New goals for fundamental science

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On the occasion of the Year of Ecology 2017 in Russia.
Authors' translation of "Makarieva A.M., Gorshkov V.G., Startsev A.A. (2017) New goals for fundamental science. Energy: Economics, Technology, Ecology, 11(2017), 2-13. [in Russian]"

Introduction

Since its origins science has been on the forefront of man's struggle against a hostile environment. In the long run, with the discovery of electricity, internal combustion engine and inorganic fertilizers our living standards have drastically improved. Today the majority of people in the developed countries have never starved or worked to physiological exhaustion. In this aspect modern people have for the first time in the history of modern civilization caught up with the aboriginal inhabitants of the natural environment where our species originated. Indeed, humans residing at an ecologically sustainable density in a highly productive tropical ecosystem with an optimal climate did not overwork to gain food; in consequence, they had never had a stimulus to develop science and technology.

Thus, science and technology have ultimately solved this monumental task - to provide human beings, forced to live outside their native environment, with food, clothes and shelter without overworking. Where this task has been solved, the scientific and technological progress expectedly ceased to further improve human conditions. (The very idea of "improving living standards" implies their suboptimal status.) As for the fundamental science, it moved on beyond the scales of time, space and energy that are pertinent to human existence. Intense studies in the field of high energy physics relate to energy scales far exceeding those of nuclear physics, while astrophysics is penetrating the Universe's depths from which we are separated by millions of light-years. As time goes, people are beginning to perceive the rapidly diminishing returns of the investments in science and technology [1]. The authority of science in general and scientists in particular declines.
[1] Mokyr J. (2013) Is technological progress a thing of the past? VOX (CEPR's policy portal).

This situation is dangerous, since never before in its history has the humanity been dependent on science more than it is now. Our exponentially growing civilization is unstable. The apparent security of the modern life styles is ephemeral. Human population has grown up to near ten billion - this number is several orders of magnitude higher than the ecologically sustainable population numbers of other animals of comparable size. Moreover, modern humans consume per capita about fifty times more energy per unit time than they would in their natural ecosystem. Anthropogenic impact went beyond the biosphere's sustainability threshold: soils, water and temperature regimes are rapidly degrading world over.

A new challenge for science has emerged. How to preserve the achieved level of progress? How to avoid an ecological collapse and the associated global social chaos and a worldwide decline of living standards?

To solve that task novel approaches seem necessary that would replace the historical confrontation between science and biosphere. Such approaches are apparently taking their time to show up. In the meantime environmental problems continue to be addressed along the conventional scheme -

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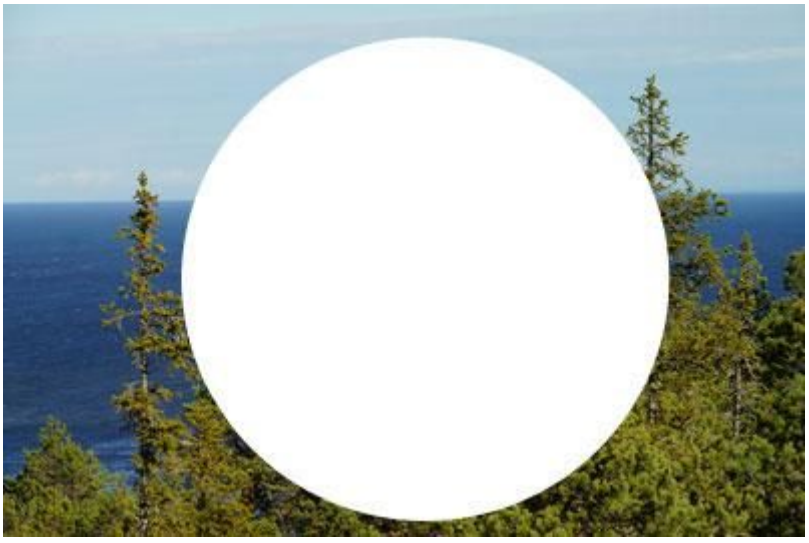
struggle with industrial pollution. "Struggle with pollution" capitalizes all the conceptual depth of human interactions with the global environment.

A major white spot in modern science relates to the question of how nature works when undisturbed by humans: how natural ecosystems - forests, bogs, oceans - sustain themselves. How did it so happen that life in these ecosystems never discontinued and their environment remained suitable for life for hundred millions of years? It is namely this stability and persistence that make natural ecosystems distinct from all, without exception, anthropogenic biosystems including our global civilization.



Historically, in those countries who championed the scientific and technological progress - and who nowadays continue to determine the global scientific agenda - the imperative of an anthropogenic transformation of nature has been most influential. In consequence, wild nature in these countries had been transformed into non-existence. In some poorer countries, on the other hand, where natural forests still exist, there is neither a solid scientific base nor a strong stimulus to study natural ecosystems. Here high population numbers and the associated low living standards dictate a rapid process of selling out the remaining natural resources; natural forests are being exterminated. The situation in Russia and Brazil is, in some aspects, more favorable: besides an independent scientific base these countries still preserve ecosystems with only minor degree of disturbance over much of their territory [2].

[2] Kobyakov, K.N., Shmatkov, N.M., Shvarts, E.A., Karpachevsky, M.L. (2015) Loss of Intact Forest Landscapes in Russia and Effective Forest Management in Secondary Forests as Its Alternative for Biodiversity Conservation and Sustainable Rural Development. XIV World Forestry Congress, Durban, South Africa, 7-11 September 2015.

The interdisciplinary concept of *biotic regulation* was formulated in Russia; some of its aspects are currently developed by an international team of scientists. It offers a quantitative proof for the statement that the environment remains suitable for life owing to the impact of life itself. The stabilizing environmental impact of natural ecosystems is proportional to the area they occupy. It follows that natural ecosystems protected from human exploitation should be allowed to operate on sufficiently large global areas - such that their cumulative impact is sufficient to keep the global environment and climate in a stable state. When the stability threshold of natural ecosystems is overcome by human interference, the environment will degrade to an unsuitable for life state irrespective of whether we humans continue to directly pollute it (e.g. by emitting carbon) or not.

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Modern humanity owes to science not only all of its achievements; science is equally responsible for the ever growing fragility of our world. Our civilization will stand a chance of escaping the approaching ecological collapse if and only if the fundamental science does allocate some of its huge internal resources to focus on the problems of stability (not growth!) - of the biosphere, human society and global environment. One specific task in this endeavor would be to study the ecological peculiarities of *Homo sapiens* as a big animal species, one of the many in the biosphere. In this article we will briefly discuss two from the longer list of the most important stability problems: the water cycle and human mental health in an overpopulated world. In the concluding section we consider the fundamental ecological problem of big animals as destabilizers of terrestrial ecosystems.

Where does water come from?

In 2015 the authorities of the Kingdom of Saudi Arabia declared that the next year would become the year of the last wheat yield [3]. This statement was conditioned by the depletion of the underground water reserves in this desert country where the population numbers have tripled over the last forty years. A recent grain exporter, the country all of a sudden found itself without water. The available estimates [4] indicate that a similar catastrophe threatens many key agricultural regions of the world, including California, India and China.
[3] Halverson N. (2015) What California can learn from Saudi Arabia's water mystery.
[4] Famiglietti, J.S. (2014) The global groundwater crisis. Nature Climate Change 4: 945-948.

While population numbers in those regions where science was developing remained low, there was enough water. Thus, no incentives existed to study where this water comes from. In consequence, modern science cannot boast significant advances in understanding how the water cycle works, let alone how it can be stabilized. The problem is as follows.

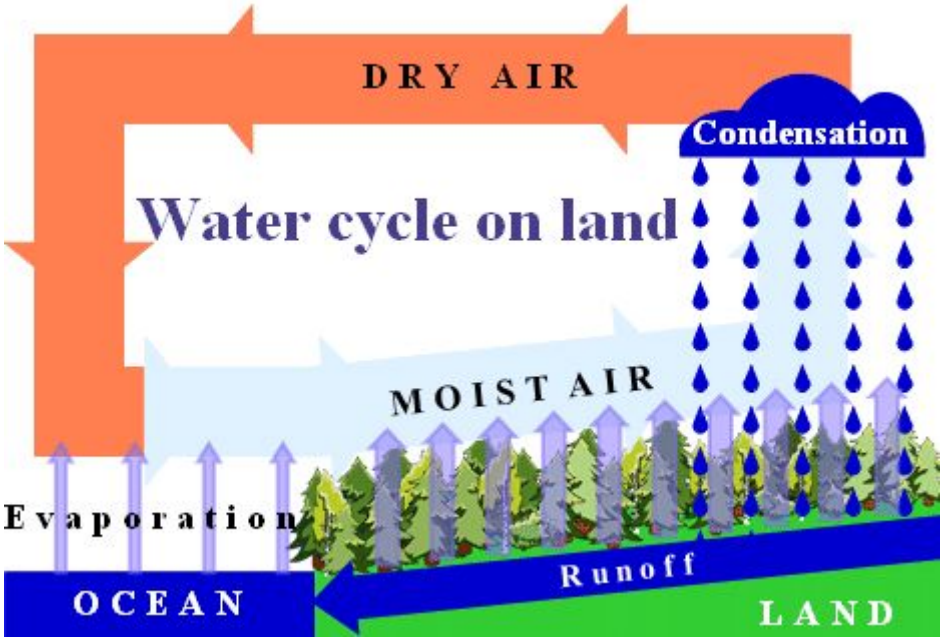

Fig. 1. Stationary water cycle on land.

As the continents are elevated over the ocean, liquid water on land does not stay: under gravity, it runs off to the ocean (Fig. 1). There is very little fresh water on land: if its store is not continually replenished, rivers would run dry in just a few years. The compensatory flow of water from ocean to land occurs via the atmosphere. Water evaporates from the ocean; then winds bring it to land in

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the form of water vapor. Here moist air must rise to produce rain. It is when the air rises that it cools, the water vapor condenses and precipitates feeding rivers and watering life on land. Thus, whether land gets its water is contingent on two processes: whether winds blow inland from the ocean bringing in water vapor and, second, whether moist air ascends over land.

It so happens that namely these two questions in modern meteorology are rendered with least certainty. Modern models of wind circulation are built by fitting key parameters (most importantly, parameters of turbulence) to observations [5,6]. These models do not have predictive skills beyond a few days — which is, by the way, the time scale of water vapor turnover in the atmosphere.
[5] Voudouri A. et al. (2017) Objective calibration of numerical weather prediction models. Atmospheric Research 190, 128-140.
[6] Makarieva A.M. et al. (2017) Kinetic energy generation in heat engines and heat pumps: the relationship between surface pressure, temperature and circulation cell size. Tellus A, 69, 1272752, doi: 10.1080/16000870.2016.1272752.

Independent measurements of river runoff offer an opportunity of checking whether the atmospheric models correctly capture the inland moisture transport. Indeed, according to mass conservation, the amount of water vapor brought to land by winds must be equal to the reverse flow of water via runoff to the ocean. Atmospheric models do not pass this test. For example, for the Amazon river basin the modelled import of moisture turns out to be twice less than the observed runoff. Discrepancies of similar magnitude pertain to all regions of the world and cannot be fixed even by fitting [7].
[7] Hagemann S. et al. (2011) Impact of a statistical bias correction on the projected hydrological changes obtained from three GCMs and two hydrology models. J. Hydrometeor. 12, 556-578.

Not only the terrestrial water cycle but all atmospheric phenomena involving phase transitions of water present similar problems: monsoons, tropical cyclones, the global atmospheric circulation. Meteorological science recognizes the water challenge. However, the methods proposed to address this challenge tend to adhere to the "more of the same" principle. More computer power and more observations, including satellites, are expected to significantly improve the models' predictive skills. But despite the ever growing computer power and observation networks no breakthroughs have happened.

Take hurricanes, for example. Modern hurricane models are based on the premise that hurricanes extract heat from the ocean. By this logic, the warmer the ocean, the more hurricanes. In 2013 based on the observations of an anomalously high surface temperature of the Atlantic ocean all world's leading weather centers forecasted an (hyper)active hurrican season. In reality, in 2013 hurricanes practically did not happen. This "bust" received considerable coverage in American media which unlike their Russian counterparts should generally be credited for ther interest in environmental science.

Global atmospheric circulation presents another example of a mismatch between the long-term weakening predicted by models and the observed wind strengthening in major circulation cells [e.g., 8]. About the difficulties in predicting monsoons see, e.g., [8a].
[8] Kociuba G., Power S. B. (2015) Inability of CMIP5 models to simulate recent strengthening of the Walker circulation: implications for projections, J. Climate 28, 20-35.
[8a] Acharya N., Kar S.C., Mohanty U., Kulkarni M.A., Dash S (2011) Performance of GCMs for seasonal prediction over India—a case study for 2009 monsoon. Theoretical and Applied Climatology 105, 505-520.

Recently a proposition was put forward that to solve the water challenge the number of atmospheric researchers should grow as well. A mainstream journal *Nature Geoscience* appealed to young mathematicians and physicists urging them to choose a career in atmospheric sciences instead of astronomy or cosmology. Young researchers were invited, for the planet's sake, to build yet more complex and detailed climate models [9].
[9] Scheirmeier Q. (2015) Climatologists to physicists: your planet needs you. Nature 520, 140-141.

While such an appeal could possibly boost the currently insufficient interest of young scientists in meteorology, comparison to physics suggests that the problem here could be deeper. The astonishing progress physics made in the last two centuries reflects a unique collaboration between experimentalists and theorists, the latter's role being to think experiments over. Theorists must synthesize all the available experimental data into a comprehensive and self-consistent quantitative description of the studied phenomenon. This should be done in such a manner that the emerging new knowledge be consistent with the fundamental laws of nature and with all the available observations including those from other fields of science. This type of mental activity — drawing a coherent picture of the world — requires special skills and special criteria of success. The culture of theoretical research reached its peak in modern theoretical physics, especially high energy physics and astrophysics. Spreading this culture across other fields of science is necessary if the interdisciplinary problem of preserving our civilization is to be solved.

In modern atmospheric science theorists as an organized community do not exist: the division of labor is largely between people doing observations and modellers. In the absence of a vibrant community of theorists the physical ideas about atmospheric circulation laid out as early as when physics as a science was an indivisible whole, are rarely scrutinized in the light of new data; they may ultimately become a dogma. In the modern paradigm the single physical idea underlying descriptions of atmospheric circulation is, as proposed by Halley a few centuries ago, the Archimedes buoyancy. The warm air rises, the cold air descends. In essence, all existing models exploit this idea. In every atmospheric problem a temperature gradient is found, then all the necessary parameters are tuned such that the temperature-associated pressure gradients generate the observed winds.

Meanwhile, besides differential heating, there is a distinct physical process generating atmospheric pressure gradients. There is also a distinct theoretical approach quantifying the significance of this process for atmospheric circulation. The process is condensation of water vapor in the rising air [10]. Water vapor presence in the atmosphere induces the ascending air motion. Water vapor removal from the gas phase creates a local pressure shortage and generates pressure gradients making winds blow towards the condensation area. Hurricanes and tornadoes intensify not by extracting heat from the ocean but via condensation of water vapor previously accumulated in the atmosphere through which they must move to gather their fuel [11,12].
[10] Makarieva, A. M., Gorshkov, V. G., Sheil, D., Nobre, A. D., and Li, B.-L. (2013) Where do winds come from? A new theory on how water vapor condensation influences atmospheric pressure and dynamics. Atmos. Chem. Phys. 13, 1039-1056.
[11] Makarieva A.M., Gorshkov V.G., Nefiodov A.V. (2011) Condensational theory of stationary tornadoes. Physics Letters A 375, 2259-2261.
[12] Makarieva A.M., Gorshkov V.G., Nefiodov A.V., Chikunov A.V., Sheil D., Nobre A.D., Li B.-L. (2017) Fuel for cyclones: How the water vapor budget of a hurricane depends on its movement. Atmospheric Research 122, 7300-7307.

Plants, especially trees in natural forests, are the main source of water vapor on land [13]. Trees accumulate and store moisture in soil and then emit water vapor into the atmosphere in the process

of photosynthesis. Thus, by regulating the atmospheric vapor, natural forests control the inland moisture transport on a continental scale. Forests act as a biotic pump of atmospheric moisture [13].
[13] Makarieva A.M., Gorshkov V.G., Li B.-L. (2013) Revisiting forest impact on atmospheric water vapor transport and precipitation. Theoretical and Applied Climatology 111, 79-96.

Thousands of years ago modern deserts, including the Arabian desert, used to be covered by lush vegetation. It was during these periods of biotic pump functioning that the vast underground reservoirs had been slowly filled with water. Then the vegetation cover degraded for some reason, possibly under the impact of humans or some other big herbivores. The biotic pump of atmospheric moisture stalled [14,14a].
[14] Gorshkov V.G., Makarieva A.M. (2007) Biotic pump of atmospheric moisture as driver of the hydrological cycle on land. Hydrology and Earth System Sciences 11, 1013-1033.
[14a] Wright D.K. (2017) Humans as Agents in the Termination of the African Humid Period. Frontiers in Earth Science doi: 10.3389/feart.2017.00004, see also Did humans create the Sahara desert?

In recent decades, while the Kingdom of Saudi Arabia attempted to secure food independence, those ancient groundwater stores have been used up for irrigation. To restore the water cycle in the KSA requires relaunching the biotic via recovery of natural vegetation.

In Russia, too, the abundance of fresh water is not guaranteed by the geographic position of our country. The great Russian rivers exist as long as the great Russian forests remain viable and self-sustainable. Their viability (and, hence, the Russian biotic pump) are under threat: forests in Russia are burnt and over exploited. To restore and sustain the regulatory climatic functions of natural forests is a most urgent and important task [15], an intellectual challenge incomparable in scale with the fashionable "title" projects of modern science like colonization of Mars.
[15] Korotkov V.N. (2017) Basic concepts and methods of restoration of natural forests in Eastern Europe. Russian Journal of Ecosystem Ecology, 2, doi:10.21685/2500-0578-2017-1-1.

The atmospheric science, let alone the science of ecosystems, has been long considered as being of secondary importance compared to those fields of science that historically attracted most of the humanity's brilliant minds, the outcome being the enormous scientific and technological progress of the last century and a half. However, at present when the stability of the water cycle and climate in general has been undermined, the humanity has become critically dependent on the quality of climate and ecosystem sciences and on the efficiency of their interaction.

Psychological health and overcrowding

Ecological rights that have been lost

Technological progress spared humans from rapid physiological ageing and sufferings associated with hard physical labor. This achievement came at a cost though — some essential ecological rights humans enjoyed in their natural environment have been lost in the civilized world. One of them is personal freedom. In the natural environment every adult individual was able to provide food for himself/herself. Thus, every adult human depended only on himself and on his close social group where all members were well acquainted with each other. In the modern world most people depend on each other in a complex manner. No individual, no matter how strong, clever and capable he or she is, would be able to sustain his or her living standards if the other members of our multibillion civilization ceased to work.

At the same time the natural fertile environment has been almost ubiquitously destroyed: fish and game stocks have been globally depleted, soils degraded, fresh water flows overused or poisoned. To make for one's living in the "natural" manner — i.e., independent of millions of strangers — has become impossible. What is even more important, human population numbers have grown so high that any large-scale transition to more "natural" ways of getting food, e.g. by abandoning chemical fertilizers, would only facilitate degradation of the remaining natural ecosystems. (Because a larger per capita area will be required.) Such a transition will make global ecological collapse closer. Thus at current population numbers there is no way back to personal freedom. If the population numbers are reduced, there is possibly a way forward [16].
[16] Makarieva A., Gorshkov V., Wilderer P.A. (2016) What Can We Learn from Natural Ecosystems to Avoid a Civilization Breakdown? Section 3.3 in Wilderer P.A., Grambow M. (eds.) Global Stability through Decentralization? In Search for the Right Balance between Central and Decentral Solutions. Series Strategies for Sustainability, Springer International Publishing Switzerland, doi: 10.1007/978-3-319-24358-0_3

As industrial processes sustaining human life became increasingly specialized, urbanization followed — a life style whereby many people of different professions live on the same relatively small territory without knowing each other. Population densities spiked while per capita living area declined by several orders of magnitude compared to the natural environment. Numerous studies demonstrated that overcrowding and overpopulation results in diverse behavioral aberrations in different species of mammals, including aggression and lack of parental care [17] and in all species produces stress and anxiety. To minimize the negative effects of this permanent stress the urbanized societies had to elaborate special ethical rules that would at least partially protect psychological health of people subjected to overcrowding.
[17] Calhoun J.B. (1962) Population density and social pathology. Scientific American 206, 139-148.

Behavioral norms under overpopulation

The individual territory of humans has shrunk from several square kilometers in nature to a hundred square meters in modern civilization. Rudiments of the ecological human right to individual territory have been codified in the notion of the *inviolability of the home*. Such a law is present in one form or another in the juridical norms of all countries. It means that no intrusion of strangers into the closed private space of an individual is to be tolerated. Here "intrusion" implies the stranger abusing visual and/ or tactile sensations of the home owner. Possible abuse of the other three out of five sense organs — hearing, smell, taste — does not normally fall under this law. However, a satisfactory law system guaranteeing psychological stability of an urbanized society cannot be formulated without a detailed investigation of the ecological peculiarities of the *Homo sapiens* species.

In January 2016 in Moscow a terrible accident happened. After repeated calls to the police to take measures against the noise, a man who could not sleep shot a young woman who was advertising something using a megaphone under his window. This tragedy came as a reminiscence of Anton Chekhov's story "Let me sleep": a teenager girl servant, exhausted by her unbearable, all day long duties, strangled the ever crying baby she had to take care about at night and, finally, fell asleep... In both cases the tragic outcome resulted from violation of a basic ecological human right: the inviolability of the private spacetime was disrupted by acoustic signals.

Modern juridical norms regulating environmental noise are based on assessing sound intensity as measured e.g. in decibels. That sounds of equal intensity may have a distinct information content and thus a distinct physiological impact is largely ignored [18, but see the *Noise and Health* journal].

[18] Gorshkov V.G., Makarieva A.M. (2001) Pollution of the environment by audible information. Ecology and Education, No. 3-4 (2001), 10-16. [in Russian]

Some artificial monotonous sounds may resemble what one can hear in nature — to the sounds of wind, sea and falling water the human organism is genetically adapted. Such sounds may cause only minor discomfort even at high volume. Much more stressful for the human nervous system are the sounds of our civilization that have a pattern and carry some information. Examples are music, human voice and dog barking. Human genetic program is not adapted to ignore such sounds. In a natural environment it is the territory owner who decides whether such sounds are allowed or not. If the home owner cannot control such sounds heard within his territory, they, unlike the sounds of wind or sea, inform the territory owner that his home has been intruded. This information causes stress, which further motivates either depression and escape or aggression and territory defense.

Importantly, people are keen to decipher sounds signalling about a potential intrusion — *irrespective of how low such sounds can be*, we automatically listen for them with attention and eager. The negative impact of the audible information pollution is determined not by decibels but by the audibility threshold, which depends on the distance from the source of noise. If the source of audible pollution is located outside one's home but the noise can nevertheless be heard inside, such noise should fall under and be prohibited by the *inviolability of the home* law. It is necessary to study the various sounds of our civilization, their timbre and rhythm, for their compatibility with the genetic program of *Homo sapiens* and restrict the disturbing sounds accordingly, up to their formal prohibition by law.

Leaf blowers

In recent years Russian cities met with a new source of noise: motorized leaf blowers. These devices use internal combustion engines without efficient noise suppressors. The information noise they produce is impossible to adapt or get used to, because sound intensity and frequency vary all the time: the blowers produce both "loud droning and deafening sound". In Russian cities such blower machines are increasingly used to clean residential areas from garbage (like small pieces of paper etc.) as well as to handle snow and even small water pools. They disturb peace around people's homes for several hours a day.

Fig. 2. The use of blower machines should be prohibited as undermining citizens' health.

Besides the noise, the blowers churn up a lot of dust suspending in the air dangerous biological and technological particles, including animal feces and solid chemicals originating from traffic fumes. The smallest of these particles penetrate freely through biological membranes of our bodies and reach lungs causing allergies and oncological diseases. Creatures who breathe closest to the ground are the first to suffer: children and ground-feeding birds like house sparrows. Our observations in St. Petersburg, Russia suggest that local sparrow populations disappear from areas with intense use of leaf blowers. Thus the presence/absence of sparrows could serve as an indicator of lethal air pollution near the ground. Before the blower machines become ubiquitous and do away with peace, quieteness and clean air around our homes, their use should be prohibited.

Dog barking

Unlike domestic animals in rural regions, pets in cities are not an economic asset. Pets serve as a substitute of another ecological right lost by humans — the right to communication (visual, audible, tactile contact) with other biological species from the natural ecosystem. Those who observed mammals, birds and other animals in their natural environment may recall a distinct emotion (which the "Avatar" creators attempted to convey) of being part of the process of Life where all beings are interrelated. Children with their hypersensitivity miss this communication most strongly; a pet can literally make a kid happy. The majority of zoo visitors are kids and their parents. Like swings and carousels are technological substitutes for the missing trees and lianas where children used to play

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in our species' natural environment, zoos serve to partially meet the genetically encoded demand for communication with other species (the right for biodiversity).

Thus, animal pets (cats, dogs, guinea pigs, canaries, aquarium fish, etc.) have a positive effect on the psyche of people in cities. With one exception: dogs that bark loudly are sources of intense stress for everyone except possibly their owners. For millennia people have used barking dogs to defend individual territories. Thus if one hears a dog barking, and it is not one's own dog, this is a signal that one's territory has been invaded. Conversely, the owner of a loudly barking dog unconsciously appropriates the territory where this barking can be heard. Noise from the blower machines produces a similar effect: it disturbs inhabitants of the residential area but increases the social significance of the cleaning workers (because it is they who control sounds on the territory they occupy). One person can thus terrorize a large number of people who are unable escape the noise in their own yard or home.

Implications

In societies with a long history of urbanization the rules protecting psychological health under overpopulation gradually established as an essential part of the behavioral norms. Peace and silence are commonly valued and protected by law. Loud and prolonged sounds of car sirenes have been prohibited and cars equipped with noise suppressors. Car alarm systems became silent; there are no more aggressive sounds irritating all people around — the alarm signal is delivered individually to the smartphone of the car owner. It became a common habit to use earphones to listen to music — indeed, music is the most aggressive form of audible pollution as it imposes a particular emotional state on the listener. Instead of motorized lawn mowers it is possible to use skythe or not to mow lawns at all. Many songbirds, for example the nightingale, make their nests on the ground in shrub and grass thickets. If these habitats are protected from cats and dogs, the birds will be able to settle in cities and please the city dwellers (who otherwise do not have many opportunities to communicate with nature) with their songs — the natural sounds of spring. Studies show that their happiest moments people experience while in green natural environments [19].

[19] MacKerron G., Mourato S. (2013) Happiness is greater in natural environments. Global Environmental Change, 23, 992-1000.

In those countries where urbanization is more recent and still on-going, there has not been sufficient time for the behavioral norms protecting psychological health to get firmly established. The level of stress in the society is elevated. Especially when the economic situation worsens, this additional stress raises social tension threatening state stability. Aggressive reactions to prolonged stress are in most people suppressed by fear of criminal punishment. But this aggression can magnify social chaos bursting out in social unrests that may originate for a different reason.

Comprehensive studies of the ecological peculiarities of our species and targeted adoption of behavioral norms maximally accounting for ecological human rights can reduce stress in the society and strengthen social stability at minimal financial cost.

Conclusions

For reasons deserving a separate discussion some humans had to abandon their natural ecosystem — the one where *Homo sapiens* originated. Our ancestors settled on territories with a cold climate and low biological productivity to which the human organism is not adapted. Permanent dissatisfaction with these conditions and the desire to transform them to resemble the genetically

programmed optimal standard of living determined the vector of scientific and technological progress for the millennia to come.

Historically, humans surrounded themselves by a few useful biological species, plants and large animals, and thus got used to view the rest of the biosphere through the prism of their knowledge about these unnaturally functioning organisms — picked out, as man himself, from their natural ecological niches. Accordingly, the dominant view on life became anthropocentric: it was conceived that all organisms as humans themselves continuously adapt to the unpredictably changing environment. It doesn't therefore come as a surprise that modern civilization is unstable and balances on the verge of ecological collapse consuming resources that formed in human absence — fertile soils, fresh water, wood and fossil fuels. Moreover, our civilization has not accumulated knowledge of how life — which is, in contrast to the civilization, stable — is organized. In any field of science, be that economics without growth, climate stability or the morphological stasis in evolution — an interest in stability guarantees the scientist becoming marginalized and expelled from the mainstream, with all the associated consequences for his or her career. Modern discourse is rigidly focused on *growth* (*progress*, *development*, global *change* and so on).

However, since growth associated with the technological progress has come to an end, the ideas of stability tend to spontaneously pop up in the agenda more and more often. We will conclude this article by a brief discussion of some principles of life stability and the distinct role of large animals, including humans.

The regulatory part of the biota

A distinct property of life is its fantastic complexity as compared to any processes in the inanimate world. This complexity can be understood as encoding for life's ability to regulate the environment preventing it from degrading to states unfit for life. As environmental regulation is an ultra complex task, its fulfillment necessitates life be complex too[20].
[20] Makarieva A.M., Gorshkov V.G. (2016) Stability of the information of life. Part I. Preventing the decay of the genetic information of life. Part II. Evolution and progress. Energy: Economics, Technology, Ecology, 3(2016), 47-54; 4(2016), 42-49. [in Russian]

Biotic control implies that organisms directionally change ambient concentrations of various substances. For the entire global environment to be under control, there must be a continuous coverage of the Earth's surface by living cells. This is how the biosphere is indeed organized: there are on average several living cells per each square micron of the Earth's surface. (In other words, an imaginary line drawn from the Earth's center to the stratosphere will on average intersect several living cells -- in the ocean, in soil, under forest canopy and even in the atmosphere.)

Regulation of the environment by the biota occurs at the expense of solar radiation -- an energy source represented by particles with zero mass (photons). The flux of solar energy (it is of the order of 100 W/m^2) cannot be changed by life. Its magnitude constrains the number of living cells per unit area of the Earth's surface. As far as all living matter functions at approximately the same optimal power of the order of 1 W/kg [21] and the efficiency of solar energy use by life is of the order of 1%, there cannot be more than one kilogram of living cells per square meter of the Earth's surface. If we collected all living cells and spread them evenly over the Earth's surface, the resulting continuous layer of living matter would be 1 mm thick. With density of living cells approximately equal to density of liquid water, 1 kg/m^3, this is indeed equivalent to 1 kg/m^2. This living layer regulating the environment consists of the smallest organisms: phyto-, bacterio- and zooplankton in

the ocean and bacteria, fungi and green leaves on land.
[21]Makarieva A.M., Gorshkov V.G., Li B.-L., Chown S.L., Reich P.B., Gavrilov V.M. (2008) Mean mass-specific metabolic rates are strikingly similar across life's major domains: Evidence for life's metabolic optimum. Proceedings of the National Academy of Sciences U.S.A., 105, 16994-16999.

Large animals, including humans, cannot regulate the environment. Indeed, thickness of the "layer" formed by bodies of large animals is several orders of magnitude larger than the thickness of the regulatory part of the biota. Therefore large animals consume thousand of times more energy per unit time per unit ground surface area than the biosphere produces. For this reason large animals cannot form a continuous planetary cover to perform environmental regulation. In consequence, all large animals are parasites with respect to the biota capable of controlling life-compatible environment. They exist in the environment prepared for them by other organisms.

Humans have been mostly interested in domesticated animals and plants; there's also some interest in a few --predominantly rare-- wild animals and plants[22]. People have long noticed that all this life that is under the radar of human interest does not regulate the environment. This knowledge has been codified in a common opinion held by variously skilled experts: there is no biotic regulation of the environment. Nature conservation is still predominantly understood as protection of animal species. Forests are protected against fires to save wood for forest industry. Protection of free-living bacteria and fungi that regulate the environment together with forest plants is seldom if ever mentioned.
[22] Gaston K.J. (2011) Common ecology. Bioscience, 61, 354–362.

Large animals as a threat to life stability

Not only are large animals unable to participate in environmental regulation but they, to sustain their own life, have to destroy (eating it away) local biomass of the regulatory part of the biota. Thus they are not just a burden on the rest of the biota, but threaten life stability. In the presence of large animals, biomass of the regulatory part of the biota widely fluctuates and life becomes unstable. How does life solve this problem?

Per unit area occupied by their bodies large animals consume much more food than the biosphere produces and so they cannot exist in a sessile state (motionless) but must move from one place to another eating away local biomass stores[23]. Apparently, the smaller this local store, the more quickly animals must move to provide themselves with food. Since the speed of locomotion is limited by the bioenergetic expenditures, diminishing the biomass of the regulatory part of the biota -- theoretically, down to zero -- the ecosystem can protect itself against the threat associated with large animals.
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In this way the problem of ecological stability is solved in the oceanic ecosystems, which occupy two thirds of the Earth's surface. Here the biomass of the regulatory part of the biota is represented by phytoplankton, bacterioplankton and the smallest multicellular organisms of zooplankton. The biomass of the ocean is virtually zero -- smaller by a factor of thousands -- compared to land biomass. Only the smallest zooplankton can live on phytoplankton and bacterioplankton. Live biomass of large animals -- "cruel killers devouring each other" -- is negligible in the ocean. In less than a century people have almost eradicated the biomass of whales and fish to end up with stringent quotas on their consumption. Thus the ocean solved the problem of life stability and the

oceanic ecosystems protected themselves against the presence of large animals by having reduced the biomass of the regulatory part of the biota practically to zero.

Now there remains the problem of life stability on land. Terrestrial ecosystems cannot solve this problem as the ocean did -- reducing the biomass to such a minimum that large animals cease to be a threat. Life is not possible without water. Water is delivered (pumped) to land via the atmosphere by the undisturbed natural forest consisting of tall trees. And trees have a large biomass. With the negligible oceanic biomass, forest biomass practically accounts for all the biomass of the regulatory biota on the planet. This is mostly the "non-living" biomass of tree trunks and branches. It is maintained in an energetically inactive state (its energy consumption per unit mass is very low), but it is normally protected against destruction by insects, bacteria and fungi. But tree biomass can be destroyed by large animals. The most vivid example is how humans are destroying forests still in neglect of what they mean to human life. But even without humans forest biomass and generally plant biomass on land is unstable. There are no physical factors on land that would prohibit the appearance in the course of evolution of large animals destroying plant biomass. Namely these "peaceful vegetarians" rather than "brutal predators" pose the main threat to the stability of terrestrial ecosystems. In the boreal zone the beasts destroying trees are exemplified by beavers, in the tropical zone these can be elephants, rhinoceros, giraffes and other big herbivores.

Fig. 3. An aspen tree on a river bank cut down by beaver. While beavers are semi-aquatic, the

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evolution could well produce their terrestrial version which would indiscriminately fell all trees in the forest.

The biota of land as a whole could remain stable on a global scale as long as large herbivores-destroyers of trees appeared locally and existed within a limited area. Having destroyed the vegetation cover within their range these destabilizing species would disappear and leave their territory to be colonized by plants and animals incapable of ecosystem destruction. The vegetation would regain stability and remain stable until the new species-destroyers evolved. It is possible that climate instability of the African continent-- the alternating wet and dry periods on the timescale of thousands and millions of years-- has such ecological underpinnings. Same mechanisms might be at work in the epoch of dinosaurs. Generally we believe that the role of megaherbivores in forest ecosystems merits focused research. The elimination of megaherbivores by humans [24] could have had a positive impact on forest stability if humans themselves with their use of fire had not become an even more powerful agent of forest disturbance.
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The pan global human dispersal and invasion of terrestrial ecosystems resulted in deforestation and increased aridity over most land. However, unlike all other animals, humans possess one unique feature, which can make recovery of life stability on land possible. It is our ability to study nature scientifically and to consciously change our behavior in accordance with the accumulating knowledge.

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