

## ELECTRONIC INFORMATION SYSTEMS FOR MONITORING OF POPULATIONS AND MIGRATIONS OF INSECTS

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The purpose of the work was to analyze existing information systems (IS) of biological objects and to propose the methods for development of such IS for insects on the example of *Noctuidae* (*Lepidoptera*). A detailed analysis of technical information concerning the distributed networked systems, access to computer systems to the common data in electronic IS and the organization of biomedical databases in the Internet was done. The peculiarities of IS' prototypes development for environmental monitoring of the fauna have been discussed, in particular changes in the number of butterflies' populations throughout France (including western and southern departments), the *Noctuidae* (*Lepidoptera*) in the steppe zone of Ukraine (Striltzivskiyi Steppe), and the development of such IS for all territory of Ukraine.

The results could be used to develop electronic IS for other biological organisms.

**Key words:** electronic information systems, bioinformatics, insects *Noctuidae* (*Lepidoptera*).

*Peculiarities of biomedical objects important for electronic information systems construction.* The works for construction and development of new electronic information systems (ISs) with biomedical databases (DBs) are actual and important in biotechnology as well as in biology and medicine in general. During application of modern information technologies (IT) and computer technologies (CT) in these spheres, it was necessary to keep in mind following peculiarities of biomedical objects that are important for electronic information systems construction [1]. These peculiarities complicated ever the computer processing of biological data, results, and development of technical information systems (tIS) in general. This was, first of all, the problem of the complexity of medical and biological objects, which has several reasons [1].

1. The first reason was an objective one: the complexity of biological organisms by

themselves. On the Earth there are millions of species that are characterized by a large variability of individual organisms, populations, and etc. The species have complex chemistry, physiology, developmental cycles and behavior, which are the result of billions years of evolution. There are hundreds, if not thousands of ecosystems, in which many species are associated also with large number of complex relationships.

2. The second reason was a subjective one. Since ecosystems are located at different territories of different countries, they often interfere with the interests of different groups of people: scientific, economic, commercial, others, which influence on the process of biomedical objects studies. During field studies, monitoring, the data obtained in different ecosystems often differ in precision and accuracy, they are made in different meteorological or geographical conditions. Many of such observations were made by

amateurs, but their results are important too. When creating electronic databases all such field data observations and experiments should be formalized, unified and standardized.

If to speak about genetic materials that characterized the certain types of ecosystems, then these obtained scientific data are really accurate and conform to generally accepted standards. Most often these data were the ideal material for electronic DBs and ISs. The ambiguity appeared when an IT professional during his work must match these exact data, for example, with the name of the specie. But there are not exact standards of specie names still; the systematic of biological species is under the revision constantly. Besides of these, the constant evolutionary changes of biological organisms are continuing. Also there is a fact that many species on the Earth have no their names still.

The application of IT / CT in biology was very complicated also because that most of the existing computer methods are developed for certain conditions, certain tasks, limited time periods. In reality, the scientists deal with the evolution (both molecules and species), processes during time intervals in hundreds and thousands of years, with organisms that consist of billions of molecules. There were no standard methods still for the solution of such problems; they needed to be invented. The simple transfer of the methods developed already for technique or for other branches of sciences, a lot of valuable biological information were lost.

A particular problem was the digitization of biological data, on which all modern biological knowledge is based. Up to 2001, even in the United States, where the biological data digitizing process was initiated, it was necessary to digitize information on more than 750 millions of biological species [1]. Consequently, this labor-intensive task needs to be solved all over the world.

Biological ISs were designed either for academic purposes — to maximize the accumulation of information about the groups of living organisms, or for the needs of the economy, in particular for biotechnology, for monitoring of polluted areas in industrial centers, and etc. [1–10]. Mathematic methods as well as models that we described in our previous articles and published by other authors also may be used for ISs functioning or to be simulated in result of their functioning [10–81]. A spectrum of mathematic methods were used for the newest biomedical ISs elaboration [1, 11, 75, 77–80, 82–146, 159].

Content for described in this article databases was obtained usually from the results of biological and medical observations and experiments [10, 12–17, 24–44, 47–49, 61, 68, 71–74, 82–90, 94, 104, 106, 109, 111–113, 125–159]. All such technical information systems (tIS) are electronic databases (DB) distributed in networks today [1–11, 25–69, 90–109, 112–120, 159]. Present work was done after the analyzis of approximately 250 current publications in fields of biotechnology, other linked branches of biology and technology, including articles with original authors' works. The newest parts of authors work were supported by patents [12, 160–167].

*Biomedical information systems for environmental eco-monitoring.* If to monitor the changes that occurred with species populations and their areas under different influences over a period of time, and to record the data about their changes in the electronic databases, then such data can be used for computer modeling of species' populations (areas). If it was registered that areas of these species' distributions reduce, it was necessary to find the reasons of this decrease. If the reason of these area changes was, for example, the damaging anthropogenic impact, then it was necessary to give appropriate recommendations for the neutralization of this impact. Such an algorithm should be put in basis of modern scientifically grounded nature conservation [1, 91].

It was difficult to achieve rather representative geographic survey and the survey in which fauna changes could be traced during a certain time. Such works are quite expensive usually, and the quality of records varies even in the case of accurately executed work. However, because of constant worsening of environmental living conditions, because of constant climate change, then the significance of studying of various bioorganisms' distribution changes are increasing. In our investigations we (Prof. Zoya F. Klyuchko and Dr. Elena M. Klyuchko) have studied such influences on organisms-bioindicators *Noctuidae (Lepidoptera)*, and a part of our works under the DBs and ISs construction we did with this biological material [1, 9, 42, 135, 136, 139, 140, 144, 156, 157, 159].

An important condition for organization of the local IS network for eco-monitoring was the construction and perfect organization of local networks of biological ISs. They could provide an opportunity for effective organization and cooperation of teams of scientists and other professionals. Nowadays, all local scientific

establishments in Ukraine have already constructed local computer networks, which give users the possibility of more effective group work with the joint use of hardware resources — printers, scanners, modems, faxes, as well as software and information resources, including DBs. As through own local computer, the user can also control the databases using a “database management system” (DBMS) at the local computer network. In general, program-application can be run under the control of DBMS or its kernel, or to be independent one. Most often, the electronic ISs in Ukrainian scientific establishments were based on a ready local computer network of this research institution, and contained only a client-server database at this local network. Later the systems with configuration of such types were transformed into the corporate systems in the Intranet. Such system, unlike the client-server version, is focused not on the data but on information that is available easily to biologist-scientist and combines the benefits of centralized systems for many users of client-server type. However, the separate programs of such systems and contents of some databases — simulation and animation models, etc. — had their value also outside of local ISs, for example, for universities. Therefore in future, the certain content (separate sets of data, partially — the information) from ISs of domestic scientific institutions would be desirable to visualize in the Internet [1], and to make it available in the global network. Such measures allowed both to improve the acquaintance in the world with Ukrainian achievements, and to establish better international cooperation for the further progress of our science and technology. In this article, we will consider a number of specific examples of electronic ISs — domestic and foreign — which could become successfully the prototypes in further IS development for biotechnology.

*Analysis of electronic information systems for monitoring of organisms-bioindicators.* Analyzing the current published data on developed electronic ISs for organisms-bioindicators monitoring (most of all we are interested in ISs for insect monitoring), it is necessary to remember the following [1].

1. The possibility of usage of electronic ISs for the registration of organisms-bioindicators in Ukraine for our domestic scientific practice, for nature conservation or for works in agriculture. It would be noted that all the elements necessary for large-scale ISs’ development and their implementation in Ukraine we have today. The

quality standards of each constituent element of such ISs in Ukraine are enough high today and this allows to obtain positive results. However, in our country there is a peculiarity that have to be taken into account when constructing such systems. The peculiarity is that the large-scale system for nature protection, crops protection, and etc. was developed during the USSR period in Ukraine; this system was perfect for its time. This system united numerical professionals in biomedical sciences, it included also numerical “biological research stations” (bio-stations) for nature observations and studying, significant number of nature preserves with relevant scientific units where were accumulated the results of living organisms’ observations for decades, including pests of agricultures, and etc. During long decades biological expeditions were financed, the works of individual professionals and amateurs in biological data collections were supported. All this networked and branched structure operated successfully until the 1990s of the XX-th century, and partly it works still. The achievements of these works were in successful management of agriculture, implementation of environmental measures, and so on. For example, the catastrophic mass migrations of locusts (*Locustae*) from the Danube Delta to other territories of Ukraine were stopped in the early 1960s due to successful works of young Ukrainian biologists. Doctors-epidemiologists and biologists stopped numerical mortal epidemics here (human as well as animal), and so on [1, 42].

2. The disadvantage of this monitoring system in Ukraine in XX-th century, from contemporary point of view, was the lack of data digitization, lack of computers, and, consequently, inability to use modern information and computer technologies (ICT). Even today the information about significant part of results is stored as paper versions and, therefore, it is difficultly accessed. Necessary contemporary requests are that the bio-stations or other observation points should be better computerized, which now is financially possible (if to use mostly inexpensive computer models). Consequently, even basing on the developed ready network of domestic bio-stations, it is possible to develop efficient electronic information systems, for example, for tracking of migrations of locusts (*Locustae*), moths (*Noctuidae*, *Lepidoptera*) and other organisms. In domestic practice, probably, it may be advisable to make local systems of personal computers (PCs) of bio-stations as basic elements for future electronic systems for bio-organisms monitoring [1].

3. In process of development of domestic electronic monitoring systems, it is important to adhere one of basic principles of Internet systems. This is the principle of decentralization, which in theory increases the reliability of such ISs: when one node fails, its function performs another similar one. In today's practice in Ukraine, the decentralization principle is very natural and appropriate. Since the individual networks' segments are developed today spontaneously by individual professionals and amateurs in biology, they are actually a networked union of more or less equal elements, and priorities in such networks are not well defined in comparison with similar networks in some foreign countries in Western Europe, America, Australia [1].

*Network systems with distributed databases.* The networked systems with distributed databases are used successfully in world practice today [1]. Distributed database is constructed from several fragments located in different nodes of the network. They can be managed by different database managing systems (DBMS) from the point of view of programs and users who access the distributed database outside this system; such system can be perceived as a single local database (Figs. 1, 2).

Information about the location of each part of the distributed database and other necessary information was stored in the data dictionary. Such a dictionary can be stored in one of the nodes, or be distributed. In order to ensure correct access to the distributed database, a two-phase protocol for transaction record was used.

*System access to common data.* The main objects of access in contemporary network electronic ISs can be: the database as a whole,

separate tables, records, and etc. [1]. When accessing the common data, DB management tools provide two main access methods: monopoly and collective. As IS objects of access can be the specifications of reports and on-screen forms, requests and programs.

*Concept of signal transmission in the development of electronic information systems in biotechnology.* Lets investigate the possibility of transferring of some approaches and concepts in radiophysics into the practice of development of networked computer ISs for biotechnology [43]. In process of development of computer systems for biology and medicine, the information side of problem solution, the technical IS details, mathematical justification, and solving of IS implementation problems are considered usually. However, there is another, equally important approach exists also. This is an approach from the point of view of classical radiophysics, when the information presented in the form of signals that pass through the links of the classical chain:

1. Receiver-transmitter →
2. Channel of signal transmission →
3. Receiver-transmitter →
4. Channel of processing (analysis) of observational data (measurements).

Below in present article it will be shown that this sequence, which has already become classical for physical processes, in fact can be accepted in biology and medicine, where it can be accepted for the construction of medical and biological ISs and devices. However, during this scheme use in these spheres, each link will have a different physical meaning (and hence, technical implementation).

*An analysis of experience of IS prototype construction for biotechnology and eco-monitoring of fauna.* One of interesting examples of modern IS for environmental

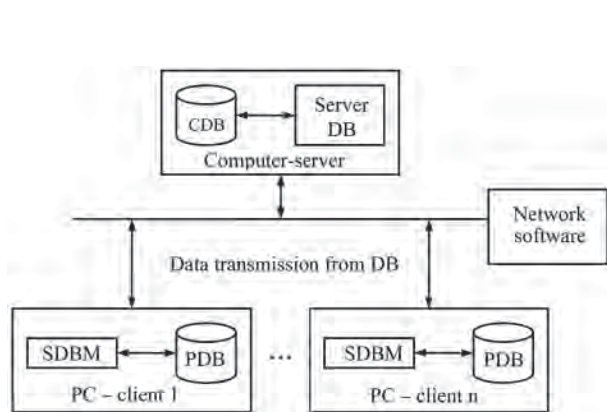


Fig. 1. The simplest scheme of electronic information system with databases' server [1]

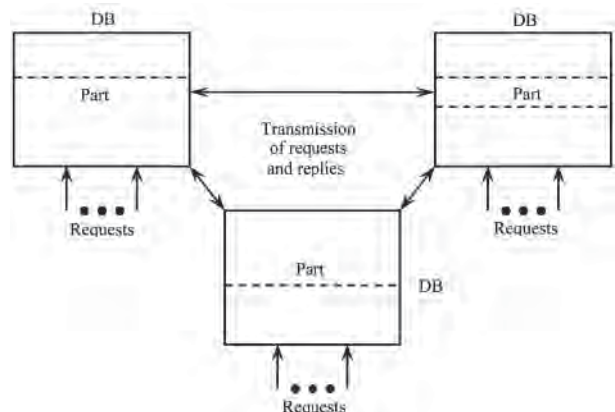


Fig. 2. Distributed databases of electronic information systems [1]



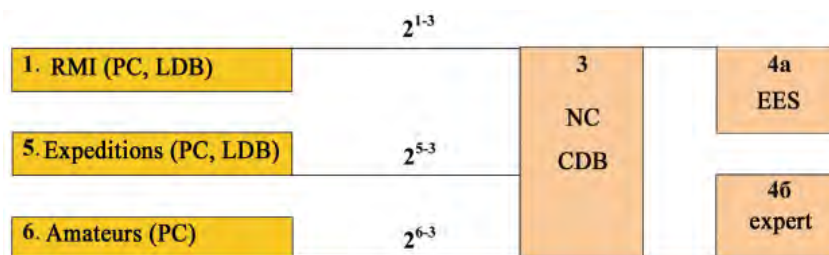


Fig. 3. Structural scheme of IS for tracing of insects' migrations

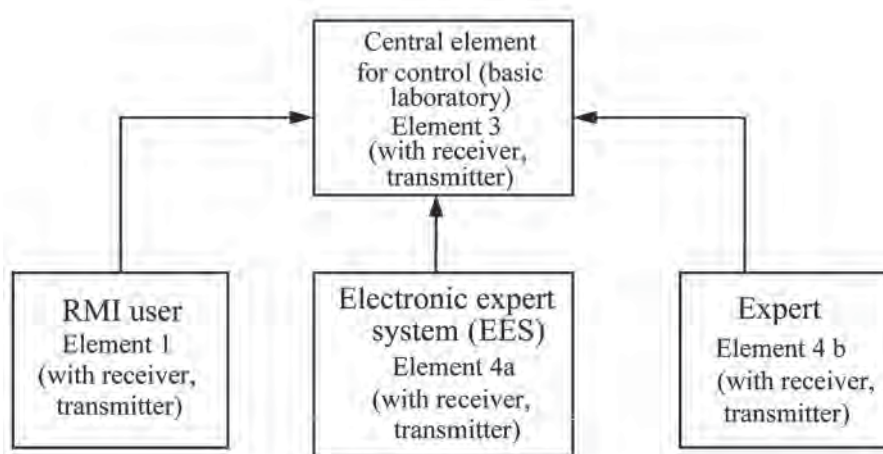


Fig. 4. Fragment of structural scheme of IS for tracing of insects' migrations

monitoring and agricultural services was the IS, that had been developed in Australia [1, 15, 43]. This information system consisted on two remotely-spaced radars that were used for insect monitoring (RMI); they both were connected to the node computer (NC) of the basic laboratory (Figs. 3, 4).

Each RMI was equipped [15] with meteorological surveillance devices under the control of portable computers (PCs) that allow receiving and analyzing the data. PCs were connected to node computer (NC) host computer through a modem, and then connected to a public telephone network. PC-NK communications were used to transmit observation data, to perform remote services and to conduct diagnostics. A specially organized automated system was developed to analyze meteorological information and the data about insects' migrations, recorded by the radar. On the base of this analysis the statistical reports and their graphical representations were prepared daily according to information received by radars. The reports and graphs provided the data on the intensity, amplitude, velocity and movement of insect migration directions, orientation, size and frequency of migrant wings, as well as weather conditions at the surface of each point of survey. Such

reports were transmitted to NCs and inserted automatically into the Internet pages, which users could see since 12.00 p.m. next day.

This network was used for environmental research in regions where insects' migrations are possible [15], for predicting of mass invasions of such dangerous insect pests like locusts, which can completely destroy the annual harvest. Network technologies applied in this method allow remote radar control through the network, as well as provide the user promptly with insect tracking results in a convenient and easily understandable manner. The RMI's radars were highly specialized, they can provide high-quality and quantitative information on high-altitude insect migrations (above 200 m) in the selected region. Radars worked in vertical sounding modes and detect insects flying over them. There were two types of conducted analysis. The primary type of analysis, called quantitative, was a conical scan, during which the size, shape, direction of movement, orientation and velocity of insect clouds were determined. During the secondary analysis the vibrations of insect wings were detected, their characteristics were determined (frequency of the wings vibration, etc.); these characteristics were the main in the set of parameters, which subsequently determine

the type of migratory insects. The results of the primary and secondary analyzes of both RMIs were recorded on PCs of radar centers. PCs servicing the RMI were connected to the internal network (intranet). Information from them was transmitted to an external Internet networks; there it was stored at server from which the users can visualize it on their own computers through standard browsers. After conducting a series of studies during several years and accumulation of results in the databases, it is possible to determine the frequency and seasonal patterns of migratory insects' movements in different directions, and subsequently to predict the insects' migration. In addition, basing on datasets obtained from radar, one can construct decision making computer system.

Since all elements of this IS (two RMIs, NCs, all PCs, etc.) were connected online, and the described operations were performed by RMI in automatic mode, RMIs can perform the data collection functions remotely and independently from the laboratories that analyze and interpret these data. In the future, the data were transmitted to the centers where the places of control, the centers of scientific expertise, as well as the operating system for managing of pest number control were located. Although certain decisions were made by electronic system, it is also necessary to involve in this scheme an expert-biologist to make sometimes the adjustments. Experts-biologists in this system also participated in the organization of expeditions to different regions insects' collection purposes. Collected information was transmitted to the basic laboratory for scientific interpretation and for the operation of the electronic decision making system. This system was developed to track the number of such insect pests like *Chortoicetes terminifera* and *Helicoerpa punctigera* [1, 43].

*Analysis of the structural scheme of electronic information system for monitoring of bioobjects migrations.* Let's analyze the described above example in terms of the concept of signaling [1, 43]. An electronic prototype system was a new step in insects monitoring, in controlling of environmental situation at large territories and in agriculture transforming into a science-intensive industry. This system was highly specialized, efficient and technically enough simply implemented. Developing this idea we constructed original IS that differs in some details and solutions from Australian prototype. Its structure and functions are described below, and also at (Figs. 3, 4). Such system would be based on abovementioned set

of domestic bio-stations and other previously developed system elements, and it is really important for Ukraine, where agricultural incomes form the significant part of national income.

*Element 1.* The complex of RMI performed the functions of remote insect detection. These data were transmitted to the RMI intranet where the data were collected in computers' databases. Then the data were processed according to procedures of primary and secondary analysis and transmitted outside. As one could see, the element 1 had a complex structure and can be subdivided into elements by itself (set of PCs, some of their own databases, etc.). Let's consider element 1 as integral, without division into sub-elements for simplification. Then it could be seen as a receiver-transmitter (reception of control signals from the center — from the decision-making system and data transmission to the center). Element 1 was equipped with computer interface that connect it with element 2.

*Element 2<sup>1-3</sup>.* It was a channel for signals transmitting from element 2 to the central control element 3. As one could see, this channel was technically implemented as Internet system based on cable networks. The use of a wireless data transmission system was possible too.

*Element 3.* The central element of control, implemented as a basic laboratory. It also has a complex structure. First, it contains NC, to which the data from RMI (element 1), PC research groups (expeditions, element 5), individual users (item 6) flowed. Secondly, it contained a database for all received data recording. Element 3 was combined with elements 4a — an electronic expert system and 4b — an expert-biologist. Element 3 was also provided with computer interface that connected it with element 2. Thus, element 3 can also be considered as receiver-transmitter (receiving data from element 1 and reversal transmission of control signals from the center and elements 4a, 4b — decision making systems to element 1).

*Element 4a.* Electronic expert system (EES). Based on the databases of element 3, the system performed a number of analytical operations, for example, to determine the specie of migratory insects and to make decision about the level of danger of this specie. If information from RMI elements 1, 5, 6 was recognized as dangerous one, EES sends corresponding message to element 1 and visualizes it in the Internet, from which each user can find it through standard

browser. As a result of obtaining and/or visualizing information about the dangers in the system, the commands were generated about the preventive and protective measures for environment ecology or agriculture. In accordance with these functions, the element 4a also had an interface for its connection with element 3. In addition, the element 4a also had an interface for its connection (via element 3) with element 4b (expert-biologist) and with elements 5 and 6, from which the data are received also.

*Element 4b.* In cases of ambiguity, lack of information from element 1, in other non-standard situations it might happen that corresponding decision can not be done by element 4a. Then the system switched the work to a living expert-biologist who was at this time on duty (element 4b). In this case, the functions of data analysis, decision-making and transmission of control signals to element 1 are moved to element 4b. To perform the above functions, element 4b had interfaces for combining it with elements 3, 4a, and elements 1, 5, 6 (via element 3) for obtaining of additional data.

*Elements 5 and 6.* The part of the data that had to be analyzed when making a decision, comes from the research groups (expeditions, element 5) and individual users, like farmers or amateurs (element 6). Individuals (elements 5, 6) who collected such data and transferred them to element 3 do this via their own computers (PCs) using cable networks or wireless communications (through appropriate interfaces).

*Elements 2<sup>5-3</sup> and 2<sup>6-3</sup>.* These elements were the channels for signals transmitting to/from the central control element 3 from/to elements 5 and 6. In fact, they are similar to the above-described channel for signals' transmission from the RMI (element 2<sup>1-3</sup>). These channels were also implemented through the Internet based on cable networks or needed a wireless data transmission system. In system-prototype, the functions of this channel were carried out also through the Internet site that visualizes data (for example, in form of tables, reports, individual data, and etc.) about the current state of environment.

*Organization of biomedical databases in the Internet.* During our work under the development of ISs with DBs for biotechnology, we proceeded from the fact that the data in DBs would come from many points (bio-stations, field expeditions, amateurs, and others, Fig. 5); and IS information had to be visualized in the Internet [1].

Therefore, the idea immediately began to evolve from the corporate intranet system construction. Such system united the advantages of centralized systems for many users of client-server type. The following features characterized her: 1) the server generates information suitable for the use, but not the data (for example, in case of DBMS there were database records); 2) during the exchange between client and server, the open standard protocol was used; 3) — system-application was at server, and therefore for user work on client computer it is enough to have a program-navigator (Figs. 1, 2) [1, 43].

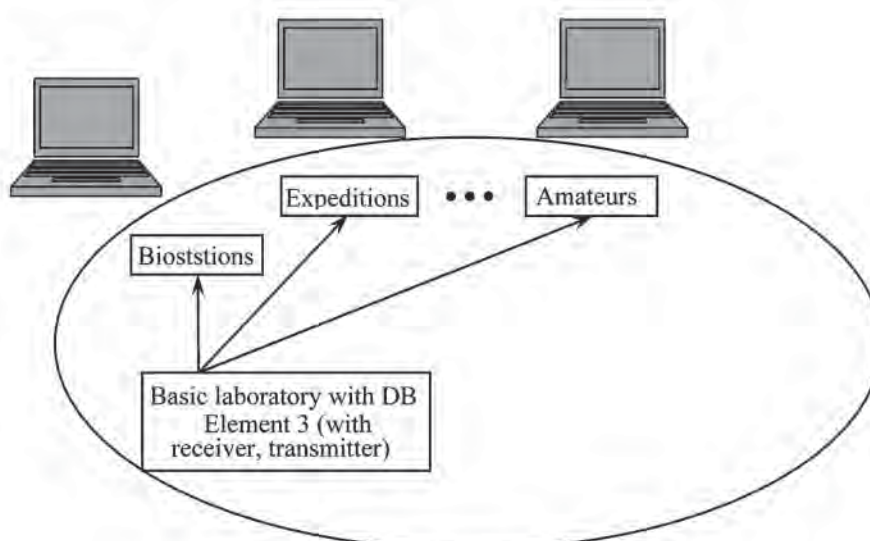


Fig. 5. Scheme of the part of "EcoIS" system for tracing of insects' migrations

For DB accessing from client side, the main mean of implementing of interaction mechanisms between Web-client and database server was Java. Additionally, ActiveX control elements can be used. As auxiliary information processing tools on client side JavaScript, Jscript, and VBScript languages are often used to extend the capabilities of declarative HTML language based on the addition of procedural means (but these tools were not used for interaction with database). Programs — scripts were executed on computer Web — browser in interpretation mode. To access database servers from Java-programs have been developed the standard JDBC (Java DataBase Connectivity — database compatibility for Java), based on ODBC concept. The JDBC standard was developed by Sun/JavaSoft companies and it provides universal access to various DBs in Java language.

In access model to database on the server side, the reference to the database server is usually executed by calling of the Web server programs by another programs that are external to them in accordance with conventions of one of CGI and API interfaces. Programs developed in accordance with CGI interface were called CGI scripts. External programs interact with database server using SQL language, for example, directly to a specific server, or using the ODBC driver [1]. External programs were written in programming languages like C, C++, PHP. Access to database on the side of application program server was used during the use of these programs' servers. In this case, the main language of development of distributed applications was Java.

*Publication of information in the Internet.* The visualization of information from "EcoIS" in the Internet was made using widely spread modern technologies, so this does not require a special description. It is necessary to emphasize only that for such publication it is necessary to solve a number of routine tasks, known to all developers of global network software [1].

1) Building of IS in the Internet basing on the multi-level architecture of the database.

2) Organization of DBMS interconnection on different platforms.

3) Use in the Internet of information from existing local network databases. These tasks appeared when necessary to publish an information from intranets in the global network.

4) Construction of local intranet — networks basing on publication technology.

5) Databases in the Internet. In this case, the local networks were built on Internet

principles with the availability to access the global network. It is The use of the databases to organize information and use the SQL language to find the necessary information in the database were recommended.

6) Use of DBMS tools for data security.

7) Standardization of the user interface basing on the use of Web browsers and user-friendly interface design [1].

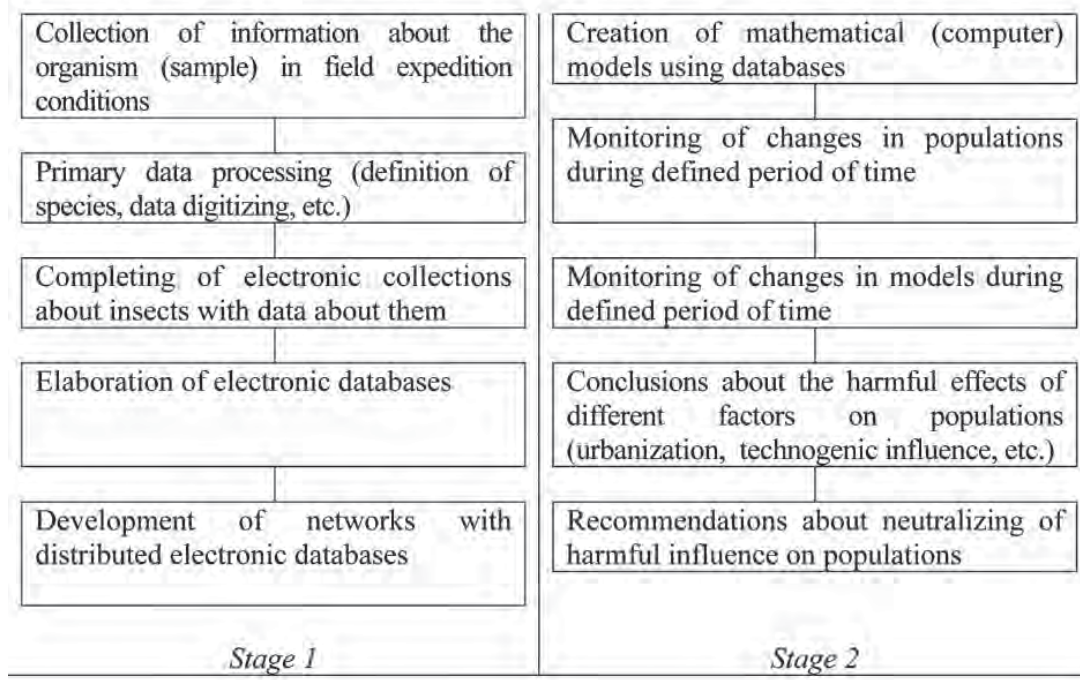
Above mentioned could be illustrated also at Fig. 1 and 2. The easiest scheme of electronic information system with databases' server is shown on the Fig. 1. The distributed databases of electronic information systems are given in Fig. 2.

*Algorithms for environmental monitoring of fauna.* The algorithms of eco-monitoring of the fauna may be subdivided naturally into two groups of steps (Fig. 6). [1]. Modern electronic databases with spatial information distribution in the Internet and modern mathematical modeling based on the data from such databases, similar interdisciplinary approaches allow us to investigate at contemporary level how the geographic, ecological and environmental factors acting continuously every day, as well as the these factors that influenced throughout the history, so, how they both effect on the organisms' spread and biodiversity. In addition, such approaches allow us to determine how to preserve better this biodiversity in context of intensive increase of anthropogenic influence. Environmental monitoring of biological organisms to prevent their numbers reduction as a result of various damaging factors — urbanization, man-caused impacts, and etc., are important contemporary tasks. The sequence of steps for such problems solution could be described by an algorithm (Fig. 6) in two steps [1].

*Eco-monitoring of bioorganisms of Striltsivskyi Steppe preserve (Ukraine).* Electronic databases with spatial distribution of information in the global Internet network, mathematical modeling based on data from such databases, allow us to investigate at the current level how geographic and environmental factors influence on the distribution and number of organisms. Such methods can be used to preserve a healthy environment for people who live in ecologically unfavorable conditions. The generalizations presented in this section are based on original data as the result of long-term monitoring of insects' — moths' (*Noctuidae*, *Lepidoptera*) fauna in Striltsivskyi Steppe preserve (Ukraine, Luhansk region) [1].

Fauna monitoring of different biological species have been conducted in Ukraine during





**Fig. 6. Two stages of ecomonitoring data processing using DB construction:**  
*stage 1* — construction of CBO and electronic DB;  
*stage 2* — monitoring of populations and areas of the species using the DB based models

the last decades, but such works are irregularly often; during these studies only a few species were monitored sometimes. Some original data of environmental monitoring of fauna of Striltsivskyi Steppe preserve (Luhansk region, Ukraine) by the authors are given in the fragment of the Table.

This *Noctuidae* fauna monitoring has been conducted during more than 40 years (from 1965 to 2007) by Prof. Zoya F. Klyuchko (Shmalgauzen Institute of Zoology of the National Academy of Sciences of Ukraine). During this time there were registered 318 species from 144 genera of *Noctuidae*. Taxonomic analysis reveals that the largest number of species belongs to 17 genera: *Cucullia* (21 species), *Hadena* (13), *Mithymna* (12), *Acronicta* (10), *Catocala* (9) and *Apamea* (9), *Xestia* (8), *Lacanobia* (7), *Euxoa* (7) and *Agrotis* (7), *Eublemma* (6) and *Caradrina* (6), *Lygephila* (5), *Amphipyra* (5), *Sideridis* (5), *Orthosia* (5) and *Noctua* (5). One of the characteristic features of the moths fauna was the large number of genera, that are represented by 1–4 species (127 genera, or 88.2%). The second peculiarity was that composition of moths species' collected in different years varies significantly by their number — 191 specie on 1965 and 260 ones on 2006–2007 (Table). But international experience of such works in

other countries evidences that such a picture, however, may be the result of the improvement of methods of observation and registration of insects over time [1].

During the 40 years of monitoring in this preserve, the numbers of meadow-forest species have increased (90 or 28%). This increase was registered both in species number and in frequencies of individual moth samples collecting during the season. At the same time, the number of forest species increased (18 or 5.6%), including the genus *Catocala* (*C. fraxini* L., *C. pacta*, *C. elocata* Esp., *C. hymenaea* Den. & Schiff.). Also the numbers of *Amphipyra* and others increased too (Table); which was an important feature of changes in the local fauna. This fact can be explained by an increase of territories, occupied by forest bushes and trees.

It is necessary to emphasize the significance of obtained original results of long-term monitoring of Striltsivskyi Steppe moths fauna and the huge amount of work done. It should be noted that the accumulation of large arrays of such results is only the first step in the algorithms of contemporary environmental monitoring (but very important step!).

As was noted above in this section when analyzing foreign experience, such reliable information has to be proposed further to

The results of dynamics of changes of *Noctuidae* species quantities, obtained as a result of long-term fauna monitoring by Prof. Klyuchko Z. F. in Striltsivskiyi Steppe preserve (Luhansk region, Ukraine)

Name of specie	Number of moths' registered in different years				Distribution in biotopes
	1965	1996–2002	2006	2007	
<i>Eublemma purpurina</i> Den.& Schiff.	31		21	8	Fost
<i>Phytometra viridaria</i> Cl.	30	1	2	2	Fost
<i>Lygephila lusoria</i> L.		3		3	Fost
<i>L. lubrica</i> L.	33	8	3	4	Fost
<i>L. craccae</i> F.	34		3		MeFo
<i>Drasteria caucasica</i> Kol.	28		2	1	St
<i>Euclidia triquetra</i> Den.& Schiff.	464	1	6	1	St
<i>Catocala hymenaea</i> Den.& Schiff.		1	56	26	Fo
<i>Abrostola tripartita</i> Hufn.	12	2	4	2	MeFo
<i>A. asclepiadis</i> Den. & Schiff.	2		26	3	FoSt
<i>Trichoplusia ni</i> Hbn.	2		2	13	FoSt
<i>Macdunnoughia confusa</i> Steph.	70	3	13	12	FoSt
<i>Diachrysis chrysitis</i> L.	80	2	71	11	Eur
<i>D. stenochrysis</i> Warr.	70	3	82	12	Eur
<i>Autographa gamma</i> L.	122	4	5	13	Eur
<i>Phyllophila obliterata</i> Rbr.	100	2	1	6	FoSt
<i>Acontia lucida</i> Hufn.	210	3	9	12	FoSt
<i>A. titania</i> Esp.	70	2	17	14	FoSt
<i>A. trabealis</i> Scop.	986	7	6	32	Eur
<i>Oxycesta geographica</i> F.	1397	5	28	86	St
<i>Acronicta megacephala</i> Den. & Schiff.	4	3	16	10	Eur
<i>Mycteroplus puniceago</i> Bsd.	104		14		FoSt
<i>Tyta luctuosa</i> Den. & Schiff.	210	5	88	79	Evr
<i>Cucullia dracunculi</i> Hbn.	14	4	6	4	FoSt
<i>Calophasia lunula</i> Hufn.	94		5	16	FoSt
<i>Epimecia ustula</i> Frr.	120		4	7	St
<i>Schinia scutosa</i> Den. & Schiff.	186	7	15	16	Evr
<i>Heliothis virescens</i> Hufn.	60	1	2	2	Evr
<i>H. maritima</i> Grasl.	143	5	5	22	Evr
<i>Helicoverpa armigera</i> Hbn.		2	8	9	Evr
<i>Periphanes delphinii</i> L.	3		29		St
<i>Cryphia fraudatricula</i> Hbn.		1	5	10	FoSt
<i>Pseudeustrotia candidula</i> Den.&Schiff.	120	4	39	31	Evr
<i>Caradrina wullschlegeli</i> Pueng.	53			1	FoSt
<i>Hoplodrina octogenaria</i> Goeze	15		1	9	MFo
<i>H. blanda</i> Den.& Schiff.	80	1	2	4	MFo
<i>Athetis furvula</i> Hbn.	21		1	8	MFo
<i>Actinotia polyodon</i> Cl.	1		52	6	FoSt
<i>Apamea ferrago</i> Ev.	408		4		St

Note. Designations of species depending on the biotopes of collection: FoSt — forest-steppe; MeFo — meadow-forest; St — steppe; Eur — eurybionts.

digitizing and organizing in the form of databases distributed at IS-based networks.

The table can actually be seen as an example of a printed table, an output of relational database. In fact, it is only a short fragment with dozens of records from hundreds of observations collected by domestic biologists over decades of professional work. All information in it may be in future the subject for processing in accordance with the algorithms described above for relational databases. When structuring the data in the form of such databases, further environmental studies and forecasts become possible [1].

With effective conservation practices, it would be advisable to use such data for the purpose of ecological forecastings, especially because of today's technogenic pressure in Ukraine, when the natural steppe areas are shortening quickly. For the further, the details of such databases would be nice to analyze using series of mathematical methods discussed in publications [1–9]. Using such analytic methods it would be possible to find whether the number of species were changed or not, whether the species' spectrum was changed or not, and etc.). Successful prediction of fauna changes would promote the further use of regression methods for the design of digital maps of species on the base of local databases connected in ISs. Comparing the results of analytical processing using above described novel computer methods and traditional ones one could discover sometimes that output results are different in both cases; and this is important for the implementation of large-scale economic projects linked with monitoring. On Fig. 7 there are some *Noctuidae* (*Lepidoptera*) from Prof. Klyuchko private collection used for our electronic databases construction.

*Monitoring of bioorganisms' populations using databases.* Data from electronic collections of biological organisms (CBO) are available for further processing [1, 14]. For example, in recent years they have been used to make patterns of species distribution (modeling of areas changes). The influences harmful for population could be studied as on one specie number monitoring during any time period, as well as monitoring of species' populations and their areas of distribution throught the country. For the illustration let's observe an ecological problem solution by modern computer and mathematic methods in different departments of France [1, 14]. The monitoring of species' changes

in time was done and the conclusion was made about the presence of anthropogenic influence in studied regions. Two models there were developed, the adequacy of which was compared [14]: 1 — geographic model (GM) based on directly obtained data, and 2 — model based on the data from neighborhood regions (NM — neighbor model). For GM model there were used regional data: latitude, longitude and altitude (above sea level) data; they were called "direct GM data". While the data in framework of the second model (data on the number of species and distribution of species in surrounding regions) were based on the data from the nearby areas according to NM. Both models were done for significant fluctuations of species composition that characterized the rich fauna (68–78%). However, during the application, the NM demonstrated more successful results than GM, where only geographic variables were taken into account. A large amount of the data about species distribution was calculated according to logistic and auto-logistic regression models (222 of 246 species, 90.2%). Auto logistic models were based on information from neighboring regions. It was impossible to perform such analysis for the cases of rare species, when 5 or 6 of them only were registered in one administrative unit (2.4%), or in cases of widespread species that were registered in more than 90% of administrative units (7,3%). It was found that the use of auto-logistic models dominated over the logistics in case of the species' distribution study (with the use of stepwise logical regression); the use of variables, registered in near-located regions helped to creation of 64.5% successful models of species distribution (22.8% models had not such data). The simple measure of proximity (not dependent on distance)  $C_2$  dominated for most models (89 of 246 species, 36.2%); unlike the distance-weight dependent measure ( $C_1$ ; 77 of 246 species, 31.3%). The models that were developed, appeared to be valuable in detecting of faulty records and fauna losses, in order to fill the "white spots" during the design of fauna maps in regions. Studies demonstrated a significant visible reduction in species' number in the western and northern regions of France. In addition, significant changes in species' number for some administrative units in time period after 1970 were detected, as well as differences in the data that were forecasted and those that were detected in reality. In some regions the probabilities have been calculated for some



Fig. 7. Some materials of *Noctuidae* (*Lepidoptera*) used for electronic DB construction in our works (photos are from private collections of Prof. Klyuchko Z. F. and from her monograph [168]):  
 1 — *Cucullia biornata* Fisher von Waldheim, 1840; 2 — *Cucullia umbratica* (Linnaeus, 1758); 3 — *Cucullia lucifuga* ([Denis & Schiffermüller], 1774); 4 — *Lamprosticta culta* ([Denis & Schiffermüller], 1775)

species; these values were presented and published in the Internet [14].

For stepwise logical regression, two measures of “closest neighbors” were used [14]:

$$C_1 = \left( \sum_{j=1,k} W_{ij} y_j \right) / \sum_{j=1,k} W_{ij} \dots, \quad (1)$$

where  $C_1$  is the averaged number of regions that had a weight, among the set of  $k_i$  neighboring regions;  $i$  and  $y_j$  — are the presence or absence of species in area  $j$ . The weight given to the area  $j$  —  $w_{ij} = 1/h_{ij}$ , where  $h_{ij}$  — is Euclidean distance between regions  $i$  and  $j$ . In the developed scheme  $k_i = 8$  units — the nearest neighboring regions were selected. This number corresponds to the maximum number of neighboring regions for the case where the selected regions-units conditionally had square form, and two times higher than the number recommended for the units of hexagonal form. For some regions the cases of more neighborhoods

have been studied. It was found that the distance between neighboring regions in this case exceeded the distances that butterflies can fly throughout their lives, except those species that migrate seasonally over long distances during their lives. Then

$$C_2 = \sum_{j=1,k} y_j / K_i \dots, \quad (2)$$

where  $C_2$  — is simply the proportion of areas in which the specie was registered, among the set of  $k_i$  neighboring district  $i$  [14].

So, if somebody use the methods of forecasting of changes in the number of species and their territorial distribution, developed by these approaches, they can fill the “white spots” on maps of nature. Such methods also allow more precise identification of regions that should be in the center of special attention. Regression methods allow to elaborate good models for predicting of changes in number of species and their distribution. Most species



have clearly defined distribution areas and borders that can be successfully predicted based on the main geographical variables (region, latitude, longitude, and altitude). Recently, in order to solve biological problems, the regression model was supplemented with auto-logistic functions, which allowed predicting a decrease in the number of species. The comparison procedure in the process of solving the problem of species propagation was further improved, using the possibilities of forecasting by the logistic and auto-logistic model (for nearby geographic points). The result of this work was to obtain the values of the probability of species distribution in different regions of the country [14].

Thus, in present article using the set of examples there were demonstrated that electronic information systems with databases about living objects are really necessary for professionals and amateurs today. We have investigated different examples of IS deeply, some important peculiarities of medical and biological objects that have to be taken into account during biotechnological IS elaboration were discussed. Analysis of electronic ISs for monitoring of organisms (bioindicators) has been done. Necessary technical information was given about: network systems with distributed databases, computer system access to the common data; organization of biomedical databases in the Internet; peculiarities of information publication in the Internet. Also an analysis of IS development for biotechnology and eco-monitoring of fauna and analysis of IS structural scheme for monitoring of bioobjects migrations were done. The data about eco-

monitoring of bioorganisms' populations in France and in Ukrainian Striltzivskyi Steppe Preserve were given.

Analyzing examples of electronic systems for insects' monitoring, it is necessary to emphasize the following. If to develop and to apply in Ukraine IS similar to Australian prototype, then it should be noted that all elements that we have distinguished, analyzing the prototype, are present in Ukraine as well, but they are not functionally linked between themselves. There are enough number of bio-stations, preserves with relevant scientific units, highly qualified professionals who could realize such project successfully. The disadvantages of such domestic analog realization, from contemporary point of view are the lack of data digitization, lack of computers, and some others. So, basing on developed network of domestic bio-stations, it is possible to construct an efficient electronic system, similar to prototypes described above.

In the described prototype system from Australia, one of the basic principles of Internet systems was not realized: the principle of decentralization, which in theory increases the reliability of such ISs: when one node fails, its function performs the similar one. So, for our practical purposes (increase of reliability) some elements of prototype have to be duplicated.

For biomedical ISs successful construction they would be previously theoretically modeled using the concept of signaling from radio physics. The acceptance of this abstraction during the electronic ISs design for biomedical objects should be successful in construction of such ISs analogues.

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## ЕЛЕКТРОННІ ІНФОРМАЦІЙНІ СИСТЕМИ ДЛЯ МОНІТОРИНГУ ПОПУЛЯЦІЙ ТА МІГРАЦІЙ КОМАХ

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Метою роботи було проаналізувати наявні інформаційні системи (ІС) біологічних об'єктів та запропонувати методи розроблення такої ІС для комах на прикладі *Noctuidae* (*Lepidoptera*). Проведено детальний аналіз технічної інформації щодо мережевих систем з розподіленими базами даних, доступу комп'ютерних систем до загальних даних в електронних ІС та організації біомедичних баз даних в Інтернеті. Обговорено особливості створення прототипів ІС для екологічного моніторингу фауни, зокрема зміни чисельності популяцій метеликів на всій території Франції (в т.ч. у західних та південних департаментах), совок *Noctuidae* (*Lepidoptera*) у степовій зоні України («Стрільцівський степ»), а також подібної ІС для всієї території України.

Одержані результати можуть бути використані для розроблення електронних ІС для інших біологічних організмів.

**Ключові слова:** електронні інформаційні системи, біоінформатика, комахи *Noctuidae* (*Lepidoptera*).

## ЭЛЕКТРОННЫЕ ИНФОРМАЦИОННЫЕ СИСТЕМЫ ДЛЯ МОНИТОРИНГА ПОПУЛЯЦИЙ И МИГРАЦИЙ НАСЕКОМЫХ

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Цель работы заключалась в том, чтобы проанализировать имеющиеся информационные системы (ИС) биологических объектов и предложить методы разработки такой ИС для насекомых на примере *Noctuidae* (*Lepidoptera*). Проведен детальный анализ технической информации о сетевых системах с распределенными базами данных, доступа компьютерных систем к общим данным в электронных ИС и организации биомедицинских баз данных в Интернете. Обсуждены особенности создания прототипов ИС для экологического мониторинга фауны, в частности изменения численности популяций бабочек по всей территории Франции (в т.ч. в западных и южных департаментах), совок *Noctuidae* (*Lepidoptera*) в степной зоне Украины («Стрельцовская степь»), а также подобной ИС для всей территории Украины.

Полученные результаты могут быть использованы для разработки электронных ИС для других биологических организмов.

**Ключевые слова:** электронные информационные системы, биоинформатика, насекомые *Noctuidae* (*Lepidoptera*).