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**ПРОБЛЕМА ВЫЖИВАЕМОСТИ КОРАЛЛОВ И ИХ ЗНАЧИМОСТЬ ДЛЯ  
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**Аннотация**

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В данной статье дается оценка значимости кораллов для мировой экосистемы в целом. Выделены основные проблемы выживаемости кораллов, которые требуют незамедлительных решений.

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**Ключевые слова:** кораллы, коралловые рифы, выживание, экосистема, море, океан.

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**THE PROBLEM OF CORALS SURVIVAL AND THEIR IMPORTANCE FOR  
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**ABSTRACT**

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The importance of corals for the global ecosystem as a whole is evaluated in the article. The main problems of corals survival, which require immediate solutions, are highlighted.

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**Keywords:** corals, coral reefs, survival, ecosystem, sea, ocean.

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The human race has always faced the problem of survival. Getting food was, though not the only, but the main condition for survival. With the growth of the human population, the need for food also grew, which, in turn, increased the need for associated resources, such as land, timber, metals, etc. Conflicts flared up between people over the possession of certain resources. Wars became the last argument for the right to own a resource. Devastation and hunger were coming with wars. The most devastating consequences that have been documented occurred in the 20th century after two world wars. During World War II alone, of the 60 million victims of global conflict, at least a third died from malnutrition and related diseases. After the end of the Second World War, the world community was more than ever determined to end once and for all the troubles that have plagued humanity since its inception, primarily with hunger and poverty [1].

To tackle hunger, the Food and Agriculture Organization of the United Nations (FAO) was created in 1945 as a specialized UN agency. FAO's goal was to ensure food security for all and to guarantee regular access to high quality food for the population. Since the first day of FAO's existence, 34 countries have joined its ranks, and today the organization has more than 194 member countries and operates in more than 130 countries around the world. It focused its early years on researching a deeper understanding of the global nutrition situation. Research helped to determine the correct vector of development, which in those years was aimed at grain and livestock farming. Since the 1980s, FAO has been focusing on water resources [2]. Water resources – water in liquid, solid and gaseous state and their distribution on the Earth. They are found in natural water bodies on the surface (in oceans, rivers, lakes and swamps); in the depths (groundwater); in all plants and animals; as well as in artificial reservoirs (reservoirs, canals, etc.). Most of the water resources, namely 97%, are contained in the world ocean [3]. The ocean is an essential component of the Earth's ecosystem, a source of biodiversity, food and life.

In 2014, FAO recognizes the modern fisheries sector as a vital source of food and nutrition, employment, trade, economic well-being and recreational services, and formulates the blue economy concept. This vision places particular emphasis on conservation and sustainable management, based on the premise that healthy ocean ecosystems are more productive and a prerequisite for a sustainable ocean economy. The concept includes aquaculture, capture fisheries, seafood production systems, ecosystem services. Aquaculture promotes responsible and sustainable strategies and best practices for fish, shellfish and algae farming. Capture fisheries support the implementation of the Code of Conduct for Responsible Fisheries (CCRF) and related international legal instruments to restore fish stocks, combat IUU fishing (illegal, unreported and unregulated fishing) and promote good fishing practices and sustainable growth. basis. Seafood production systems help build efficient seafood value chains and improve life support systems. But ecosystem services are still a major part of the blue economy. Ecosystem services foster regulatory regimes and approaches to restore critical coastal habitats, biodiversity, including carbon sequestration, storm and wave protection, tourism, and more [4]. Coral reefs (Fig.1), which are one of the most valuable ecological and economic ecosystems on our planet, play a special role in all this.



Figure 1. The coral reef. [Electronic resource]. <https://puteshestvoovat.com/wp-content/uploads/2019/12/bolshoj-barernyj-rif.jpg>

The coral reef ecosystem covers less than 0.1% of the world's oceans, at the same time, it supports more than 25% of marine biodiversity and life for up to a billion people, providing a wide range of ecosystem services such as coastal protection, fishing, sources of medicines, recreational benefits, and income from tourism [5].

The distribution of coral reefs across regions of the world is uneven (Fig.2).

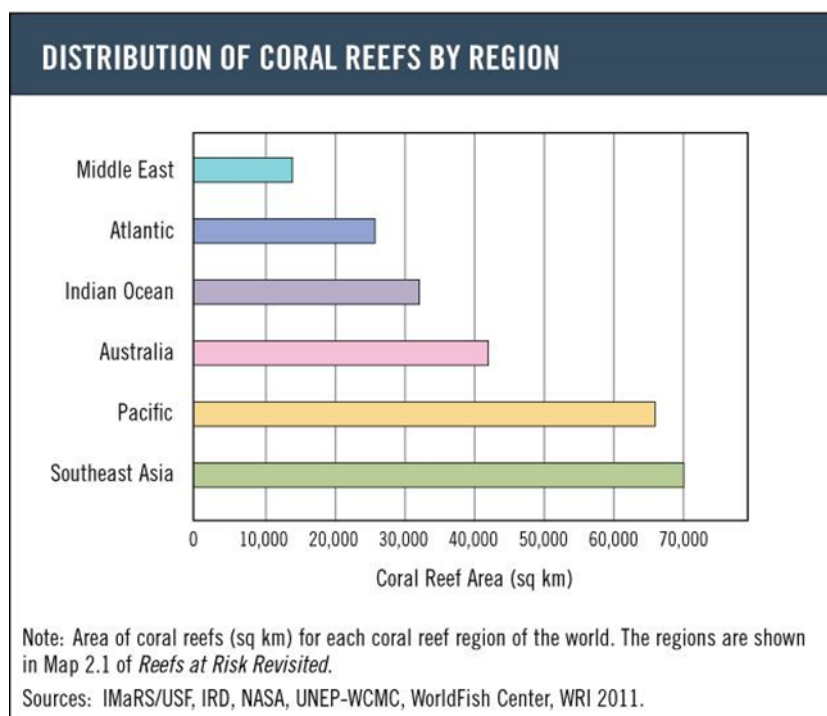


Figure 2. Distribution of coral reefs by region. [Electronic resource]. <https://www.wri.org/data/distribution-coral-reefs-region>

The world's coral reefs cover an area of approximately 250,000 sq km, with the highest concentrations in Southeast Asia and the Pacific. According to the report of the Intergovernmental Panel on Climate Change (IPCC) 250,000 sq km is only 50% of the coral reefs of the planet, which were in the 70-80s of the 20th century. According to the same report, 50% of the reefs have been lost in the past 40 years due to warming seas. That is, reefs are extremely sensitive to changes in the temperature of the habitat. If nothing is done, even with a warming of only 1.5 ° C, up to 90 percent of reef-forming corals could be lost by 2050 [5].

To start helping coral reefs, you need to understand what a coral reef is, namely, what it is made of and how it is formed. Coral polyps form reefs (Fig.3) – these are marine colonial or solitary invertebrates living on the bottom of warm tropical waters. Coral polyps are divided into 2 large subclasses: six-rayed and eight-rayed.

Six-rayed coral polyps (Hexacorallia) are solitary or colonial marine organisms with a multiple of 6 tentacles. Polyps with a different multiplicity of tentacles (5, 8, or 10) are rare. In total, there are 4,300 species of six-rayed coral polyps. The most abundant order of six-rayed coral polyps are madreporous or stony corals (Scleractinia). Currently, 3,600 species have been described. They are characterized by the presence of a calcareous skeleton. It is these corals that are the main reef-formers. Solitary stony corals can grow up to 50 cm in diameter and live at great depths of up to 6 km. But most of the representatives of this order are small (up to 5 mm) polyps. They organize a huge colony consisting of hundreds of thousands of polyps and weighing several tons. Eight-pointed coral polyps (Octocorallia) (Fig. 3) are a subclass of coral polyps that have a corolla of eight tentacles. It is the oldest species, whose fossils have been found in deposits estimated to be 145 million years old. Presumably they all descended from one common ancestor. These are very small polyps – their size usually does not exceed 1 cm. Most of the eight-rayed coral polyps have a hard-calcareous skeleton and are involved in reef formation [6].

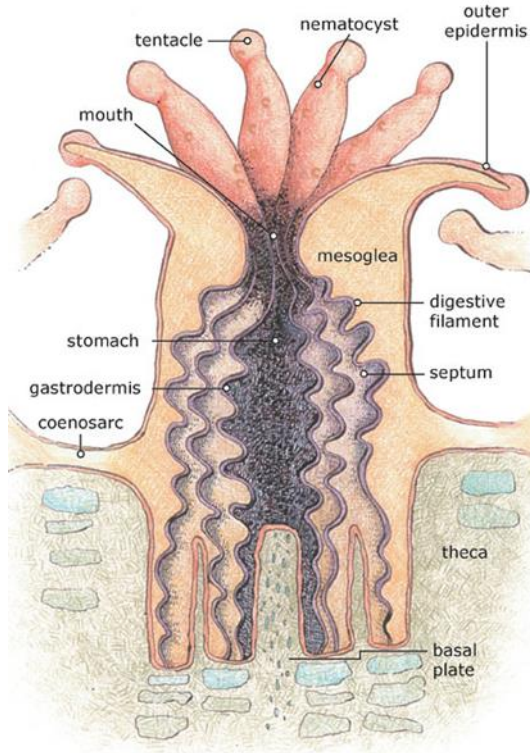


Figure 3. Polyps Up Close. [Electronic resource].  
[https://oceanservice.noaa.gov/education/tutorial\\_corals/media/supp\\_coral01a.html](https://oceanservice.noaa.gov/education/tutorial_corals/media/supp_coral01a.html)

Polyps are anatomically simple organisms, much of the polyp's body is taken up by a stomach filled with digestive filaments. Open at only one end, the polyp takes in food and expels waste through its mouth. A ring of tentacles surrounding the mouth aids in capturing food, expelling waste and clearing away debris. Most food is captured with the help of special stinging cells called nematocysts which are inside the polyp's outer tissues, which is called the epidermis. Calcium carbonate is secreted by reef-building polyps and forms a protective cup called a calyx within which the polyps sit. The base of the calyx upon which the polyp sits is called the basal plate. The walls surrounding the calyx are called the theca. The coenosarc is a thin band of living tissue that connects individual polyps to one another and helps make it a colonial organism [7].

Coral polyps have one thing that makes them so colorful and why many coral polyps actually live – it's symbiosis with dinoflagellate algae. The degree of coral dependence on such symbiosis varies greatly: for example, the sea anemone *Anemonia* may well live without zooxanthellae (unicellular photosynthetic symbionts, in this case a coral symbiont), and some corals cannot do without dinoflagellate symbionts. At least 5 species of dinoflagellates (4 of which belong to the genus *Symbiodinium*) are known to act as zooxanthellae. When zooxanthellae and reef-building corals interact, both organisms benefit. Zooxanthellae give their host up to 50% of fixed carbon, most of which comes in the form of glycerol, less in the form of glucose, alanine, and organic acids. Coral also supplies the alga with some organic compounds (urea, glycerol-3-phosphate, amino acids). In the coral reef ecosystem, phototrophic dinoflagellates are the most important primary producers, organisms that are capable of producing organic matter from inorganic ones. Corals with zooxanthellae have been shown to calcify faster. (Calcification (calcification) is a process of improper redistribution of calcium, its transition from a dissolved state in lymph, blood to solid formations). And the faster this process occurs, the faster the reef grows [8].

This symbiosis with algae explains the sensitivity of corals to higher habitat temperatures and the subsequent death of coral reefs. A change in the seasonal temperature maximum by only 1 °C seriously disrupts the ability of dinoflagellates to photosynthesize. As a result, a chain reaction is triggered, which leads to a breakdown in relations: the corals chase the symbionts away in a process called coral bleaching, since without the symbionts they are practically white. Corals do not necessarily die right away, but if conditions do not return to normal quickly enough, they will begin to die. And they die of starvation, since they need the food they get from the symbionts [9].

Scientists associate an increase in the temperature of the world's oceans with an increase in the level of carbon dioxide. The oceans, along with the atmosphere and soils, participate in the geochemical carbon cycle. Marine ecosystems not only emit carbon dioxide, but also absorb it, and the proportion of "captured" CO<sub>2</sub> is greater than that of emitted. Over the past 200 years, the ocean has absorbed about a third of the carbon emissions associated with human activities, and continues to remove about 25% of the excess CO<sub>2</sub> from the atmosphere every year. Excess carbon disrupts the balance of chemical compounds in oceanic ecosystems and increases the acidity of waters, which has increased by about 30% since the start of the industrial revolution. At the same time, the content of such important substances as calcium carbonate, a compound that animals need to build

shells, has significantly decreased. In acidic water, coral reefs die, their skeletons are thinned and destroyed.

The increase in carbon dioxide in the atmosphere due to human activities has a global, but indirect, negative impact on the ocean. There are various types of human activities that cause direct, local harm to the ocean ecosystem:

1. Agricultural activities. A colossal amount of fertilizer runoff from fields into the ocean has caused the appearance of "dead" zones – most often along the coast, where many rivers flow. These lifeless zones during the period of active use of fertilizers can reach an area of 12-14 thousand sq km.

2. Mining and oil spills. The construction of offshore drilling platforms rarely takes into account their impact on the environment, and in some developing countries there is little control over the activities of drilling platforms. Disasters become known only when it is impossible to hide their scale, as in the case of the 2010 Deepwater Horizon tragedy in the Gulf of Mexico (Fig. 4). As a result, more than 2 thousand km of coastline, the main habitat of corals, were polluted. Hundreds of thousands of marine lives were killed.



Figure 4. Oil on the water surface in the Gulf of Mexico. [Electronic resource]. [https://inlnk.ru/me\]Nm](https://inlnk.ru/me]Nm)

3. Disposal of radioactive waste. Pollutants can accumulate in the tissues of living organisms, leading to their degradation and death. And the person who eats their food gets a bunch of incurable diseases.

4. Plastic pollution. Whole islands are formed from plastic in the ocean, one of which is 3 times the area of France and is 1.6 million sq km. These plastic islands impede normal air-water gas exchange, prevent the penetration of sunlight into the ocean, which leads to the formation of "dead zones" and the death of marine organisms [10].

Under the auspices of the UN (United Nations), conventions are adopted to reduce carbon dioxide emissions into the atmosphere, bans are introduced on the disposal of radioactive waste in the ocean, etc. But the positive effect of all the measures taken will be felt only years later. Corals

can die earlier. And along with them, a quarter of all species of marine life that find food and shelter on coral reefs will disappear. The food ties of the entire world ocean will be disrupted, which will negatively affect at least a billion people whose lives are directly related to the ocean, and the rest of the people will feel the consequences through economic consequences, demographic and climatic changes, hunger, etc.

While politicians are busy creating a legal framework for building relationships between mankind and the world's oceans, some scientists have focused on direct assistance to corals.

In 2021, Japanese scientists first modeled the formation of a symbiosis of coral polyps and dinoflagellate algae in a laboratory environment. To do this, scientists led by Noriyuki Satoh from the University of Okinawa grew a cell culture of *Acropora tenuis* coral polyps in Petri dishes, and then added *Breviolum minutum* dinoflagellates to Petri dishes with coral polyps and began to observe them under a microscope. 30 minutes after the start of the experiment, 40% of the polyp cells captured algae. After a day, some polyps destroyed algal cells into separate fragments, while other polyps enclosed them in membrane sacs (Fig. 5). Scientists are trying to manipulate dinoflagellates in various ways to help corals survive. After a series of experiments, they bred *Cladocopium goreau* dinoflagellate strains that are resistant to overheating. Such symbionts will remain in corals even at high temperatures [11].

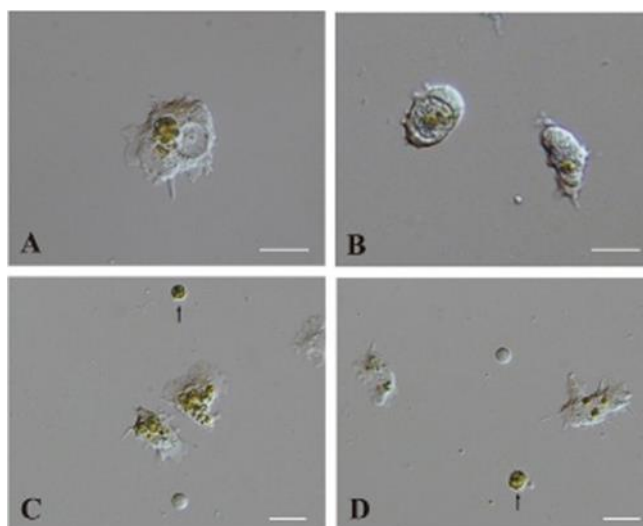


Figure 5. Coral polyps one day after the start of the experiment. [Electronic resource]. <https://nplus1.ru/images/2021/07/16/9ef3f9728fbc604ca7b59188799b815.jpg>

Another group of researchers led by Professor Madeleine van Oppen from the Australian Institute of Marine Science adheres to a methodology, the essence of which is to accelerate the processes that occur normally in nature (mutational process, natural selection, acclimatization, changes in the community of symbiotic microorganisms). The main components of this process are the breeding of resistant corals by selection, the laboratory evolution of the aforementioned symbionts, zooxanthellae, active modification of the coral microbiome, stimulation of coral acclimatization. They call this method human-assisted evolution. The van Oppen group has created interspecific hybrids *Acropora loripes* – *Acropora tenuis*, some of which are distinguished by their resistance to high temperatures and acidity of water.

Many other researchers see the way out of using environmental bioengineering to modify these dinoflagellates and restore the health of marine ecosystems. The possibility of taking such a radical approach to solving environmental problems raises many theoretical and ethical questions. The introduction of genetically modified coral polyps or their symbionts into natural ecosystems can conserve reefs, but the risk of unintended and unwanted environmental consequences cannot be ignored. After all, organisms with new properties can gain a competitive advantage over their relatives and even become invasive, i.e. their proliferation will threaten biological diversity [12].

But there was also a different approach – to understand what is happening with corals around the world over time and to make effective, evidence-based coral rescue decisions. For this, in 2017, Vulcan Inc. (a private company founded by former Microsoft co-founder Paul Allen and his sister Jody Allen), together with Ruth Gates, a Hawaii-based explorer, have conceived a massive project to create the first detailed online map of the world's coral reefs. The project took 4 years and was completed in September 2021. More than 2 million high-resolution satellite images from around the world were used to compile the map. The map was named "Allen's Atlas of Corals" and the Internet address is <https://allencoralatlas.org>. The Atlas also includes a monitor that records coral bleaching due to global warming and other factors. The map is updated daily with lots of data (Fig.6).

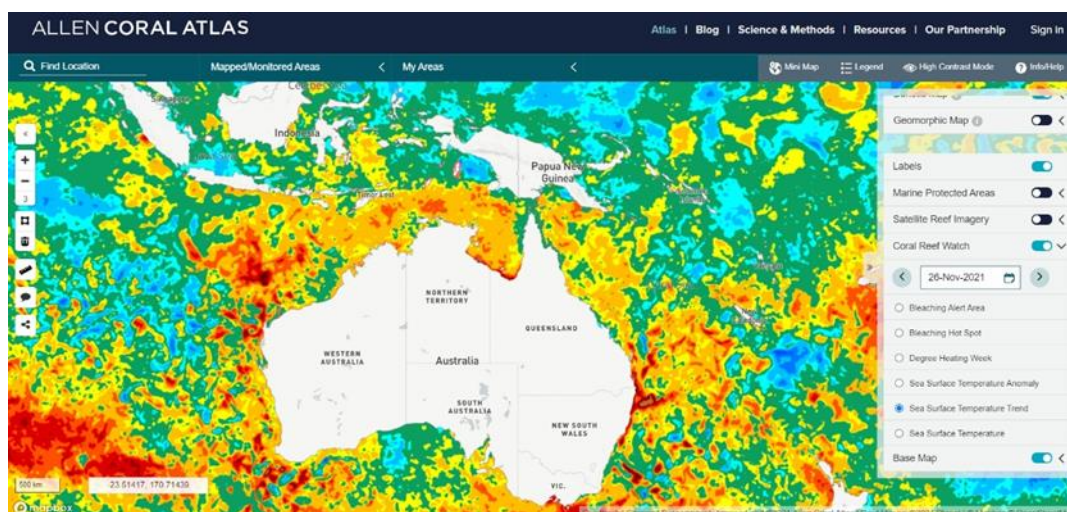


Figure 6. Fragment of a coral map with data on ocean surface temperature as of November 26, 2021. [Electronic resource]. <https://allencoralatlas.org/atlas/#3.24/-19.8769/143.7166>

Allen's Coral Reef Map contains information about all the corals on the planet down to 15m depth, which allows scientists around the world to conduct their coral rescue research as efficiently as possible and in a much shorter timeframe than acting at random [13].

Human activities are rapidly changing the environment and not for the better. The belated response of organizations like FAO, which should act proactively but act after the fact, in particular, is leading to the extinction of corals and the associated catastrophic consequences. For more than 40 years, corals have required special attention to themselves, but only for the last 7 years have they received it. The Intergovernmental Panel on Climate Change (IPCC) estimates that 90% of all corals in the world will die by 2050. By 2100, almost all (over 99%) of the world's coral reefs will be destroyed [14]. We can only hope for scientists-enthusiasts, as well as patrons and philanthropists who sponsor their work. Of course, they will not preserve the corals in the form in

which they can be seen now. But observing the results of the work of Professor Madeleine van Oppen, Professor Noriyuki Satoh and other scientists, there are very high hopes that they will be able to save the corals from complete destruction and gradually restore the population, thereby preventing a global catastrophe.

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