Mathematical Modelling of Marine Systems

Marine environment as an ecological-economic system*

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Abstract — On the basis of systems analysis of the consumption and reproduction of marine resources, a conceptual model for the management of maritime-industrial complexes is suggested. The management of such complexes calls for simulation experiments, with involvement of models for the respective marine ecological-economic systems. A new method of dynamic-stochastic modelling is suggested to generate models synthesizing the expert-and-analytical approach to the estimation of the system's dynamic operator with the method of Kalman's adaptive filtration.

INTRODUCTION

Because of man's increasing impact on the marine environment, methods of simulating the sea ecosystem are being rapidly developed today which rely on the theory of marine dynamic processes and mathematical biology. However, the available models for the marine ecosystem are too cumbersome and complicated, which hampers their application to the problems of marine environment management. The available dynamic models of sea ecosystems typically ignore the economic aspects of marine resource consumption. Only a few attempts have been made to address the problem of conservation and utilization of biological resources on a broad scale, when the natural environment is regarded as a cohesive ecological-and-economic system.

One of the pioneering works dedicated to the ecological-economic modelling of marine ecosystems is ref. 1. The logical-and-information approach to describing marine ecological-economic systems (MEES) suggested there represents an original application of the ideas taken from statistical mechanics. The approach allows one to describe an equilibrium state of the marine systems and to analyse the system's response to anthropogenic forcing.

The ecological-economic models available today rely on the principle of combining self-sustained modules, such as hydrodynamic, ecological, economical, and others, into a fairly complicated system. In view of the great number of input parameters, the application of such models in the natural-economic management systems represents a serious problem [2].

Another negative aspect is the lack of a general systemic methodology for the study and employment of marine resources. Following the principles of systems analysis, it is necessary to elaborate a systemic concept for the development of maritime industrial complexes (MNIC) and to suggest realistic technologies for the management of marine ecological-economic systems. It is vital to provide a unique information base for theoretical models of the marine environment and control-and-measuring systems, providing

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information for these models from practical observations. Finally, it is necessary to optimize the procedures of data collection and processing, the planning and consumption of marine resources, and the ecological control of the sea environment.

The purpose of this work is to study the ecological-economic aspects of modelling of the marine environment in terms of systems analysis. More specifically, we will address the problem of generating a systemic ideology for the management of maritime natural-industrial complexes, using dynamic-stochastic modelling of marine ecological-economic systems.

SYSTEMS ANALYSIS OF THE CONSUMPTION AND REPRODUCTION OF MARINE RESOURCES

The term 'marine resources' implies all the material objects and properties of the sea environment, which are constantly needed by the national economy, are restricted in volume and call for additional expenditures for their consumption. The multi-disciplinary problem of study and utilization of marine resources consists in the development of a theory for the management of marine ecological-economic systems. That theory is expected to provide for the construction of models of maritime industrial complexes, which consume sea food and mineral resources, produce gas, oil and construction materials on the continental shelf, transport diverse loads by the sea, etc. In other words, we are concerned with the control of the natural evolution of the sea environment and with the management of the available MNIC and those being designed.

Let us focus on the problem of MNIC management in terms of systems analysis [3, 4]. That problem comprises a suite of logically related individual problems: purpose-diagnostic-prediction-management. By applying the systems principle of decomposition and synthesis [5], we can present the general problem of MNIC development as a diagram shown in Fig. 1.

The systems concept for MNIC development represents a combination of targets for the consumption of marine resources in the conditions of conservation of the homeostasis of the ecosystem in which MNIC is functioning. The systems concept also contains ideas permitting the objective in question to be achieved. The targets of development must include indices of the economic efficiency of trade, the level of pollution of the sea, homeostatic conditions for marine organisms, etc. The ideas of realizing the goals ensue from the general principles of systems analysis, as follows:

- synthesizing the MEES prognostic model and the system providing observational data in one information module;
- assimilation of the observations by the numerical model of the MNIC;
- selection of the method of management through model simulation experiments;
- managing the complex by virtue of adaptation of targets to the real conditions of functioning.

The decomposition of the systems concept of MNIC development yields a tree of evolutionary purposes, whose upper stratum determines the principal directions of study of marine ecological-economic systems:

- the development of a hierarchy of dynamic models of MEES, having various degrees of averaging (aggregation);
- the construction of information technologies designed to control consumption and regeneration of marine resources;