

The Role of the Regional Data Center (RDC) of the Pacific Research Fisheries Center (TINRO-Center) in North Pacific Ecosystem and Fisheries Research

Dr. Igor V. Volvenko

Pacific Research Fisheries Center (TINRO-Center), 4, Shevchenko Alley, Vladivostok, Russia

Abstract— In 2015 the Regional Data Center (RDC) commemorated its 41st year. The main goal of the Center is to collate data on the marine and oceanic bioresources of the Far Eastern region, the state of their environment and exploitation, and to facilitate the collection, analysis and processing of such data. The RDC is part of the Russian Far East Research Institute located in the city of Vladivostok. The full name of the institute is the Federal State Budgetary Scientific Institution Pacific Research Fisheries Center, or the TINRO-Center for short. Most of the work performed by the RDC is related to the Concept of Information Support for Bioresource and Ecosystem Research in the North-west Pacific. The Center is chiefly focused on: 1) the development and implementation of automated workplaces for scientific and technical personnel on expeditions and on shore; 2) the maintenance of an archive of primary expedition data on paper and digitally; 3) the development and management of large databases (DB) with data collected in scientific and research expeditions and while fishing; 4) the creation based on databases of higher quality IT products – knowledge bases and geographic information systems (GIS), containing the results of processed data from the long-term monitoring of the status of marine and ocean ecosystems; 5) the performance of any user request regarding the database and GIS for information support of the current scientific, practical and administrative work of all the institute's departments; 6) the development of new approaches to data processing and the automation of related processes through the creation of proprietary software; 7) the establishment of inter-institutional data exchange and the creation of DB for public use; 8) advice from the personnel of the institute on methodological issues related to the statistical and cartographic processing of data; 9) the development of regulations and normative documents regulating the relations arising from the collection, storage and provision of access to the data held in the RDC; 10) scientific work performed by RDC scientists, performed alone or in collaboration with staff from other laboratories. These ten areas of focus reflect the role performed by the RDC on a daily basis in providing information support for climatic and oceanographic research, the study of the state of marine ecosystems, short-term and long-term forecasts of the state of the fisheries resource base, the sustainable management of fisheries and mariculture, and the planning of research expeditions.

Keywords— *information support for fishing, the Far East, aquatic bioresources, monitoring, forecasting, database, geographic information systems, software.*

INTRODUCTION

Those or other such centers, which will be discussed in this report, were once in almost every fishery institute of the USSR. This is the legacy of universal mechanization and automation, where the most fashionable science was cybernetics, and the creation of various automatic control systems was at the forefront of scientific work. Their common history began in late 1969, when the Ministry of Fisheries of the USSR established the Coordinating Council for the development and implementation of an Automated Control System for the Fishery Sector (ACSFS) and a working group consisting of leading industry experts. Then at the Central Research Institute for Information and Technical-Economic Fisheries Research, the VNIRO and other organizations, specialized departments and groups to develop and implement the ACSFS were set up [1]. In the first half of 1970, many ACSFS laboratories, which by that time already existed in almost every sectoral research institute, were converted into departments for the development of the Automated System "Raw materials base" (ASRMB), and in the early 1980s into Regional Data Centers (RDC). Their main goal was to collect, store and process data, without which sound management (especially automated control) of fishing and the entire fishing industry is not possible. However, in the early 1990s, as a result of well-known political and economic reforms, the once famous "Long-term special program for the creation and development of an Automated Control System for the Fisheries Sector of the USSR (ACSFS) in the years 1986-2005" immediately ceased to exist, like the whole of the USSR. However, the RDC labs in most institutions were reorganized, renamed, merged with other departments or simply closed down.

The fate of each of these laboratories, the date on which they were established, and their length of service depended on the regional resource base, the scientific and research capabilities of the institute, visionary leadership, and the level of professionalism of its staff. In these terms the Russian Far East was fortunate. According to the memoirs of veterans, in 1970, the TINRO Scientific Council (at the time the only fisheries institute in the Far East of Russia) held a heated discussion about whether to include the ACSFS work in the country-wide campaign, and the majority of participants spoke strongly against the collection of statistical data on catches, considering such data biased and even false. However, in 1971 an ACSFS

independent unit was set up at TINRO, which in 1974 was divided into two laboratories - the RDC and a systems development laboratory. The latter was soon closed down and the RDC now operates as part of the Federal State Budgetary Scientific Institution Pacific Research Fisheries Center, or the TINRO-Center¹ for short. In 2015, the RDC commemorated its 41st year!

And what is surprising is that despite being founded a long time ago, the available literature rarely mentions the RDC and the results of its work (in English - just one publication [2]). Even the TINRO Jubilee collection (see, for example [3-5]) contains information about all of its laboratories except the RDC. It is not that the RDC is in any way a secret laboratory that is a purveyor of state or official secrets, and thus hides away from outsiders. It is just that the RDC has always been considered a minor technical department, only loosely related to the main scientific and practical work of the institute.

But it is not difficult to dispel this preconceived notion, in fact the main goals of TINRO include monitoring and forecasting the state of the resource base of the Russian fishery sector, and any estimates and projections, be they simulation or expert in nature, are always based on a certain amount of data from actual observation of natural phenomena and processes. The rule usually applies that the more raw data, the better the prognosis. For example, the statistical analysis of cyclical fluctuations in populations requires a time series of observations that are at least double the length of the duration of one cycle [6]. Figuratively speaking, the raw data is the cornerstone on which conclusions concerning the current status of bioresources are made and the forecasting of their future state is performed. The main goals of the RDC, which follow from the very name of the department, are precisely to collate data on the marine and oceanic bioresources of the Far Eastern region, the state of their environment and exploitation, and to facilitate the collection, analyses and processing of such data.

Over the past 20 years, this work has been related to the implementation of the Concept of Information Support for Bioresource and Ecosystem Research in the North-west Pacific [7]. It includes ten key areas of focus:

I. THE DEVELOPMENT AND IMPLEMENTATION OF AUTOMATED WORKPLACES FOR SCIENTIFIC AND TECHNICAL PERSONNEL ON EXPEDITIONS AND ON SHORE

For example, the "Automated Workplace for Trawling Research (AW TR)" (copyright 2011620758)² is designed to capture, store, view, analyse, edit, print on standard forms and automatically process data from trawl cards, size measurements and biological analyses of aquatic organisms collected during one or more of the bottom and/or pelagic trawl surveys. Data can be entered as received directly on the vessel or imprinted with the trawl cards and journals already filed, and also freely imported or exported from or into the "AW Fishery biologist" and the DB "Marine biology", in the formats that the RDC stores data collected from several thousand expeditions over many decades. Automated data processing enables a large number of tables, graphs and maps to be produced for the preparation of standard expedition reports and scientific research.

Another example is "Automated Workplaces for Driftnet Research (AW DR)" (2011620759) designed to capture, store, view, analyse, edit, print, and automatically process the data from drift-net fishing cards, size measurements and biological analyses of aquatic organisms collected during research and scientific field work on driftnet fishing. Here, the data can also be entered as data is collected on the vessel or imprinted with driftnet cards and journals already filed. Automated data processing allows you to instantly prepare daily ship reports (DSR) on a five-day, weekly or monthly basis for fishery agencies and institutions; obtain a large number of tables, graphs and maps for the preparation of standard expedition reports and research.

This also includes the creation of an "Automated Workplace for the Calculation of the Quantitative Characteristics of Microbiocenoses Obtained by Light and Epifluorescence Microscopy" (2013621443), "Parasitology" (2015620464), and the "Electronic Archive Directory of Primary Expedition Materials" (not yet registered), which has recently significantly simplified routine work performed with hundreds of thousands of items of data storage on paper (filing trawl cards, drift, snurrevaad, tiered, plankton, trapped, light, diving stations, bioanalysis journals, etc.).

II. THE MAINTENANCE OF AN ARCHIVE OF THE PRIMARY EXPEDITION DATA

The second area of focus is the maintenance of the archive referred to in the preceding paragraph, namely the inputting, storage, delivery, inventory and cataloging of filed cards and journals, and their preparation for digitization.

¹ Since 1995 so was called TINRO.

² Here and below in brackets the number of the state registration certificate of computer programs and databases in the registry of the Russian Federation.

III. THE MAINTENANCE AND DEVELOPMENT OF LARGE DATABASES (DB) WITH DATA COLLECTED DURING RESEARCH EXPEDITIONS AND WHILE FISHING

The presence and constant updating of such databases is especially important in view of the fact that there is still a number of reasons the theoretical prediction of trends in marine ecosystems remains very difficult, and constant, comprehensive monitoring is required of large and small-scale ecosystems [8].

Currently the RDC operates five officially registered databases, created as a result of research into the world's oceans conducted by TINRO: "Marine biology" (0220006765) "Oceanography" (0220006763) "Pelagic trawl macrofauna in the North Pacific" (2014620536) "Bottom trawl macrofauna of the North Pacific" (2014620535), "Observations of marine mammals" (0220812888), as well as a database containing information on the DSR transmitted daily by the branches of the FSBSI "Center for monitoring fisheries and communication systems" in the "Fishery" IT system – "Fishing" DB (0220006764).

As an example, we will look at the first above-mentioned database. DB "Marine biology" was created to provide information support for the work undertaken by the institute, including research (monitoring, long-term and operational forecasting of resources; evaluation of the total allowable catch (TAC), possible catch (PC) and other parameters of sustainable natural resource use, and the study of various biological, oceanographic and geographic laws; the preparation of reports, presentations, scientific publications, and dissertations by the personnel) and administrative (planning, accounting, managerial decision-making) work. At the moment, the database contains data from 215,793 trawl stations, gathered in the Pacific Ocean and adjacent seas in 1962-2015, including size measurements of 29,385,453 marine animals of 1280 species, and bioanalyses of 2,881,903 marine animals of 868 species of fish and invertebrates.

Continuous updating of the database is carried out not only as a result of present day expeditions, in which members of the institute are involved in, but also by digitizing historical data collected in the pre-computer era of marine research through the manual entry of data from paper stored in the primary data archive since the 1950s. RDC employees have been doing this for many years in accordance with annual work schedules, and this work will continue until all the available historical data from trawl cards and bioanalysis journals are digitized.

Examples of other DB created from data from the above-described DB are discussed in detail in the specialized papers [9,10]. Also in 2014-2015, a DB of 25,512 plankton stations that was not yet registered was created. This was collated during 235 expeditions in the Chukchi, Bering, Okhotsk, Japan/East Seas and the North Pacific Ocean in 1984-2013. Now all the new data collated during the expeditions in 2014-2015 is being inputted into all the databases.

The "Fishing" DB deserves a special mention due to the fact that it contains data for time periods that are not in the Sectoral Monitoring System (it contains data from 1980-1994 from the "RIF" IT system – Russian daily situation performance reports from the fishing fleet).

An operational test is currently being performed of the geographic information system (GIS) and the new DB in the PostgreSQL and PostGIS formats. The new format for storing the aggregated data of the "RIF" and "Fishing" IT systems enables fishing statistics from both pre-designated and arbitrary areas to be obtained in a matter of seconds. For example, within seconds you can answer the question: what was the distribution of pollock catches between the isobaths of 100 and 300 meters in the Karaginsk or Olyutorsk bays in the time period in which this species was abundant – up to 1990, and during the sharp decline in their numbers – 1991-1995. Any TINRO-Center employee can connect to the database, as it is located on the institute's local area network. You can use the database both in clients for SQL RDBMS and GIS, which support PostGIS tables with geometrical patterns (i.e., in all the well-known and freely available SQL RDBMS and GIS). To simplify the use of the RDBMS, a client application was developed in 2015 that allows you to use all the main features of relational algebra and spatial functions of PostGIS 2, choosing the appropriate options in the GUI on interactive GIS internet pages in the local area network of the TINRO-Center.

IV. THE CREATION BASED ON DATABASES OF HIGHER QUALITY IT PRODUCTS CONTAINING THE PROCESSED DATA COLLATED FROM THE LONG-TERM MONITORING OF THE STATE OF MARINE AND OCEAN ECOSYSTEMS

They can be called metadata databases or knowledge bases about bioresources, as these databases contain not the original raw data but the results of their statistical and cartographic processing.

This is done by 1) describing the features of the spatial and temporal distribution of animals, and 2) evaluating the species composition, occurrence, population density and gross reserves of bioresources. In this way the concept of information support for bioresource and ecosystem research in the north-west Pacific is implemented [7]. For point 1 the GIS³ is prepared, containing tens of thousands of digital maps of the spatial distribution of hydrocoles and integral characteristics of the hydrobiocenoses (see, for example, [11-14]) and 4 atlases are published of the quantitative distribution of nekton [15-18], for which approximately 1,000 of the most interesting and illustrative maps from each basin was selected. In them the data is compiled by one-degree trapezoids centred at the intersection of the meridians and parallels. For point 2 a knowledge base is created with statistical tables of the different indices regarding the abundance of all pelagic macrofauna species. This data is used to published reference books of the abundance, biomass and ratio of nekton species [19-22], and then all the pelagic [23-25], and benthic [26-30] macrofauna. When being prepared the data was compiled into standard aver-aging areas of biostatistical information [31]. The bottom line and technology utilized in all of the work performed is detailed in the "Material and Methods" sections of all the listed mono-graphs and in a number of separate articles (see, for example [14,32,33]), in which its practical significance is emphasized and specific examples are given of the practical application of the charts and tables in bioresource and ecosystem studies.

In 2015, at the annual conference of The North Pacific Marine Science Organization ([PICES](http://www.pices.int)) the series of reference books were awarded the PICES Ocean Monitoring Service Award (POMA) (http://www.pices.int/awards/POMA_award/2015-POMA/2015-POMA.aspx). And so for the first time in the history of the organization, Russian scientists were recognized for their significant contribution to the study of the North Pacific. At the same time five new similar reference books on net zooplankton in the Far Eastern seas and the north-western Pacific Ocean (NWPO) were prepared for publication [34-38].

The part of the project already implemented has an intrinsic value. For example, the GIS used for creating maps allow the spatial and temporal dynamics of more than 160 commercial and dominant species to be viewed. The tables also contain detailed information on the composition and abundance of nekton and macrofauna in all the surveyed areas (up to several hundred species in an area) with the occurrence, abundance and biomass of each species. Therefore, they enable the population density and gross reserves of any of the bioresources of the pelagic and bottom zones of the Far Eastern Seas to be evaluated. The derived metadata allow hypotheses to be tested about man-made global warming and its possible implications for the fishery industry. Information about the natural state of the marine biocenosis is gaining particular importance today in view of the expansion of the exploration of non-renewable resources (oil and gas) on the Russian shelf, and other types of water pollution. The data collected will form the basis for comparative environmental impact assessments, the evaluation of any possible environmental damage, and decision-making on the need for environmental protection and rehabilitation measures. Also, the work performed has allowed the reliability of the source DB to be significantly increased through the most rigorous selection, analysis and editing of the raw data.

Now plans are in place to draw up new large atlases of the spatial and temporal distribution of marine bioresources, such as those that were published at the beginning of the 2000s [15-18]. In these modern maps should cover most of the water areas, a long period of time and a larger number of species, and quantitative estimates should be made with greater precision.

V. THE PERFORMANCE OF ANY USER REQUEST REGARDING THE DB AND GIS FOR INFORMATION SUPPORT OF THE CURRENT SCIENTIFIC, PRACTICAL AND ADMINISTRATIVE WORK OF ALL THE INSTITUTE'S DEPARTMENTS

The DB and GIS are essential tools for the scientific and practical work of the various TINRO-Center departments. Based on these, sample data, tables, graphs, maps, and other IT products from the RDC are constantly used by the personnel of the institute for resources estimates, to determine the TAC, PC, fishing certification, writing scientific papers and monographs, and preparing presentations for meetings and conferences (including international such as [PICES](http://www.pices.int), [NPAFC](http://www.npafc.org) etc.).

Every day, the RDC receives, monitors, updates, and stores fisheries data transmitted through the "Fisheries" information system. Hundreds of entries are added to the "Fishing" DB, tables are produced showing the work of the fishing fleet over the past day, and containing detailed information on the catch of each species by each fishing vessel, and aggregate data for each

³ Some of them have received copyright certificates: "The nekton of the Okhotsk Sea 1980-2003" (2011620397) "The nekton of the north-western part of the Japan/East Sea 1981-2003" (2011620338) "The nekton of the north-west Pacific 1979-2004" (2011620340), "The nekton of the western Bering Sea 1982-2004" (2011620339), "The salmon of the north-west Pacific 1979-2005" (2011620738), "Integral characteristics of the pelagic macrofauna of the north-west Pacific 1979-2005" (2011620737).

fishing zone. Laboratory requests for fishery data for different species are fulfilled every month. Maps of the spatial distribution of the main species of the catch are produced and analysed every quarter.

On the basis of the reporting data of fishing companies, collective fishery organizations and organizations with other forms of ownership, the processing and compilation of data on fish and non-fish fishery species in the Far Eastern seas and NWPO is performed monthly and/or quarterly, and standard statistical tables are drawn up containing:

- catch data on fish, sea animal harvests by area and fishing zone, broken down by species;
- data on the use of the fishing fleet to harvest fish and other species by area and fishing zones indicating the type of vessel, type of fishing gear, the number of fishing operations and vessel-days of the fishery, total catch with details of the target species, catch per the vessel-day of the fishery;
- data on the catch of fish and non-fish species in the coastal areas of the Far East and the NWPO.

This data is used to provide information support for making short-term and long-term forecasts of the state of the fisheries resource base and the sustainability management of fisheries.

Biological and oceanographic data collected in research expeditions is in great demand among the institute personnel. Most often, RDC employees perform sampling of data from the DB in the specified region, time period and/or the presence in catches of certain species of aquatic organisms (sometimes with additional provisions, for example, with a breakdown according to mature and immature organisms). In recent years, the proportion of user queries has increased related not to the sampling of primary data on the specified criteria for its independent processing, but with the generation by the RDC employees of prepared tables, various graphs and maps to solve scientific and applied problems. Maps, for example, are ideal for performing a visual analysis of the spatial and temporal distribution of aquatic organisms and environmental factors, the fishing effort and results, as well as sample sizes, which the maps were produced from.

All sorts of data from the DB and GIS is used by employees of the TINRO-Center to prepare forecasts, memos, reports, scientific papers, monographs and dissertations not only on specific commercial species. The numerous examples of ecosystem research of bioresources conducted using DB and GIS are given in recent publications [39,40]. Many of them are connected with the clarification of the current status of the domestic fishery raw material base and long-term strategic forecasts.

VI. THE DEVELOPMENT OF NEW APPROACHES TO DATA PROCESSING AND THE AUTOMATION OF RELATED PROCESSES THROUGH THE CREATION OF PROPRIETARY SOFTWARE

An example of the results of the work performed in this area is the formulation of algorithms for various analytical calculations (see, for example: [41-43]), and turnkey software programs written by RDC personnel. In particular, two such programs: "The standardization of inter-circuli distances of pink salmon scales" (2009614513), and "SalmonScales" (2011611773) are used to automate the analysis of scales and the subsequent discriminative analysis of the probability of the distribution of regional groupings of juvenile pink salmon in the open sea. The importance of this for performing rapid assessments during the salmon fishing season is evident.

Another example is a software package for evaluating the horizontal opening of midwater trawls based on its vertical opening, warp length, speed and trawling depth for 25 types of trawl systems (2012618050). It enables the calculation and recording in the table of the value of the horizontal opening of the trawl mouth, which is calculated according to its vertical opening, warp length, speed and depth of trawling on the basis of empirical equations obtained in the study of mathematical models of trawl systems. This is necessary in cases when the trawl is equipped with a device that records the vertical mouth opening and the depth of the trawl, but does not measure the horizontal opening, which is typical for most modern (and in the recent past, all) Russian trawlers. Without such a program, it is impossible to determine the fished out areas and volumes, and hence to quantify the reserves of bioresources for their sustainable exploitation.

Newly developed (not yet registered in the State Register) software selects from the DB data from the trawl and plankton stations and uses it to calculate the occurrence and abundance of each species at each point, and record the calculation results in a separate DB, grouping them by region, depth range, dark and daylight, biological season and multi-year periods. Software has also been created that automates the layout of prepared tables that make up a large part of the reference books published and prepared for printing. In order to pre-check the results for possible errors and typos, this software also enables the validation tables in other formats to be generated, with data on the absolute biomasses of different species groups.

Previously this work was done in semi-automatic mode, and it took almost a year to prepare each volume of the first table reference books [19-22] for publication. Now the automation of routine processes has increased the speed of this work by 5 times, and 5 volumes were prepared for publication in 2013 [26-30] and 2015 [34-38] years. And the volume of the processed data and processing has not decreased, but in fact increased in comparison with 2003-2006.

VII. THE ESTABLISHMENT OF INTER-INSTITUTIONAL DATA EXCHANGE AND THE CREATION OF DB FOR PUBLIC USE

In 2013, at the Board Meeting of the directors of the fishery research organizations of the TINRO Scientific and Technical Association, and the Board Meeting of the Far Eastern Council on Fishing Forecasting, it was proposed to create at the RDC, on the basis of the software developed there, 3 common DB for combining all the drift and trawl survey data and data on the technical (design and operational) performance of trawl systems available in the Far Eastern fishery institutions⁴.

In the creation of a common (open to all participants in the project) IT product, the interested parties would liaise as follows.

At first, organizations which would like to participate in the project should take an inventory and submit lists of their available data to the RDC. In addition, the organizations should approve on the management level the legal issues related to the procedure of sharing data. Then they should convert their data into a specific format, and send it by e-mail to the RDC, where it is pre-processed, structured in a specialized way, stored and issued at the request of users. This procedure will be repeated regularly as new data is prepared. In response to the e-mail the RDC will confirm receipt of the data, provide status reports on the DB and maybe also submit questions related to the data provided. In response to a database request, the RDC will create and send to the user the requested raw data or the results of its statistical and/or cartographic processing, as well as a reminder of the need to refer to the source of data used.

As the DB and number of request for data grow, it is planned to provide registered users access to it on-line through a special website. Any organization that has participated in the project and contributed data to the DB will receive an access password. Without the password the site will provide general information about the database, further data entry, the problems that it has helped to solve, and links to relevant publications and patents.

All the resources required to implement the initial stage of the project are available at the RDC. Furthermore, in the event of the successful completion of this stage, it may be possible to create common databases for trapping, snurrevaad, diving, plankton, hydrological surveys, fish and invertebrate nutrition, etc.

These goals are given in "The comprehensive fisheries research program in the Far East basin in 2012-2016" [45]. However, only in 2014 were the first attempts made to exchange metadata (information about data available in each of the institutions). Already at this stage significant organizational and psychological barriers became apparent. Not all institutions agreed to share their data: many institutions do not want to provide anything, and some do not even want to receive data. We can only hope that this work will get off the ground.

VIII. THE ADVICE FOR THE PERSONNEL OF THE INSTITUTE ON METHODOLOGICAL ISSUES RELATED TO THE STATISTICAL AND CARTOGRAPHIC PROCESSING OF DATA

This area of focus is in great demand, and obviously does not require further explanation.

IX. THE DEVELOPMENT OF REGULATIONS AND NORMATIVE DOCUMENTS REGULATING THE RELATIONS ARISING FROM THE COLLECTION, STORAGE AND PROVISION OF ACCESS TO INFORMATION HELD IN THE RDC

This includes forms, guidelines, resolutions and instructions that are approved by the directorate of the institute and that all employees must follow.

X. THE SCIENTIFIC WORK PERFORMED BY RDC SCIENTISTS

This area of work performed by RDC scientists, made available in their publications, written alone or in collaboration with staff from other laboratories.

⁴ The benefits of combining data of drift and trawl surveys to improve forecasting is obvious, the importance of creating a common DB of the technical specifications of trawl systems is explained in the special publication [44].

CONCLUSION

These ten areas of focus reflect the role of the daily work of the RDC in providing information support for climatic and oceanographic research, studies of the state of marine ecosystems, short-term and long-term forecasts, the state of the raw material base of fisheries, sustainable management of fisheries and mariculture, and research expedition planning.

All this work is particularly valuable because it is performed on the main fishing basin of Russia: according to some estimates [46], in the Far Eastern seas and adjacent waters of the Pacific Ocean, 90% of the raw material base of the domestic modern fishing industry is located. Fishing in this region in the 2000s declined approximately to the level seen at the beginning of the 1970s, but it still accounts for 60-66% of the total Russian harvest of aquatic organisms in all oceans, marine and fresh waters. The Far Eastern bioresources will remain of primary importance for Russia in the foreseeable future [47], and respectively, the role of the RDC in provide information support for science and fisheries will remain an important one for many years to come.

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