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## MODELLING OF PROCESSES IN MARINE ECOSYSTEMS

**Gazyetov Ye. I., Medinets V. I.**Odessa State University, Centre of Environmental Monitoring,  
Dvoryanskaya St., 2, Odessa, 270026, Ukraine

The results of work to create the combinative model of the north-western part of the Black Sea ecosystem are described. The scheme of interactions in the marine ecosystem is presented. Flow-chart of the model containing four subsystems is briefly described. The questions of the model use and further development are discussed.

**Key words:** modelling, ecosystem, the Black Sea.

The main reasons of marine ecosystems changes, including the Black Sea, are climatic variations and anthropogenic effect [4, 6, 1, 7]. Frequently climate is the basic reason for significant structural changes in ecosystems [4]. Anthropogenic pollution causes a complex of negative ecological consequences: eutrophication, microbiological pollution of coastal waters, accumulation of chemical toxicants in different elements of ecosystem, infringement of productive — destructive and biogeochemical cycles, decrease of specific variability etc. [4, 6].

The mathematical modelling is the most efficient method for diagnosis and forecasting of ecosystem state, but as V. I. Belyaev noted, “the mathematical models of hydrothermodynamic processes are essentially better developed, than the models of biological processes” [2]. The mathematical modelling method is the most efficient for the marine regions, in which it is impossible to provide a necessary spatial and temporal regularity of experimental observations. The reason lies in the fact that natural systems are rather complicated. Functioning of those systems is formed by huge number of parameters connected with one another that are difficult to measure and observe regularly. Therefore, the main task is to reveal the most significant features of natural systems, with the aim to describe them physically and mathematically, and to reveal a representative delimitation of marine ecosystem with maintenance of the physical and mathematical regularities.

During last years the work aimed at creation of an integrated model of the marine ecosystem functioning in the north-western part of the Black Sea (NWBS) is conducted at Odessa State University. This region is the most valuable in view of the biological significance of the shallow north-western shelf, abundance of its mineral resources and the value of coastal recreational zone. The purpose of the present work is to present intermediate results of the research conducted in the area.

Fig.1 presents the description of natural media and various factor interaction [5] that determine marine ecosystem functioning in the shelf zone of the Black sea. It forms the base of the model flow-chart. The following processes and interactions are taken into account:

1. Continent — Sea: terrigenous, river and domestic discharges of nutrients and pollutants; abrasion and changing of the coastline; changes in water balance because of irrigation and other economic activities in the basins of rivers flowing in the sea.

2. Atmosphere — Sea: long-range transport of pollutants from industrial areas of

European continent into the marine atmosphere; atmospheric precipitation of nutrients and other substances into the sea; sea — atmosphere power interactions; influence of the atmospheric optical parameters to photosynthesis processes in the marine photic layer.

3. Economic activities in the sea: sea freight traffic; fishery; prospecting and mining of minerals; dredging, dumping of dredged spoils and toxic wastes; mining and transportation of oil; construction of pipelines, underwater cables etc.; naval activities.

4. Interaction between separate regions of the sea and adjacent seas: advective transport of heat, energy, pollutants and basic elements; changes in water balance with the Mediterranean and the Azov Seas.

5. Sea — Bottom: sedimentation of pollutants, nutrients, organic matter from water column and their accumulation in bottom sediments; mining of bottom marine products and minerals; secondary pollution from bottom sediments, especially in the port regions and dumping sites; gases and soluble compounds influx from breaks and bottom sediments.

6. Hydrobionts — Marine Environment: production and destruction of organic matter processes; matter transport as a result of biosedimentation and migration of hydrobionts; matter removal as a result of fishery.

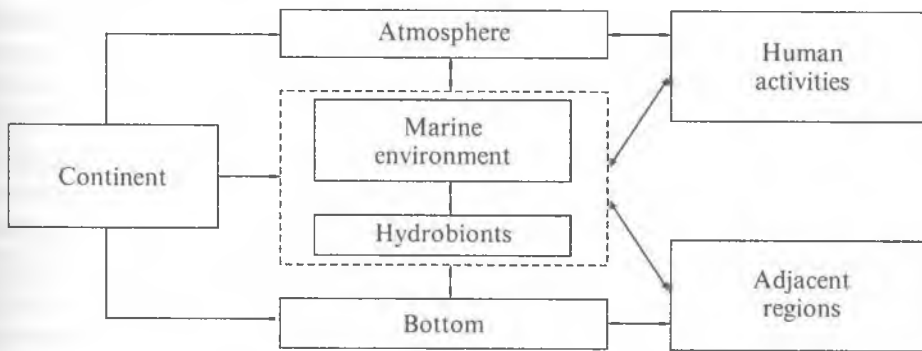


Fig. 1. The scheme of interaction of various media and factors with the marine ecosystem

Proceeding from the interaction scheme mentioned above which provides modelling of the main processes in the NWBS ecosystem functioning we have developed the model flow-chart (Fig. 2).

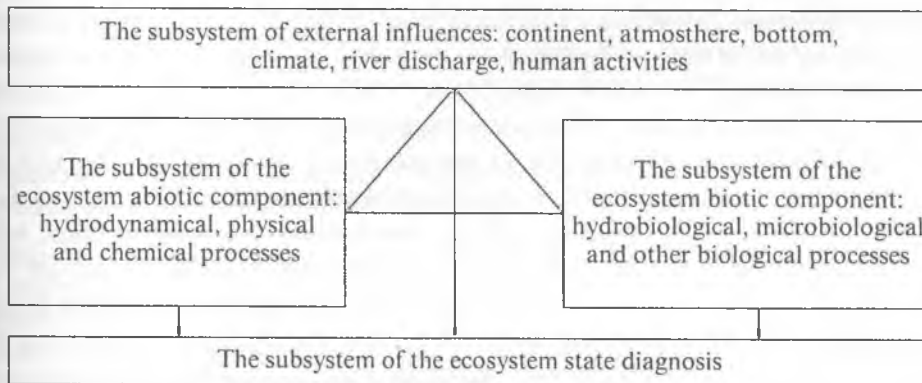


Fig. 2. The model flow-chart

The model consists of four subsystems:

— the subsystem of external, natural climatic and anthropogenic influences, the parameters of which are set as constant values within the limits of the modelling scales at the first stage;

— the subsystem of the ecosystem abiotic component describing the regularities of hydrodynamical, physical and chemical processes in the marine environment and contact zones;

— the subsystem of the ecosystem biotic component including the biological processes description and interaction between hydrobionts, microflora and abiotic factors and processes of biochemical transformation of matter and elements (bioaccumulation etc.)

The output data of the three above mentioned subsystems are the initial data for the subsystem of the ecosystem state diagnosis that gives quantitative assessment of the ecosystem state.

The main component of marine ecosystem model is the unit describing its hydrodynamical state as the special attention should be paid to mixing processes that influence directly biological system functioning and hydrochemical regime of ecosystem formation [2]. Modelling of marine ecosystem is especially important for the Black Sea shelf area.

As the hydrodynamical unit we use the non-linear hydrodynamical model for calculation of current direction and speed in the NWBS, which is described in the work [3] more in detail. The mathematical description of the model consists of a system of hydrodynamical differential equations with partial derivatives including the equations for matter and heat transport, the solution which describes the dynamics of changes of sea surface height and current speed in the time. During modelling the initial values are calculated for density, pressure anomalies, horizontal and vertical components of current speed, coefficient of vertical turbulent impulse exchange, sea surface heights, temperature and salinity. The input parameters are temperature, salinity and atmospheric pressure sets, as well as the sets of numerical values for depths and horizons, at which the numerical experiment is conducted. The output computational parameters of the hydrodynamics unit are the sets of horizontal and vertical components of current speed, temperature, salinity, water density and sea surface heights for each computational horizon and each hour.

As the biological subsystem the imitative model by L.A. Vinogradova and V. N. Vasileva has been used [8]. This model describes the phyto- and zoocoenosis state, allows to estimate assimilative capacity of the ecosystem (ACE) [4], depending on biological and meteorological factors, as well as calculate primary production and estimate the probability of hypoxia occurrence depending on seasonal changes in the biocoenosis and eutrophication rate.

The basis of the subsystem of the ecosystem state diagnosis is the imitative two-layer model of matter transformation in the ecosystem developed to describe annual cycle of pelagic communities functioning in moderate latitudes. Thus, the planktonic community differentiation into ecologically homogeneous groups is used, which is inseparably connected with the principles of description of their interaction; the parameters describing food consumption are assumed to depend on both the predator's and the victim's morphological features; the reverse connection between the growth rate and phytoplankton concentration is taken into account. Solving the task of diagnosis in the water area under research the spatial distribution of abiotic and biotic

environment parameters is described quantitatively, the peculiarities of functioning and seasonal state of the ecosystem taken into account.

At present, the described model can be used both for the diagnosis, and for the short-term forecasting of the ecosystem state: calculation of phytoplankton primary production rate; spatial distribution of abiotic and biotic components of the ecosystem; spreading of conservative pollutants in the ecosystem from point sources; assessments of hypoxia occurrence probability depending on the seasonal changes in the biocoenosis and eutrophication rate. The present stage of research allows us to speak about creation of combined imitative — hydrodynamical models describing spatially-non-uniform pelagic phytoecoenosis functioning in the regions suffering from anthropogenic pressure, in particular in the Odessa bay. Besides, the processes of increasing eutrophication and pollution of the shallow north-western shelf are important in view of atmospheric transport of nutrients, toxic metals and persistent organic substances, which accumulate in the ecosystem and accelerate its degradation. Taking into account regional climatic changes becomes a doubtless problem of marine ecosystems modelling.

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## МОДЕЛЮВАННЯ ПРОЦЕСІВ У МОРСЬКИХ ЕКОСИСТЕМАХ

Газетов С. І., Медінець В. І.

Одеський державний університет, Центр моніторингу навколишнього середовища, вул. Дворянська, 2, Одеса, 270026, Україна

### Резюме

У статті узагальнено результати роботи по створенню комплексної моделі функціонування екосистеми північно-західної частини Чорного моря. Представлено схему взаємодій у морській екосистемі, блок-схему моделі, що складається з чотирьох підсистем. Зроблено висновки щодо використання моделі та її подальшого розвитку.

**Ключові слова:** моделювання, екосистема, Чорне море.

## **МОДЕЛИРОВАНИЕ ПРОЦЕССОВ В МОРСКИХ ЭКОСИСТЕМАХ**

**Газетов Е. И., Мединец В. И.**

Одесский государственный университет, Центр мониторинга окружающей среды,  
ул. Дворянская, 2, Одесса, 270026, Украина

### **Резюме**

В статье обобщены результаты работы по созданию комплексной модели функционирования экосистемы северо-западной части Черного моря. Представлена схема взаимодействий в морской экосистеме, блок-схема модели, состоящей из четырех подсистем. Сделаны выводы об использовании модели и ее дальнейшем развитии.

**Ключевые слова:** моделирование, экосистема, Черное море.