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Dmitry Ya Fashchuk

Marine Ecological Geography

Theory and Experience

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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.

References

Abakumov VA (1991) Formation of the concept of biosphere as planetary ecological system. In: Problems of ecological monitoring and modeling of ecosystems, vol. 13, Leningrad, Gidrometeoizdat, pp 25–43 (in Russian)

Abramov LS (2005) Contribution of national geography to the Great Victory. Izvestiya RAN (Proceedings of the Russian Academy of Sciences), Series: Geography, No. 2, pp 5–13 (in Russian)

Aibulatov NA (2005) Activity of Russia in the coastal zone of the sea and problems of ecology, Nauka, Moscow, 364 pp (in Russian)

Aizatulin TA, Lebedev VL, Suetova NA, Khailov KM (1976) Boundary surfaces and geography of the ocean. Transaction, Moscow University, Geographical series, No. 3, pp 25–35

Fashchuk D.Ya (2007a) "Conductors" of ocean life. Natural factors of formation of environmental conditions in the ocean. JSC Moskovskii Uchebnik, Moscow, 208 pp (in Russian)

Fashchuk D.Ya (2007b) Undersea storage places of Neptune. Mineral Resources of the World Ocean. JSC Moskovskii Uchebnik, Moscow, 192 pp (in Russian)

Fashchuk D.Ya (2007c) Remedy from "illnesses" of the sea. Man and the World Ocean. JSC Moskovskii Uchebnik, Moscow, 256 pp (in Russian)

Fashchuk D.Ya (2006a) Anthology of Marine Adventures. History of Discovery of the World Ocean. JSC Moskovskii Uchebnik, Moscow, 240 pp (in Russian)

Fashchuk D.Ya (2006b) Laws of the "sea jungle". Origin and life of the oceans. JSC Moskovskii Uchebnik, Moscow, 240 pp (in Russian)

Fashchuk D.Ya, Chicherina OV, Leonov AV (2005) Geographic and ecological aspects of mathematical modeling of marine basins. Izvestiya RAN (Proceedings of the Russian Academy of Sciences), Series: Geography, No. 2, pp 26–37 (in Russian)

Fashchuk D.Ya (2005) On present and future of marine ecological geography. In: Horizons of Geography. Conference devoted to the 100th anniversary of Academician K.K. Markov. Moscow State University, Moscow, pp 265–275 (in Russian)

Glazovsky NF (2003) Ten years after Rio: results and prospects of transition to sustainable development. Izvestiya RAN (Proceedings of the Russian Academy of Sciences), Series: Geography, No. 1, pp 5–19 (in Russian)

Kasimov NS, Mazurov YuI, Tikunov VS (2004) Concept of sustainable development: perception in Russia. Vestnik RAN (Herald of the Russian Academy of Sciences), vol. 74, No. 1, pp 28–36 (in Russian)

Kasimov NS, Glazovsky NF, Mazurov Yu.L, Tikunov VS (2005) Geography and education for sustainable development. Vestnik MGU (Herald of the Moscow State University), Series 5: Geography, No. 1, pp 38–49 (in Russian)

Markov KK (1970) Geography of the ocean. Materials of the 5th Congress of the Geographical Society of the USSR. Leningrad, pp 3–7 (in Russian)

Mazurov Yu.L (2003) Education for sustainable development: content and macrostructure. Vestnik MGU (Herald of the Moscow State University), Series 5: Geography, No. 4, pp 3–9 (in Russian)

Medouz D, Randers J (2007) The limits of growth. Akademkniga, Moscow 343 pp (in Russian)

Radler M (2008) Modest increase in world's reserves against decrease in oil production. Oil&Gas Journal, 3(16):8–9 (in Russian)

Sadovnichy VA, Kasimov NS (2006) Establishing of education for sustainable development in Russia. Ecology and Industry in Russia, March 2006, pp 13–17 (in Russian)

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Contents

Chapter 1
Geographic and Ecological Information Model of Marine Basin

In the early 1980s, being in Kiev at the representative technical council debated the problem on expediency and possible consequences of construction of the Dnieper-Bug hydraulic center, I had occasion to explain performers of the work, specialists of the large planning institute, what expected the Black Sea in case of realization of another "project of the century". I diluted with enthusiasm on tens of thousands of dead fish, increasing volumes of fetid municipal sewage runoffs, saprobic water reservoirs, and many other possible consequences of construction of another dam on the Dnieper. Despite all my emotions, there was no tears in the room. The reaction of audience on information was more than calm. The discussion was closed with traditional question: "How much is your nature?". This meant the sum of compensation for doing damage to nature.

Only after a decade it became clear that the reason of my fiasco lay not in a lack of sound arguments but in that the mentioned facts did not represent a consistent sequence of the cause-effect relationships which would allow to incorporate the audience and "object", to show their place in the structure of relationships between civilization and nature. In that time it was impossible to develop such a logical scheme because of the wealth and diversity of information under a lack of methods for its systematization, matching, visualization, and multiplicity of interdepartmental relations and stereotypes of professional thinking.

The following analysis of numerous attempts to estimate the state of marine aquatories showed that the diagnosis and, further, the forecast of marine aquatory state at the end of the twentieth century were far from perfection. In particular, although more than a dozen of scientific research institutes and other organizations studied the Black Sea were located and functioned successfully on its coast and watershed at the end of the last century, it took 5 years to explain the causes of suffocations (mass death of bottom hydrobionts) developed from the first half of the 1970s on its northwestern shelf. In the same "speedy" fashion, despite more than the 100-year history of investigations in the Black Sea (the "most understood" sea in that time), only after the 10-year expedition and brain "storm" the

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unreality of outcrop and inflammation of hydrogen sulfide in its open part was, at last, scientifically based. In the 1990s this allowed to reject the adventurous project on "rescue" of population of the Black Sea countries and the sea itself from the supposed disaster through the construction of giant energetic complex for deepwater production and processing of this gas in Novorossiysk (Aizatulin and Leonov 1990).

In the early 1990s some elements of the concept of system approach to study marine basins started to develop in Russia (Photo 1.1). They included anthropogenic ecology of the ocean considering biological aspects of the issue "anthropogenic impact—marine ecosystem" (Izrael and Tsyban 1989) and geological ecology of the ocean studying "mechanisms of biosphere destruction through anthropogenic impact on relief, sediments, and suspended substance" (Aibulatov and Artyukhin 1993). The monograph "*Bases of hydroecology*" puts the greater emphasis on general issues and ideas reflecting the cause-effect relationships "environment–object" in aquatic (mainly, freshwater) ecosystem (Romanenko 2004). The book "*Scientific bases of water quality monitoring*" reviews organizational and methodological issues of foreign and national investigations on quality of continental

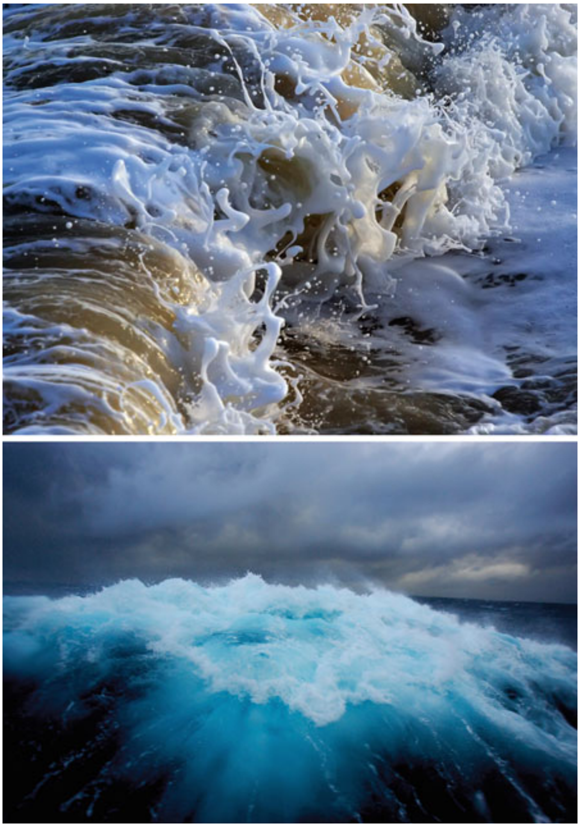

Photo 1.1 Despite the long history of investigations, the World Ocean takes time to reveal its secrets to man (by Yu. Maslyaev)

surface waters, theoretical aspects of modeling of mechanisms of its change, and problems on rating of ecological loads on water with different pollutants (Nikanorov 2005). In monograph "*Geoecological investigations on landscapes of marine shoals*" the principles of regionalization and classification of bottom landscapes, concept of stability estimation, and mechanisms of their natural-resource potential dynamics under the natural and anthropogenic impact are suggested (Mitina 2005).

Also, the examples of complex system generalization of marine ecological information for both the certain (for example, southern) seas (Keondzhyan et al. 1990; Vinogradov et al. 1992; Zaitsev 1992; Kuksa 1994, etc.) and coastal areas of the whole World Ocean (Dolotov 1996) appeared in literature. Nevertheless, all these studies addressed certainly important but partial or regional aspects of the global planetary issue- diagnosis and forecast of negative consequences of natural and anthropogenic impact on marine ecosystem state.

1.1 Marine Ecological Information

The research history of most inner and marginal seas of the World Ocean counts mostly tens of years and sometimes more than 100 years. So, the different branches of natural science accumulated a huge volume of information about regularities of functioning of single elements of marine ecosystems. Methods for obtaining and generalization of all these data are, in large extent, differed that determines their quality features. Among them the most characteristic ones are as follows:

(1) Different coverage of coastal and open areas of the sea with data; most of them are commonly referred to the more dynamic shelf zones;
(2) In most cases, large discreteness of observations in time and space;
(3) Different regularity, character (volume, structure) of observations, and methods of information obtaining, depending on professional interests, abilities, and departmental identity of observers;
(4) Multiplicity of external forcing factors and, as a consequence, large spatial and temporal variability, intricately predictable indirect and equivocal response of the sea, inaccessible for understanding without the study of ecosystem functioning mechanisms;
(5) Existence of the third coordinate (depth) in marine environment determines the essential differences in character and intensity of the same external impulses and, correspondingly, in response of abiotic and biotic components of marine ecosystem on external forcing with depth;
(6) Episodic and transient character of many natural and anthropogenic impacts determines the shortness of development of their negative consequences for the sea, which cannot be registered without continuous control system;
(7) Homogeneity of environment (only aquatic), at the first glance, simplifying the matching of ecological information, really complicates it essentially

because of the high dynamics of water mass processes (circulation structure, waving, mixing, etc.);

(8) Morphometric features of each water basin (coastal orography, bottom topography) determine the substantial spatial variability of aquatic environment response on the same external impulse;

(9) Ecological characteristics of water basin depend, in large extent, on the character of development of natural and anthropogenic processes beyond it and, not rarely, near the boundaries of corresponding watershed area;

(10) Level of generalization and data accuracy in different fields of marine science differ substantially:

- Specificity of hydrobiont life activity determines traditional quantitative generalization of biological information (assessment of stock biomass, abundance, etc.) on a basinwide basis. Only for attatched organisms (mollusks, seaweeds) or demersal fish species these characteristics are sometimes differentiated by area. Moreover, such assessments are made only in periods characteristic of hydrobionts (spawning, feeding, wintering);
- System of observations on environmental conditions existed until the 1990s (stationary network of coastal hydrometeorological stations, schemes of oceanographic stations at standard sections and ecological ranges) determined the relatively high regularity of data obtaining (daily, seasonal) and, therefore, spatial coverage of water basin with the certain type of information that allowed to make more detailed conclusions regarding the regime state both in its coastal and open areas;
- Parameters of water and bottom sediment chemical pollution in coastal zone (in the area of observations conducted by hydrometeorological service) were registered rather regularly but only at the microsurvey scale (for example, aquatory of port or bay). Just in 3–5 miles (5–8 km) from the shore this information (by expedition data) was not spread. In the open basin and areas of marine sources of pollution (drilling platforms, spoil disposals, zones of sand extraction) the observations on water pollution were carried out episodically and did not represent a system to the present day;
- Investigations on marine pollution with oil product films have very different occurrence (from one annual survey in the seas of the Arctic Ocean to 24 yearly reconnaissance flights over the Baltic Sea);
- Conclusions on sea ground pollution on the open shelf, based on materials of irregular field observations by research institutes of the Russian Academy of Science, Ministries of Geology, Fisheries, and other departments, may be authentic but only at indication of exact sampling place in each specific case;
- Monitoring of toxicological situation at the sea appears as a set of sporadic, irregular data samples (from 1 to several tens of analyses) obtained for hydrobionts caught more often in the shelf zone by coastal fishing gears (nets), in places which are the most convinient for analysts. The system of mass determinations of toxicological parameters from

commercial catches and, therefore, obtaining of statistically significant data does not exist now;
- Despite the fragmentarity of marine paleoecological and paleogeographical information, it, nevertheless, permits to trace evolution of paleobasins over millions of years and reconstruct it in perspective.

The mentioned features determine the current (very non-unique) quality level of marine ecological information, existence of blind-spots in corresponding branch of geographical science associated with its systematization, and also the need of critical attitude towards conclusions based on its analysis.

1.2 Traditional Schemes in Analysis of Marine Ecological Information

The formation of ecological situation in the sea is affected by a complex of interacting natural and anthropogenic factors. The response of marine ecosystem to external impulse is therefore indirect and ambiguous. In these circumstances:

- Results of specific investigations by different branches of marine science combined traditionally into professional or complex monographs are difficult to use for solving of contemporary problems of marine ecology. In monographs of the first type ecologically sound conclusions are often masked by methodological details, voluminous analyses, and specific terminology, which are interesting and understandable only to a narrow circle of specialists. In generalizations of the second type the complexity is formal because such publications deal usually with interesting and important but narrow special problems which are poorly interlinked among themselves;
- In the period of accumulation of ecological information the classic scheme of its generalization (structure of the typical complex monograph) was as follows: physico-geographic features of the basin-hydrological regime-hydrochemical regime-bottom sediments-hydrobiology-ichthyology. Thus, when systemizing the data, the primary attention was given to abiotic characteristics, among which it was practically impossible to select the priority parameters under such an approach. The state of hydrobiont populations, whose study allows to range external impact factors by their ecological importance, is the primary integral indicator of water basin "health";
- Traditional generalizations of data on the state of abiotic component of marine ecosystem were based on regime indices. The study of processes determining their formation, structure of the cause-effect relationships in the system "external forcing—response of marine environment—response of hydrobionts" that would allow to answer the question "why some or other events occur" tended therefore to fall by the wayside;
- Analysis of ecological importance of watershed territory for ecosystem of, for example, the Black Sea showed (Fashchuk and Shaporenko 1995; Mandych and

Shaporenko 1992) that now the contribution of basin pollution due to the direct effluents discharge by coastal plants was comparable with the similar effect from the Dnieper and Danube river runoffs. The same conclusions were made by the leading marine scientists of our country believing consentaneously that the causes of many ecological crises at the sea "lie on the coast". Nevertheless, when estimating the state of marine aquatories, today the information about watershed is included into the range of analyzed ecological data only in exceptional cases (Zaitsev 1992; Drozdow et al. 1992);

- Experience of solving of specific ecological problems in the Black Sea showed that in the contemporary context the results of one or two carefully planned (including the analysis of possible mechanisms of crisis development) directional field experiments were much more effective than the traditional long-term standard observations (Fashchuk et al. 1990; Fashchuk 1995);
- Despite the high present level of mathematical modeling and numerous examples of its use for forecasting in natural science, there is no any adequate model of marine ecosystem now. The factographic information is applicable only to statistical calculations, determination of tendencies in variations of different parameters. Its mechanical use in simulation models without understanding of nature laws does not provide practical (prognostic) result.

1.3 Geographic and Ecological Principles of Marine Ecological Data Systematization

The succession of two stages, primary accumulation of information and stage of its complex analysis, generalization, and systematization, is the objective law of natural science development. In the first half of the 1990s national oceanology found itself on the threshold of such qualitative jump. The subjective circumstances of modern times: sharp reduction in volume of field investigations and appearance of a need to solve principally new ecological problems in conditions of challenging economic situation, essentially accelerated this process.

In existing situation, the geographic and ecological approach is the most appropriate methodological principle of systematization and visualization of marine ecological information. Within a framework of this approach:

- Sea is considered as one hydrodynamic system inseparably associated with the adjacent watershed territories;
- Spatial and temporal variability of main natural and anthropogenic factors affecting marine ecosystem is assessed;
- Similar variability of the cause-effect relationships "external forcing- marine environment- state of hydrobiont populations" is considered;
- Spatio-temporal relation between evolution of marine paleobasins and their present ecological state and dynamics is traced.

The main statements of the approach are as follows:

- In parallel with conventional methods of systematization of marine ecological information, the methodology of its contemporary generalization is built on the basis of *geographic and ecological information model—"portrait" of the sea* representing a complex of ecologically significant aspects—"gingers" of the basin study by different branches of science, together with hydroclimatic, administrative-territorial, and economic features of watershed territories (Fashchuk 1997; Fashchuk et al. 1997).
- When developing model—"portrait" of the basin, the identification of priority, ecologically significant factors of external forcing and indicative factors determining stability and state of marine ecosystem is made with the use of biotic indices, whose analysis, unlike traditional approach, is carried out before the analysis of physiographic features of the basin;
- As a result of analysis of biological data, on the basis of investigations on distribution of main commercial hydrobionts and their food objects, the "centers of life concentration" representing ecologically the most sensitive to external forcing regions are defined;
- In parallel with the analysis of biological information, systematization of data on tolerance of marine organisms to pollutants and symptoms of their intoxication is carried out;
- Analysis of natural factors affecting the marine ecosystem is made not by regime indices but on the basis of *process* study, the determining ecological significance of which is established during the systematization of biological data (regime characteristics are used only for assessment of environment response to external forcing, determination of long-term trends or cycles);
- Information about forms and intensity of economic activity on marine aquatory, their distribution in space and time is a component of the geographic and ecological model—"portrait" of the basin;
- Along with natural and anthropogenic factors acting on the basin aquatory, the analyzed factors determining the state of marine ecosystem include also ecologically significant features of watershed territory;
- If the whole inner or marginal basin is studied, geographic and ecological model—"portrait" of marine ecosystem includes also information about succession of its paleobasins in geological past, based on retrospective analysis of paleoecological and paleogeographical data;—content of the "portrait" of sea (maps, diagrams, tables, descriptions) serves as a basis for development of environmental actions, recommendations on economic management, and plans of directional field experiments to study the mechanisms of crisis events in water basin;
- Based on data of directional field experiments, the simulation model experiment (drawing of scenarios of changes in natural and anthropogenic loads) for assessment of marine ecological evolutions is planned and performed.

In accordance with methodological principles of geographic and ecological modeling, the knowledge necessary for assessment of marine ecosystem state and solution of practical problems of marine ecology consists of data on factors