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Marine Ecological Geography

Theory and Experience

Springer

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Preface

As a totality of scientific disciplines studying physical, chemical, biological, and geological processes in the ocean, oceanology moves toward geography of the ocean… running up to generalization of regularities of processes in natural complexes. Furthermore, its aim is to develop physico-mathematical model of all factors...

Acad. K. K. Markov, 1970

In Declaration “Agenda 21” adopted by the UN 1992 Conference on Environment and Development (Rio de Janeiro), practically for the first time in the history of economic management on our planet, the heads of states and governments, World’s leading industrialists and scientists avowed, at last, the necessity of transition from random exploitation of natural resources to sustainable development for conservation of biosphere and, therefore, ourselves.

As it is known, the term “sustainable development” was formulated first in 1987 in the report of World Commission on Environment and Development (Brundtland Commission). It implies the establishment of contemporary economic management in such a way that future human generations will have a “field of operations” to satisfy their needs. At the first glance, the scheme of realization of the above statement seemed very simple:

- rates of renewable resource consumption nowadays should not exceed rates of their natural recovery;
- rates of development and introduction of technologies for artificial production of non-renewable raw material sources should be higher than rates of their depletion;
- volumes of dumping and burial of industrial wastes should not exceed the waste assimilative capacity of the environment.

However, the results of the first 10 years of the world community development under the banner of “sustainable development” strategy, summarized at the World Summit of Heads of the States (Johannesburg, 2002), showed that implementation of its main statements was far from “clockwork” and run against considerable difficulties.

Several interrelated circumstances directly relevant, in the author's opinion, to problems of efficiency of realization of environmental measures and rational resource exploitation on marine aquatories, component of the Agenda 21 concept of sustainable development, served as cause and motivation for preparation of the present monograph.

1. Among the causes resulting in problems at implementation of new concept, the paradigms of human thinking and blatant ecological ignorance at all levels of world social organism, from government officials to heads of industrial and agricultural enterprises, from majority of leading scientists to schoolteachers and readers, not to speak of ordinary workers and peasants, are not at the bottom.

Over the past "triumphant" century of scientific and technological progress for the years of numerous socialistic 5-year plans and capitalistic booms, the human community in its restless desire of better life, earning a lot of money, has lost somehow unnoticeably the instinct of self-preservation, disengaged from the major object of economic activity and source of its prosperity—Mother Nature. As a result, in the present twentyfirst century its crass "king" (even with Ph.D. or portfolio), instead of commandment "do not harm", still follows the light-minded thesis "somewhere we lose, somewhere we gain" or "profit at any price", continuing to camouflage the real principle "after me the deluge". The sad experience of such substitution has matched to the full extent the well-known saying "the road to hell is paved with good intentions" (Fashchuk 2005). The developers of the theory of sustainable development supposing the necessity to realize the principles of social fairness, economic development, conservation of the high-quality environment for achievement of this objective, did not take into account a huge inertia of human thinking which affected the time frames and efficiency of problem solving.

The appropriateness of the above suggestion is confirmed by the history of concept of biosphere as planetary ecosystem (Abakumov 1991). The speculations regarding dependence of life on the Earth on environmental conditions appeared in scientific community beginning from the second half of the sixteenth century. By that time, together with the flow of wealth sprung into the Spanish treasury from the New World discovered by Columbus (1492), the capitals and big cities of the leading European countries filled with a vast number of exotic plants brought by conquistadors to their sovereigns and friends as "souvenirs from America". As a result, the artificial corners of nature, botanic gardens, started to appear and develop actively (1545 Padua, 1547 Pisa, 1567 Bologna, 1577 Leiden, 1593 Heidelberg, 1623 Moscow, etc.). But it emerged that at the European conditions plants brought from the four corners of the earth behaved differently and, thereupon, required individual care. Naturally, the scientific idea responded instantly to this phenomenon and started to work actively for its description, theoretical explanation, and practical use.

Only 300 (!) years after this "discovery", in 1866, German biologist Ernst Haeckel (1834–1919) suggested the term "ecology", then, in 1875 Austrian geologist Eduard Suess (1831–1914) formulated for the first time the notion "biosphere", and, finally, in 1877 German zoologist and microbiologist Karl

Mobius (1825–1908) suggested the definition "biocenosis". Thereafter, it took more than 50 years for these categories to become common in the scientific practice and to get further development—only in 1935 the theory of ecosystems by English phytocenologist Tansley was published, and his term "ecosystem" came into natural science. In 1940 Russian geobotanist Vladimir Sukachev (1908–1967) developed the concept of biogeocenosis which was very close to ecosystem.

Thus, **it took more than three centuries** even for scientific luminaries in order to the concept of ecosystem approach slipped from formal knowledge to deep knowledge. It is easy to calculate that after this principle "naturalized" in scientific minds (1935–1940) only half a century (!) passed away until the UN 1992 Conference in Rio de Janeiro, and even much less time—from adoption of the Agenda 21 to nowadays. It remains only to take off hat to optimism of authors of sustainable development concept, believed naively that for this historic blink it was possible to "change the brains" of ministers, businessmen, farmers, and a majority of other ordinary people, decisions and actions of which affected the success of mankind's "struggle for survival".

After such a simple analysis many facts registered by both national and foreign specialists in the field of natural resource exploitation and environment protection become clear. For example, only in the 1970s–1990s dozens of decisions and resolutions on ecology and marine environment protection have been published in Russia and abroad. All of them appealed "to concentrate", "to enhance", "to consolidate" Aibulatov (2005). The sentences "complex system approach", "ecological monitoring" were constantly presented in the national and international programs on investigations of any given sea or region of the world's ocean. Their result is well-known for us…

Following the logic of the above analysis, the appeals, slogans, and directives were formal and untimely. They were addressed to the emptiness and could not be realized because there was no deep insight in consciousness of potential executives, regarding what it meant and why it was necessary. That is why even today, despite the long history of investigations, the solving of many marine ecological tasks continues for a long period, often remaining only at the hypothesis' level.

2. In the late twentieth century—early twenty-first century the monitoring system, in which the researchers believed, made a lodgement in practice of marine resource use. Its realization at conduct of any operations (especially associated with mineral prospecting and mining, development of aquaculture, etc.) really allowed to collect the huge banks of data characterizing environmental conditions and their variations in corresponding marine areas. Nevertheless, the results of monitoring are rarely analyzed in complex for functional practical and predicting conclusions.

This situation is determined not only by a huge volume of observations carried out during the monitoring period and, therefore, an objective lack of time for researchers to analyze and predict the results. Its reason is associated with a lack of methodological principles for operative analysis of information obtained and appropriate skills of executives.

Now, in most cases the qualified engineers and observers familiar with methods of formal mathematical and computer analysis, methodologies of physical, chemical, biological and other types of analytical determinations but, unfortunately, indisposed to creative abstract thinking and system analysis, are dominated in solution of these problems. Naturally, under such an approach the key in their work is to make methodically correct observations, to describe their results formally, to render a report in time, to defend an estimate of expenditures, and to draw up funding requirements for the next year but not, for example, to clear up the causes of fish kill or anomalous state of marine environment.

As a result, the invaluable collected data remain useless in archives and funds of oil producing and other companies. They allow to answer the questions on what kind and when the sea can be, what and how much the sea contains, who and in what number inhabit the sea, and, at the best case, to assess the temporal and spatial tendencies in marine ecosystem components. But, unfortunately, these data do not allow to learn, why the sea is such, by what reason the changes occur, what will happen if external forcing changes. As a result, the industrials fulfilled formally the demands of another resolution in the field of rationalization of natural resource use, continue to kill the nature blindly on the way to “future prosperity”.

It is impossible to understand and predict the life in marine basin at command. This calls for not only a trained observer but scientific analyst, who is able to assess and use the achievements in different fields of marine science in order to solve the system of “integral equations” such as the current marine ecological problems, to analyze the information, forecasting estimates, and functional practical conclusions. He must possess an universal interdisciplinary style of thinking and scientific intuition but training of ecologists able to think comprehensively and creatively, to doubt, and to feel the nature, occurs in Russia very slowly, not to speak of other countries. None of directives and resolutions can fill this deficit, which means that it is impossible to improve quality of diagnosis and forecasting of marine ecological situations, to realize operatively the principles of concept of sustainable development in this field of natural resource exploitation.

3. In the 1990s, after the UN Conference in Rio de Janeiro, the interest in ecological problems has grown considerably. This has become apparent, first of all, in creation and development of the system of ecological education, though since the 1980s Environmental Education has already existed in the world practice. In the United States and some European countries the associations of ecological education have been organized, and the future ecologists have been learned at chairs “Environmental Sciences” or “Environmental Studies” in universities of many countries.

In addition to summarizing the results, the World Summit (Johannesburg 2002) outlined the ways of efficiency enhancement for further implementation of sustainable development concept (Glazovsky 2003). In particular, the implementation of declaration Agenda 21 (1992) required the new type of education, Education for Sustainable Development“ (ESD), for sustainable development, for the purpose of sustainable development, for sustainability. Its conceptual basis differs principally from the earlier existed ecological education, first of all, that it does not provide strict “vertical” of educational process. Thus, the objective of ESD is not to decide “Where we are now” but to learn “***Where we should go***”; the intention of ESD is not a concrete product ”Getting of skills“ but the process “***Development of competence***”; result of ESD is not an instruction “How to make money” but the wish “**To participate in further education**” (Mazurov 2003; Kasimov et al. 2004, 2005; Sadovnichy and Kasimov 2006).

Therefore, the ESD system is based on quite different conceptual and methodological principles. The educational program here is not a “Final scheme” but “***Experience, consideration of specific situation***”, the gained knowledge are not “Fixed, but abstract and unified” but “***Changing, but real and multivariate***”. Thus, the new ESD system turns the traditional “Passive education and its result—niche specialism” into “***Active education and its result-broad, flexible, interdisciplinary knowledge***”. With that, “Educational system” becomes ***System of learning***, and “Formal education” transforms into “***Education durante vita***”.

In the Soviet Union, quarter of a century before the UN 1992 Conference the concept of rational use of natural resources, very close to the idea of sustainable development, was developed. In the early 1990s under this concept the new specialty “Environment protection and rational use of natural resources” was created. Ecological education in *traditional* universities included the specialties “Ecology”, “Geoecology”, “Natural resource exploitation”. In technical universities there was the courses “Life safety” and “Environment protection”. Now the first version of National Strategy of ESD was developed for traditional Russian Universities. According to this strategy, the students will gain broad, interdisciplinary systematic knowledge based on complex approach to development of society and economy of environment (Sadovnochy and Kasimov 2006).

Owing to financial support from Moscow Foundation of Schoolbook Industry created by Moscow Mayor Yuri Luzhkov, in 2006–2007 the publishing house OJSC “Moscow Schoolbook” brought out a series of author’s books addressed to future generation of marine ecologists and their schoolteachers under the common title “Under the jolly Roger to mysteries of the ocean” Fashchuk (2006a, b; 2007a, b, c). In five volumes of “Reading Books for future Magellans” the author attempted, in popular form, to attract attention of youth to marine ecological problems, to acquaint them with history of investigations of the world’s ocean and evolution of our planet, to touch the mysteries of the germ of life, to tell about its diversity, to acquaint with environmental factors and natural processes—“conductors” of this life, wealth of mineral resources in the ocean, to present the role of mankind in the ocean’s life, positive and negative consequences of their interaction. Nevertheless, ***until now there are no universal textbooks on the mentioned disciplines for higher education***.

4. Finally, there is one more fact occasioned the preparation of the monograph. At present, as a result of active development of computing techniques and computational mathematics tool, together with field observations in the sea, the mathematical models became a basic component for scientific understanding of ocean’s nature, an important element at solving of specific ecological tasks. Now hundreds of different models are developed throughout the world. They help

researchers to understand the mechanisms of functioning and interaction of marine ecosystems, to forecast possible changes in marine environment, to learn how to take control on its state. Nevertheless, despite the progress in modeling (in terms of the number of developed models), the ocean still takes time to evolve its "secrets" to mathematicians, physicists, chemists, biologists. Today, the reliability of marine ecological forecasts developed on the basis of model analysis leaves, mildly speaking, much to be desired. Some of national models, even awarded state prize during the modeling boom of the 1970s, fell into oblivion long ago because, in practice, they showed themselves to be just an instrument for exercises in calculations having little in common with the real nature (Fashchuk et al. 2005).

The conclusion that any mathematical model is just a tool in researcher's hands, is not original. In other words, the quality of modeled forecast depends on the quality of used information based on understanding of modeling object nature. And yet in ancient times classic of antique philosophy Aristotle knowing better imperfection of many his theories believed that *Attainment of truth is both easy and difficult as it is evident that nobody can either comprehend it fully or overlook it completely, but everyone adds little to our knowledge of nature, and in the aggregate these factors form the majestic picture*. Indeed, because of individual peculiarities of human conscience, his education and many other reasons there are many scientists in the world now which know "everything", for example, about the World Ocean. But really among them nobody knows "everything correctly". The absence of attempts to put together individual knowledge, "all these facts", is a reason that, unfortunately, a long-expected *majestic picture* is "developed" very rarely.

It is a geography which connects man and nature! Searching and true understanding of its laws, cause-effect relationships by physicists, chemists, biologists, mathematicians are inefficient without geographers. The world research experience evidences that today the representatives of many fundamental sciences solving the practical problems of marine ecology (and indeed not only marine ecology) obtain desired result very rarely (Medouz and Randers 2007). The author takes leave to suggest that a reason for this lies in passive, very "timorous" participation of geographers in the process. After all these were geographers who were ordained by fate to breathe life into equations and formulas of ecological models, to provide the "aggregate" of used data. The history of geographic science development confirms reality of this suggestion.

In 1942 Vice President of Academy of Sciences of the USSR academician Fersman (1883–1945) in his paper "Geography and war" noted that geography considered as a descriptive science, has become the leading force at solving of most important problems of world conflict. Explaining the reasons for this, he emphasized that *geography is anything but science about several facts of outside world. Geography is a science about the existing relationships, ratios between phenomena and man laboring in nature*. In this relation, the practical significance of development of geographic and ecological research for mankind seems as important as contribution in due time of Soviet military geographers to the victory over fascism (Abramov 2005).

In the post-war years academician Gerasimov introduced term *constructive geography* into natural science, emphasizing the importance of geography at solving of not only military but practically important economic tasks. *Military geography* was one of its directions. In present changeable world another direction of constructive geography, *ecological geography*, gains particular actuality (at the level of fundamental sciences).

In the 1970s Soviet geographer academician Konstantin Konstantinovich Markov (1905–1980) became one of the originators of theoretical bases of physical geography of the World Ocean. Noting necessity of contingence of differentiated sciences on the basis of unifying geography science, he determined the essence of geographic approach at research on the man–nature interaction. It his opinion, it consists in *learning of aggregative geographic conditions, study of natural phenomena in their unity, interrelation, and causality*.

Among objectives of physical geography, along with study of spatial structure, Markov outlined the research on interrelationship of ocean nature and continents, natural resource exploitation, and *impact of social reproduction on the ocean and ocean on social reproduction*. Herewith, both the planetary geographic regularities of oceanic life and specific physiographic features of this component of biosphere are studied.

In the early 1970s the team of colleagues supported the Markov's idea and consisted of specialists in the field of ocean physics (Lebedev), marine chemistry (Aizatulin 1939–2002), and marine biology (Khailov), proposed a concept of necessity of transition from factographic knowledge to system analysis of physical, chemical, biological and other processes forming environmental conditions and determining the state of marine hydrobionts. In the following, the authors developed the theory of Vernadsky regarding biological structure, role of boundary layers in "accumulation" of marine organisms—"concentrating of life". The approach allowed to consider an object from all sides, to understand its nature using the *optimum* of information. With its use, in 1973 the existence of biologically active centers on ocean bottom was predicted (Aizatulin et al. 1976). These centers, 'oases of life', based on chemosynthesis were found soon by submersibles off the Galapagos Isles in the Pacific Ocean (depth about 3 km).

Unfortunately, the proposed concept was not developed by marine scientists in the late twentieth century. The paradigms of contemporary natural science were stronger, and monographs of the authors *Ocean as a dynamic system* (1974), *Ocean*: *active surfaces and life* (1979), *Ocean: fronts, dispersion, life* (1984) and their digest in English *The Living Ocean* (1989) have remained practically uncalled until now.

By the beginning of the twentyfirst century the economic activity on coastal aquatories has been intensified sharply. Only in 1996–2000 the annual oil production has increased from 10% to 25%, equaled to 0.7–0.9 billion t in absolute values. The world annual gas production in the late twentieth century has reached 2,000 billion m^3, and share of marine developments has exceeded 20%, constituting more than 300 billion m^3. Herewith, the total world oil reserves for 2008 are estimated as 200 billion t, and those for gas, 175 trillion m^3 (Radler 2008). In parallel, there has been an intensification of marine transport operations, laying of oil and gas pipelines, development of fish farms and aquaculture farms for cultivation of mollusks and seaweeds, construction of ports, objects of marine tourism and recreation. The ecological consequences of such an anthropogenic stress on marine ecosystem constitute the object of a new direction of geographic science-**marine ecological geography**.

Object of its study—*spatial and temporal variability in the casual-effect relationships between abiotic and biotic components of marine ecosystem under the changing natural factors and economic activity*.

Objective of study—*causes of change in marine ecosystem state and forecast of ecological consequences of natural and anthropogenic forcing for development of scientific bases of marine resource management and exploitation*.

The methodological principles of this direction of geography have not been formulated yet. Following the logic of proposed definitions, the responsibility for formulation and solution of marine ecological problems, as it was supposed by Markov 30 years ago (Markov 1970), lies, first of all, on geographic oceanologists because it is a science which is the most capacious marine geographic discipline. Incorporating physics, chemistry, biology, geology of the ocean, it studies the corresponding processes in marine environment and has the ability to combine professionals of different specialties for achievement of target goal.

The proposed monograph includes the results of theoretical developments and practical solutions of the author—oceanologist obtained in the process of formulation of principles of marine ecological geography and their realization at Institute of Geography of the Russian Academy of Sciences under:

1. Project of basic research of the Russian Academy of Sciences *Natural processes in the external Earth's envelopes under increasing anthropogenic stress and scientific bases of ecologically safe rational use of natural resources* (2001–2005).
2. Grants of the Russian Foundation for Basic Research: No. 98-05-65031 *Evolution of hydrological systems with zones of hydrosulfuric contamination* (1998–2000); No. 00-05-64166 *State of marine ecosystems with account of the contemporary oil and gas field development on the shelf* (*taken the Black, Caspian, and Okhotsk Seas as an example*) (2000–2002); No. 01-05-84778 *Geographic regularities of anaerobic condition formation in the Earth's hydrosphere* (2001–2003); No. 03-05-64505 *Transformation and cycle of nutrients and organic matter in the White Sea ecosystems: analysis with the use of mathematical modeling* (2003–2005).
3. State contract No. 02.515.11.5037, subject 2007-5-1.5-16-02 *Development of scientific and methodological bases for estimation of the Russian marine ecosystem tolerance to extraction and transportation of hydrocarbons with the purpose to organize the system of complex ecological monitoring under different climatic conditions* (2007–2008).
4. Russian–Ukrainian Grant of the Russian Foundation for Basic Research No. 09-05-90415-Ukr_f_a *Geographic and ecological assessment of consequences of*

hydrocarbon exploration and transportation for environmental conditions and biodiversity of underwater landscapes in the Kerch Strait (2009–2010).

In Chap. 1 of the monograph the methodological principles of systemization and visualization of multidimensional ecological information for its operational dissemination among potential users are stated. Their realization results in the development of geographic-and-ecologic model of marine basin as an information base for diagnosis of the marine ecosystem state, estimation of consequences of economic activity, and modeling of its changes with the use of mathematical tools.

In Chap. 2 the geographic and ecological aspects of mathematical modeling of marine ecosystems, capabilities and features of the most relevant models such as the Russian hydrodynamic model of oil spills "SPILLMOD" and hydroecological model of organogenic compound transformation in the sea, are considered.

In the following six chapters the examples of practical realization of geographic and ecological (as a source of information) and mathematical (as a computing tool) modeling at investigations on specific ecological problems associated with consequences of natural hazards and economic activity both on aquatory itself and within the whole Black Sea basin are given. They include: history of hydrological structure formation and causes of the present dynamics of the H_2S-zone upper boundary (Chap. 3); causes of summer suffocation event development (death of bottom hydrobionts) on the northwestern shelf and their relation to regulation and changes in qualitative composition of the Dnepr and Danube discharge (Chap. 4); consequences of marine gas production in the Karkinitsky Bay and prognosis of time required for its self-purification from oil pollution (Chap. 5); prognosis of possible impact of marine fish farms on environmental conditions off the Russian North Caucasian Coast in the area of Great Sochi (Chap. 6); consequences of economic activity in the Kerch Strait (Chap. 7); consequences of the tanker VOLGONEFT-139 wreckage as a result of the unusual storm (11 November, 2007) in the Kerch Strait (Chap. 8).

In Conclusion the main world problems of the present marine resource exploitation, relevant directions of scientific research and international cooperation associated with the study of role of the World Ocean in changes of environment state on our planet are analyzed. The comparative assessment of structure, goals and objectives of Federal Target Program "The World Ocean" (1998) and the U.S. Project on the World Ocean research "Turn to the sea: future of the United States is in the World Ocean" proposed by former vice-President of the United States Gore (1999) is made. It is concluded that the effectiveness of results of both projects depends in large extent not only on volume of funding but on the scale of engaging of geographic scientific tools to their realization.

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