANALYSIS OF AIRPORTS' PHYSICAL FACTORS IMPACTS ON WILDLIFE

The impacts of manmade structures on wildlife are often underestimated due to misbelieve that wild animals avoid living in close proximity to any kind of technogenic object. However, such objects may offer a range of benefits to animals and thus become points of attraction, being still a source of hazards for these living organisms. The airports are considered to be dangerous industrial facilities for they create chemical and physical pollution, as well as host a variety of biohazards, originating from transported items and dense groups of population. Meanwhile they are often located outside the urban areas in previously pristine areas, specially allocated for this purpose and animals, whose habitat they occupy undergo all these impacts equally with passengers and staff. The aim of the research is to conduct differential analysis of physical factors of influence within the airport impact area and evaluate the negative trends for exposed animals. The physical factors were divided into the physical objects and physical fields. The assessment of these factors was based on the data obtained using special metering equipment for measuring the level of noise, light and electro-magnetic pollution, while the intensity of visual pollution and fragmentation effects by airport infrastructure were evaluated using qualitative approach. The airport facilities itself and ground access infrastructure are showed as the causes of habitat destruction by barrier and edge effects, as well as structural transformations of landscapes, in particular, relief and phytocenosis. The impact of physical fields coming from the airport territory is formed by light, vibration and electro-magnetic pollution. The intensity of considered factors is different, but the sensitivity of laboratory animals to these factors is high enough to cause a range of effects. However, the methods for mitigation of some other airport impacts can exacerbate the value of the existing sources of impacts. The light pollution is measured and defined as the most significant and damaging. Thus, there is a clear need to pay attention to the interactions between an airport and wildlife to reduce the intensity of negative effects. The predicted and described effects for wildlife could be very diverse, but they need verification by field surveys in the impacts areas of airports is highlighted.

Keywords: habitat fragmentation; light pollution; animal behavior; electromagnetic fields; vibration.

Introduction

The work of civil aviation facilities has very strong impact on the society development trends, as it is able to shape the trade, tourism and education pattern. It demands active development of infrastructure, which raises a range of social and economic controversies and concerns, including environmental. However, these concerns are more connected with potential human health issues, neglecting the impacts of civil aviation facilities on wildlife.

Object of research is the interaction of wildlife with manmade structures.

Subject of research is the physical effects of airports on wildlife.

The *aim of the research* is to consider the potential

stress factors, aggregated here as physical impacts, which wildlife is exposed to due to activity of airports and their infrastructure.

In order to reach the set aim the relevant *research tasks* were formulated:

- analyze the effects of airport structures on the environment;
- measure the level of physical factors intensity: vibration, visual, electromagnetic and light pollution;
- compare the results with data available on the threshold levels of pathological effects observed in wildlife.

Scientific novelty of the research is formed by presenting for the first time the effects of civil aviation facilities on animals with assumptions about the potential pathological processes, resulted from exposure to their physical factors.

Practical significance of the research results – the obta-

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ined data should be applied in the amendment of nature protection activity for the improvement of the environmental performance of airports.

Analysis of recent research and publications. There is a wide range of medical research results by L. Tauri, J. Nriagu, B. S. Cohen, K. H. Jung, A. Kobayashi, D. Westerdahl and others, showing that airport emissions provoke respiratory effects in humans and probably the same results are valid for air breathing animals. The health effects of aircraft noise are also intensively studied, in particular in the works of S. Morell, D. Huang the connection of vascular disorders to the activities of airports was well substantiated. Similarly, the airport noise can generate stress and jeopardize wildlife reproduction, as it is shown in the works by R. D. Alquezar, P. A. Anderson, J. R. Barber, E. M. Bayne, A. E. Bowles. However, not many researches were found to mention possible effects of other physical factors on animals. The impacts on radar systems are known to be present, as it is shown by E. Sheridan, T. L. DeVault, B. Bruderer, and J. Everaert, but the light pollution from airports, vibration are not well studied yet.

Problem statement: airports as sources of physical impacts for wildlife

Any modern airport is a system of manmade objects with elaborated structure and hierarchy. Being such a complicated industrial facility an airport include numerous sources of impacts both living and non-living environments are exposed to.

The assessment of physical factors of airport influence on wildlife should be conducted in 2 fields. First of all this is the direct impact of physical bodies or material objects, an airport is made of. The other issue is the physical pollution, spread beyond the borders of an airport facility.

Structural elements of airports. Airports require vast territories, mostly occupied by two main components – runways and terminal buildings, as well as maintenance hangars, parking, and other facilities. The runway remains the most important organizing element, taking at least 500 hectares of land, demanding on the scale of an airport's operations. This is the first disturbing element for wildlife, and the intensity of disturbance depends on the location of the airport.

The most important is their location in relation to urban centers: normally airports have been placed outside the cities to reduce discomfort for residents due to aviation noise and to provide efficient maneuvering for aircrafts. But this increases the possibility of contact between animals and airport facilities, because it is an intrusion into natural areas previously not transformed and visited by people. After the beginning of construction wildlife is stressed by the noise and pollution and thus forced to move to other territories. But this is the case for major animals, while smaller animals, like rodents may find such changes useful, as they receive new forage areas with reduced predator pressure. This leads to overpopulation, diseases propagation and creates threats to equipment integrity.

Nevertheless, many airports built over 30-40 years ago at the city outskirts are now located at the edge or even inside the developed urban areas. In such situation an airport becomes a new spot of nature for scanty urban fauna, in particular birds: they use airfields to look for food, becoming a problem for flights safety. At the same time some animals feel uncomfortable at huge open spaces and this al-

so prevents their normal activity. Leveling of relief and drainage of territories is also a problem, especial for wetlands. Forced to leave traditional areas some of the birds move to the airport areas and try to find new residence there, causing problems for air traffic and operations.

Airport location issues. As for the specific location of an airport it is chosen accounting multitude of factors, each of which has certain interactions with wildlife:

1. The demand for a particular airport services defines the types of aircrafts, accepted by the airport and thus affects the number and length of runways and the size of airport terminals, and therefore the physical size of the airport itself. The larger the airport is, the higher the need for territory transformation and area seized from wildlife habitats are. This seems to be obvious, but it exacerbates the above-described problem of free spaces.

2. Runway configuration affects the choice of an airport placement in terms of the possibility to build intersected or parallel runways. The better option for an efficient airport is parallel runways, but they need 30 % more territory. Under such conditions more populations and habitats will be affected. Moreover, intensive traffic and big aircrafts create additional cumulative aposematic effect on animals, due to increased noise and movement of huge objects.

3. Altitude affects the diversity and nomenclature of biota in the area of airport location. In those cases, when an airport is located at higher altitudes it will demand longer runway, but simultaneously the area available for construction is limited. As a result the needs of local wildlife are not accounted in the decision making process.

4. Climate conditions, in particular humidity and temperature, are the most important factors in terms of species composition typical for the territory of airport placement. Local variations in prevailing winds have effect on the birds' migration and food relocation. From more local point of view, the combination of climatic parameters define how attractive the airfield will be for animals and which of them are attracted. For instance, the airfield may be dryer or vice versa richer in greenery, as compared to adjoined territory, and thus attract certain species and favor or threaten their survival, depending on the level of animal control activity at an airport.

5. Topography is important for the choice of airport placement, as it needs the flat relief. If the latter is created by intrusion of man this heavily affects the local habitats quality and microclimate conditions, which will finally lead to transformation of local biocenosis.

6. Environmental considerations are partially accounted in the choice of airport location and normally they are located away from the sensitive areas. However, if an airport was build long time ago, its location could be chosen omitting the specifics of local ecosystems, as they were not known.

7. Adjacent land uses affect the activity and expansion of an airport. If there is a choice of possible territory to be added to an airport, than the competition between valuable agricultural land and natural areas may be not positive for natural zones.

8. The operational processes, namely aircrafts flight is affected by the presence of certain obstructions, like mountains, hills, and heavily built-up areas. Additionally flying over residential areas may be limited to certain hours by noise restrictions. The same may be applied to flying over

protected areas. However, it doesn't cover those natural ecosystems without the protection status.

9. Intensity of flights is an important issue in terms of limits for the available airspace and constrains for new airport operations. The same factor affects the risks of bird collisions and increases pressure on living organisms from busy sky, producing noise and pollution. This is especially true for those metropolitan areas, served by few airports with overlapping airspace, like in London, Moscow, San Francisco, Paris, New York, Seoul, Tokyo, Shanghai, and Washington.

Airport ground access. The crucial element of the civil aviation infrastructure is that an airport must be accessible to the communities it serves. As a result any airport needs specific line objects, namely highways, railways or subway to provide access to it. The connecting infrastructure to the airports located outside cities at the distances over 10 km has a range of serious implications for wildlife. The lines of road dissect the pristine natural areas and cause the fragmentation of habitats – a common problem of the modern times. The traffic intensity is the decisive parameter for the problem: highway with more than 10000 vehicles per day makes such road impermeable barrier for almost all species [4].

If an airport is located less than 5 km away from an urban area its effect is not very profound as the territory within the suburban zone is already changed and sensible animals have moved away from the territory. Our research has showed that the diversity of the biocenosis at suburban area is at least 2.5 times lower as compared to the same territories without human intervention. This is especially true for railway and metro connections. Highways give rise to the same problems, but they are also associated with higher incidence of wildlife – vehicle collisions, which put both people and non-human animals at risk. Basically, the fragmentation affects all types of land animal movement – moving in search for food and shelter, mating search and territory care. These will definitely put animals under the lethal risks due to starvation, lack of inter-individual communication or protection from predators. Seasonal migrations and availability of land for youth are also affected and contribute to genetic diversity [6].

Additionally roads as well as airport facilities impacts spread far from the immediate borders of the facility, creating edge effect, when wider areas around and along these objects are not comfortable for animals, due to pollution and change of plant diversity, distorted by intrusion of ruderal and alien species. This threatens the food reserves for animals and imposes risks as some of the newcomers can be dangerous for animals, cause allergic reactions in humans and problems for agricultural fields.

The injuries to animals are less cared and noticeable, but the mortality is the problem visual to anybody. Unfortunately, there is no good method to mitigate this problem and all of the applied are not free from serious shortcomings. For instance, the major method to reduce the possibility of collisions with animals is setting the fences along the road, but this aggravates the fragmentation effect and ruins connection between separated parts for all animals except birds. Another example is the cutting tall trees along the roads to prevent entering the exact edge of the road by wildlife gives possibility to avoid serious collisions with large animals, but simultaneously increases the destruction of habitat, edge effect and loss of food and shelter for birds.

Most of the airport possesses two types of ground access – highway in combination with metro or railway. Placing two or more forms of transport infrastructure along the same corridor (in the immediate vicinity) may be positive for some species, since only one barrier is created. But as in the case with fences, such solution increases the barrier effect for other species [13].

Separate attention should be paid to birds. The primary concern is about the minimization of collision risks, which is provided by the ornithological control department of airports. The use of deterring methods has negative impact on birds, but it is considered acceptable as compared to possibility of aircraft accidents. Nevertheless there exists a problem of collisions with airport towers. This is resulted by temporary meteorological conditions, which either reduce visibility or lead to low cloud ceiling, hiding stellar cues for birds' orientation [4]. From the other side, birds don't feel disturbed about barrier effects of airport facilities and ground access roads directly. However, the indirect impacts can be considerable as their food base could shrink. They could be also limited in their habitat area and lack shelter and nesting places due to deforestation.

Methods and materials. The physical factors of airports are different in nature and they need to be evaluated using different approaches. The intensity of physical fields was measured using special equipment. Thus, the light pollution was measured via standard photometry with Luxmeter Yu-116 and complemented with visual observations. The level of vibration was measured with the vibrometer Wintact wt63B, which was placed on the of soil ground, but not on the solid covers, like concrete or asphalt. Electro-magnetic field intensity was tested with the electromagnetic field meter ПЗ-31, which is used to detect and control biologically hazardous electromagnetic radiation. It works within the high-frequency ranges typical for airports.

In all cases measurements were conducted around the airport outside its industrial area at the points at four geographical directions from the airport, where there are no artificial structures and the plant cover is well preserved. The measurements were conducted in summer 2020.

A serious issue for the assessment is the absence of any regulations or threshold value of physical impacts on animals. In order to process the results, obtained in this research, the experimental results from open access publications were used.

Research Results

Traditionally airports are analyzed in terms of noise pollution they produce. In this research we decided to cover the other important components of physical pollution – light, vibration and electromagnetic fields.

Light pollution from airports. Due to peculiarities of aviation services provision, the intensive illumination at airports is a matter of safety and control over operations. Using the standard luxmeter measurements of illumination at the vicinity of Kyiv Boryspil and Kyiv Sikorsky airports were measured in summer and autumn, 2020. The values varied from 690 to 1125 Lux, depending on the location (the highest was at the international terminal entrance and airfield facilities. As a result the level of light pollution at night around the airport is almost equal to the level of light at sunrise at the busiest airports – this phenomenon of over-illumination is typical for all airfields. For those airport located in the vicinity of settlements, the specific problem is

light-trespass, which affects the living activity of people at the adjoining areas. The light pollution from distant airports is better defined as clutter – excessive groupings of light sources, which confuse organisms and distract them from the obstacles, leading to accidents.

Light pollution impacts wild life by complicating orientation in space, change intraspecific interactions, alter predator-prey relations, and affect animal physiology. But primary effects of light pollution are observed at plants, whose living processes are extremely dependent on the light and cycles of illumination. The most prominent consequences of exposure to light pollution are disruption of flowering and developmental patterns. As a result they fail to start flowering, then defoliation and enter the dormancy condition on time [3]. The resulted damage to plants by winter process and reduced reproduction of vegetation species puts animals to threat of food shortage and lack of shelter.

Birds are actually the most affected by the airport light pollution, as it prevents normal navigation, circadian rhythms and mating processes. Insects, which make up considerable part of birds diet are also strongly affected by airport illumination, but this may have double effect on birds' populations: airports attract food for birds in this way, as a result birds penetrate to the territory of airports in search for easy food and thus increase both injuries and accidents incidence.

Hydrobiontes in the water bodies within the airport impact area could be also affected by light pollution; in particular, over-illumination of water surface prevents zooplankton, such as *Daphnia*, from eating surface algae, which eventually contributes to algal blooms and elimination of fish and water plants due to water quality reduction [11].

Finally, it must be noted, that light pollution is also a powerful deterrent factor for nocturnal animals and it form a sort of non-material barrier, contributing to habitats fragmentation. This is especially true for ground access roads.

Vibration effects on wildlife. Vibration, caused by airport is rarely considered as a serious negative environmental factor. However, the intensity of vibration by landing aircraft or working engine is considerable enough to be felt by living organism. Moreover, sources of vibration at the airport facilities are tightly bounded to the sources of noise formation: high-level and short-term sources of vibration are run-ups, engines start-up, take-off and landing; thrust reversers; high-level and long-term sources of vibration are taxiing and idle, working auxiliary power units, maintenance equipment, as well as ground access transport. The highest impact for wildlife rises from long-term sources, as they create the hazardous background for living organisms in the airport area. Still it is necessary to account the attenuation of vibration over the distance, at which representatives of wildlife can be found. The research works show that it may reduce the vibration speed by a level of at least one power with 100 m [5].

Vibration plays considerable role in the lives of the whole spectrum of wildlife, from the simplest to the most complicated types of organisms, as alongside with sound it is involved in such vital processes as communication, interpersonal (especially, mating and parents-young relations), population (territory occupation) and interspecies (predator-prey) relations, foraging and food storage, survival strategies etc. [7]. Nevertheless, vibration effects are highly understudied, although certain facts are known from simple

observations, such as response in different domesticated and other species prior and in time of earthquakes.

The impact of vibration on an organism depends on the whole range of equally important factors, such as amplitude, frequency, acceleration rate and others. Yet, one of the crucial parameters when studying biological effects – is resonance frequency. As soon as biological systems possess certain tolerance to the factors of influence, to characterize the possibility of physiological disorders a few ranges of near-resonance frequencies effects are used: resonance frequency range (RFR) – range with the highest potential of the most adverse physical effects; sensitivity frequency range (SRF) – levels at which vibration is still perceived and may cause distress.

Those values are poorly known for most wildlife species. Those, that are known, exist mostly for domesticated or highly synanthropic species [9]. For instance, resonance frequencies for rats are 27-29 Hz (abdomen), 225-230 Hz (thorax), and 75-80 Hz (head) [14]. For piglets vibration sensitivity manifests in stress hormones increase and behavior alterations at acceleration of 1 m/sec² and frequency of 2-18 Hz (in case of whole-body vibration) [10]. Similar values caused avoidance behavior in chicken [1]. Among other adverse effects cardiovascular processes alteration, fertility decline, stress and aversion, other neural and muscle alterations in mice, rats, pigs, dogs and rabbits, as well as mortality in mice (at extreme values of 10-25 Hz and more than 140 m/sec² in case of whole-body vibration for 5-10 minutes) can be mentioned. Alternatively, it has been also investigated, that exposure to vibration can also have potential positive implications for organisms. Examples of this can be the same mice and rats, who exhibited, among other things, increased fat and bone formation, decrease in bone volume loss, alterations in serotonin volumes, improvement of metabolism, improved healing etc. [12].

Yet, such therapeutic effects are possible only at certain specific vibration values, in highly controlled environments. Yet it is highly likely, that the most common reaction to the vibration manifestations would be aversion (although in certain laboratory a posteriori research [15] mice responded to earthquake vibrations with decreased activity).

The measurements of aircraft vibration show that it lies within the range from 216-256 Hz at the level equivalent to 92 dB [8], and the vibration measured with standard vibrometer during the aircraft landing outside the airport territory was quite low and corresponded the level of 13 dB within the frequency range of 8-16 Hz. At the given level of the possible effects will be avoidance behavior of animals, stress (increasing concentration of cortisol in blood) with digestive processes disorders and fertility reduction – this assumptions are based on the results of testing under laboratory conditions.

Effects of electromagnetic fields on wildlife. The sources of electromagnetic fields (EMF) at the territory of an airport are diverse and numerous. The most prominent and known to be the noticeable emitters are radiolocation and navigation equipment (screens and antennas), control towers, battery and transformation stations as well as other electric equipment. The measurements conducted by the research group in a range of Ukrainian airports (Kyiv Sikorsky, Kyiv Boryspil, Odesa) show that the levels of EMF, created by the above mentioned sources in Ukrainian airports stay within the hygienic standards (they normally fall within the range 1.2-1.6 V/m) or the processes of radiation

attenuation reduce the increased levels (the highest values under antennas are from 32 to 60 V/m) to the acceptable.

However, the sensitivity of wildlife to EMF is higher than that of humans. Thus, the study shows that density of nesting, number of youth and overall density of population in birds decrease by 50-80 % at the areas exposed to electromagnetic field strength of 3-3.5 V/m [2]. Laboratory mammals (rats, mice and rabbits) demonstrate behavior disruption (active avoidance, panic reaction, disorientation and a greater degree of anxiety) even under the influence of a power density as low as 0.1-0.4 mW/cm² at 1.5 GHz. The reproductive disorders are also common among mammals exposed to high-frequency EMF typical for airports, including miscarriages, progressive drop in the number of pregnancies, embryos defects and spatial memory [2]. The aggregated effects bring populations to dangerously low number and threaten their extinction without the signs of direct mortality increase. Moreover, animals don't have mechanisms of reaction to EMF of artificial origin, as they are a new environmental factor, and stay within the exposure area exacerbating the negative trends in the population. Unfortunately, due to the formal correspondence of the EMF parameters to sanitary standards there is no possibility to introduce any additional protective measures.

Discussion of the obtained results. Among known negative airport impacts on the environment, physical factors are underestimated, except for the noise pollution. The intensity of these factors influence and magnitude of the consequences depend on the exact location of an airport: enterprises located in close proximity to an urban area produce lower individual effects, because such territories have already been damaged by settlements activity. And in this case the exact effects of airports are not separated from those by urban areas. Another important issue is the absence of any threshold values appropriate for making conclusions about the real magnitude of negative impacts. The given research relies on the data obtained under controlled environment conditions, which makes the possible range of deviation under natural conditions quite wide.

Conclusions

1. Airports' activity gives rise to a wide variety of environmental externalities, for which only humans are usually considered as an injured party, but wildlife at the areas adjoined to airport facilities is also seriously affected.

2. The analysis of airport facilities structure showed that there are two groups of physical disruptors: physical bodies (airfields and ground infrastructure) and physical process, like vibration, propagation of light and electromagnetic fields.

3. The airfield as an open space may play both attracting and repelling role for wildlife, leading to increased mortality or relocation of animals. The same set of problems is created by ground access roads and parking areas. The most prominent impact of all the structural objects of airports and highways is instant and gradual destruction of habitats due to, correspondingly, construction of facilities and fragmentation of natural ecosystems.

4. Light pollution from airports is very intensive and can provoke a range of negative effects on mobility, nutrition, reproduction, physiological processes and biorhythms for all groups of wildlife. The measurements at the airport area (Kyiv Boryspil airport and Kyiv Sikorsky airport) at night

time show the values over 1000 Lux, which are few powers over the natural illumination.

5. Vibration is measured to be quite insignificant outside the airports territories, but animals are known to be more sensitive to vibration and research results from lab experiments demonstrate a range of behavioral disorders among lab animal subjected to constant effects of vibration.

6. EMF at the airports turned to be low enough to meet the requirements of sanitary standards. However, as in the case with other physical factors, animals are more sensitive to the low-level EMF, which accompany the activity of airports and numerous research works prove animal health risks from exposure to EMF.

7. Predicted negative consequences from airport activity for living organisms are defined based on the results of lab experiments and must be supported by field data, which are currently unavailable and will be the next stage of research.

8. Methods and equipment used to prevent animal contact with sources of hazard at airports and access roads are often the reason of additional negative action and pressure and need to be improved. However, light pollution and fragmentation – the most significant consequences of airport physical factors impacts – can be efficiently mitigated without causing harm to animals. Simultaneously, there is need to reconsider the need and parameters of buffer zones around the airport territory in order to prevent both violation of technological processes safety and reduce negative impacts of physical factors on animals. However, this task still lacks reasonable solutions due to habitats fragmentation issues.

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АНАЛІЗ ФІЗИЧНИХ ЧИННИКІВ ВПЛИВУ АЕРОПОРТІВ НА ФАУНУ

Досліджено вплив аеропортів на тварин, ареали яких перетинаються зі спорудами та інфраструктурою аеропорту. Здійснено диференціальний аналіз фізичних чинників у зоні впливу аеропорту та оцінено негативні тенденції для тварин, що потрапляють під цей вплив. Проаналізувавши наявні дослідження з оцінювання впливу аеропортів на довкілля, встановлено, що питанням впливу цих об'єктів на диких тварин приділено мало уваги, а більше зосереджено насамперед на забезпеченні польотів, тобто засобах відлякування тварин, які також стають джерелами негативних впливів на живі організми. Під час виконання дослідження фізичні чинники поділено на дві групи – фізичні об'єкти та фізичні поля. Для оцінювання інтенсивності відповідних типів забруднення використано спеціальне обладнання у поєднанні з якісним аналізом. Показано, що будівлі та споруди аеропорту, а також під'їзна інфраструктура створюють яскраво виражені бар'єрний та крайовий ефекти, а також передбачають структурні перетворення рельєфу та фітоценозів ще на етапі будівництва і надалі під час експлуатації аеропорту інтенсивність впливів підвищується через нарощування обсягів перевезень та розбудову відповідної інфраструктури. Отже, продемонстровано, що аеропорти виступають істотними причинами знищення ареалів тварин. Основними неврахованими формами фізичних полів, що здійснюють вплив на диких тварин з території аеропорту, є світлове та електромагнітне забруднення, а також вібрації. Встановлено, що рівень кожного з досліджених типів забруднення є різним за інтенсивністю, але, як свідчать спеціалізовані дослідження, чутливість лабораторних тварин до цих факторів досить висока і може призводити до низки негативних наслідків. Зазначено, що додатковий негативний вплив на диких тварин можуть мати деякі природоохоронні засоби, зокрема шумові бар'єри, які посилюють фрагментацію ареалів. Виявлено, що найнебезпечнішого рівня досягає світлове забруднення. Відзначено нагальну потребу дослідити взаємодію між аеропортом та дикою природою, щоб зменшити інтенсивність негативних наслідків. Сформульовано перелік потенційних шкідливих наслідків для дикої природи, але наголошено на необхідності перевіряти ці прогнози шляхом польових досліджень у зонах впливу аеропортів.

Ключові слова: фрагментація ареалів; світлове забруднення; поведінка тварин; електромагнітні поля; вібрація.