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Forum

Scientometric evaluation of the projects in biology funded by the Ministry of Science and Technology, Republic of Croatia, in the 1991-1996 period

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Abstract

Background and purpose: *This study covers 91 projects in the field of biology funded, during the 1991-1996 period, by the Ministry of Science and Technology of the Republic of Croatia. The projects were carried out by 21 research units. These included the following university institutions: the four biological departments of the Faculty of Natural Sciences in Zagreb (Molecular Biology, Animal Physiology, Botany, and Zoology), the Faculty of Veterinary Medicine, the Faculty of Agriculture, the Faculty of Forestry, the Faculty of Food Science and Technology, the Medical School in Zagreb, the Medical School in Rijeka, the Faculty of Education in Osijek, and the Faculty of Natural Sciences in Split. The participating non-university institutes were: the Rudjer Bošković Institute (IRB), the Institute for Oceanography and Fisheries in Split, the Institute of Forestry in Jastrebarsko, the BC - Institute of Plant Breeding and Production, the Institute for Medical Research, and the PLIVA Research Institute. The Croatian Museum of Natural History and the Croatian Academy of Science and Arts with their departments in Zagreb and Osijek also received project support. A total of 494 research professionals, working alone (10 projects), or in teams of up to 20 (1 project) individuals, participated in the projects under consideration. The purpose of this study was to document the scientific productivity of these projects and the scientific impact of the published results. The data we present will hopefully facilitate the evaluation of the projects by the Croatian Ministry of Science and Technology.*

Material and Methods: *Scientific productivity was measured by the number of publications indexed in the two most relevant secondary sources, the Science Citation Index (SCI) and the Biological Abstracts (BIOSIS). Scientific impact was evaluated by citation analysis. The specific differences between biological disciplines concerning publication rates and citation dynamics were duly considered. The extent of communication within individual projects was deduced by evaluating co-authorship on joint publications.*

Results and Conclusion: *The Faculty of Food Science and Biotechnology and the Rudjer Bošković Institute were the most productive research institutions. On the other hand, as many as 21(23.07%) projects did not result in any published papers indexed in the SCI. Six projects (6.5%) did not even publish in journals covered by BIOSIS (a considerably less exclusive secondary source than the SCI), i. e. they failed in scientific productivity. Articles by authors from as many as 16 projects were not cited in SCI-registered journals. Concerning the 90 principal investigators (project leaders), 31(34.4%) did not publish any papers in SCI-indexed periodicals, whereas the 15 most productive individuals accomplished an output of 10-43 articles. Of the research professionals (excluding principal investigators) included in the projects under consideration, 233 (56.9%) did not author any SCI-indexed paper. Surprisingly, 37% of the scientists selected*

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as principal investigators for the current (1997-1999) funding cycle are without SCI-indexed publications for the 1991-1996 period.

INTRODUCTION

To a large extent, science is a "self-evaluating" system. Scientific publications and contributions to conferences are not only meant to present research data, but also to evoke comments, improvements, comparison with other work, etc. The infrastructure of science is based on continuous evaluation. In universities, institutes, research councils, and laboratories, a considerable amount of time is devoted to the evaluation of the scientific work of groups or individuals for appointments, promotions, grants, (honorary) degrees, prizes and awards, acceptance of publications, etc. Frequently, "evaluation" is used to indicate an analysis of past or ongoing performance, at various levels of aggregation, in different contexts and for different purposes, without a specific assessment of goal-attainment. According to van Raan *(1)* there are important reasons for the increasing demand for improved evaluation criteria. First, there are problems with the traditional peer review system, in particular, when budgets are barely increasing, or even decreasing, when an assessment of social or economic relevance is required, and in the evaluation of inter-disciplinary research. A further reason is the necessity for "accountability", often at the macro-level. For example, a Ministry of Science and Technology has to defend his budget for research against the many other needs of society.

At present, the evaluation of scientific activities lies, almost exclusively, in the hands of the scientists themselves, the peers. Briefly defined, peer review relies upon the experience and foresight of senior colleagues to evaluate the correctness of procedures and the plausibility of results, and to allocate scarce resources *(2)*. Expert or peer evaluation, as less objective, is inevitably plagued by cronyism, elitism, and conflicts caused by competition in the same field of research. There are particular problems with expert or peer reviews in developing countries and, even more so, in countries in economic transition, such as Croatia. The main obstacle, in such necessarily small scientific communities, is the lack of a sufficient number of competent individuals with expertise in all the required scientific disciplines.

In addition to the peer review method, science policymakers have at their disposal scientometrics (bibliometrics), the quantitative analysis of science. The respective methodology has now been developed for more than two decades, and exploits numerical parameters computed from publication and citation data as criteria for decisionmakers, in particular, in public funding agencies and universities.

The quantitative analysis of science now occupies a significant place in the evaluation of research outcomes and as a criterion for the allocation of resources for research. Moreover, the results obtained in bibliometrics and related disciplines are starting to convince policymakers that the growth of scientific knowledge can be measured, interpreted, and managed. The main challenge for the quantitative evaluation of science has been, how to translate numerical parameters into fair and meaningful criteria for grading research performance and outcomes.

With the creation of the Science Citation Index (SCI), the scientific literature became a distinct data source, a research instrument for the quantitative analysis of science. Early analysts, using data from the SCI, devised the concepts and measurement techniques that today remain the bedrock of bibliometrics. They established that the principal units of analysis should be *publications* (such as papers, articles, journals), *citations* (that is various counts and treatments of the bibliographic references attached to publications), and their producers (including individual authors, teams of co-authors, or larger aggregations such as projects, programs, centers, laboratories, and institutions). When subjected to the primary methods of analysis - counting, linking, and mapping - these units yield measures of higher-order concepts: coherent social groups, theory groups, networks, clusters, problem domains, specialists, and subfields *(2)*.

In summary, there are two ways of evaluating research performance: in a qualitative fashion relying upon peer reviews or in a quantitative manner relying upon scientometrics, and there are hybrid approaches. In this study we chose the scientometric approach, because of its objectivity and because all required materials (CD ROM databases) which were at our disposal.

Scientometrics, as a quantitative method, is frequently used in science policy and research, and acts as an aid for peers to help tham arrive at a better judgement *(16)*. The key source of information about scientometrics or bibliometrics is the journal Scientometrics. Similar subjects are also covered, for example, by the Journal of the American Society of Information Science, Information Processing & Management, College & Research Libraries, and the Journal of Documentation.

During the past twenty years more than a hundred scientometric articles by Croatian authors were published, mostly in the Croatian language and in domestic journals. The majority of these papers were connected to scientific subfields covered by the SCI, such as medicine, chemistry, or the scientific activity of an institution would be analyzed *(1)*.

Scientometric research on the performance of Croatian biologists has mostly been done by the staff of two institutions: the former Institute for Information Sciences and the National & University Library *(7-9, 12-15)*. Recently, two scientometric articles *(10, 11)* were published that included the entire scientific activity of the Republic of Croatia.

The purpose of this study was to document the scientific productivity of the projects in biology during the 1991 - 1996 period and the scientific impact of the published results. The data we present will hopefully facilitate the evaluation of the projects by the Croatian Ministry of Science and Technology. Scientific productivity

was measured by the number of publications indexed in the two most relevant secondary sources, the Science Citation Index (SCI) and the Biological Abstracts (BIOSIS). Scientific impact was evaluated by citation analysis. The specific differences between biological disciplines concerning publication rates and citation dynamics were duly considered. The extent of communication within individual projects was deduced by evaluating co-authorship on joint publications.

Significance of the publications of the Institute for Scientific Information (ISI), the Science Citation Index and Current Contents, and of the secondary publication Biological Abstracts (BA or BIOSIS Previews)

The Institute for Scientific Information, Philadelphia, USA, was founded in 1958 by Eugen Garfield to provide researchers with access to current research information of the highest quality. Today, ISI maintains the most comprehensive, multidisciplinary, bibliographic database of research information in the world. The ISI database covers over 16,000 international journals, books, and proceedings in the sciences, social sciences, and arts and humanities, indexing complete bibliographic data, cited references, and author abstracts for every item it includes. As a leader in the information industry, ISI is actively engaged in a number of exciting Research and Development efforts and initiatives to provide immediate desktop access to the most significant scientific literature. ISI's Citation databases Arts & Humanities Citation Index®, Biochemistry & Biophysics Citation Index(TM), Biotechnology Citation Index(TM), Chemistry Citation Index(TM), CompuMath Citation Index®, Materials science Citation Index®, Neuroscience Citation Index(TM), Science Citation Index (SCI)®, Science Citation Index Expanded(TM) and Social Sciences Citation Index® are indispensable tools for uncovering current research and tracking retrospective information. At this moment, ISI's publications cover following journals that are published in Croatia: Chemical and Biochemical Engineering Quarterly, Croatica Chemica Acta, Food Technology and Biotechnology, Neurologia Croatica, Periodicum biologorum, Strojarstvo, Tekstil and Veterinarski arhiv (partly) in the Science Citation Index Expanded(TM), Collegium Antropologicum and Društvena istraživanja in the SSCI, while the A&HCI covers the International Journal of the Aesthetics and Sociology in Music *(4)*.

Because ISI is the only information provider in the world that captures and indexes cited references of every article included in the database, these indexes are the only ones that enable us to employ the special search technique, cited reference searching. These cited references are, in effect, links to prior relevant research established by the publishing authors themselves. They can be used to retrieve related articles *via* a unique search methodology called cited reference searching. Cited reference searching is exclusive to ISI. A cited reference search in the ISI database is run against source journal coverage and therefore is restricted to citations found in the approximately 7,000 highly influential research journals indexed. If the author is cited in works outside of this group, those citations will not be retrieved *(3)*.

The SCI covers over 3,300 of the world's leading scientific and technical journals in a broad range of disciplines (in printed form, on magnetic tape, and on CD-ROM). Online format (Science Citation Index Expanded(TM)) covers over 5,300 scientific and technical journals. The following disciplines are included: agriculture, astronomy, biochemistry, biotechnology, chemistry, computer science, engineering, environmental science, food science, genetics, geosciences, immunology, material sciences, mathematics, medicine, neurosciences, oncology, pediatrics, pharmacology, physics, plant sciences, psychiatry, surgery, veterinary science and zoology.

The Current Contents Search® (CC Search®) database provides access to the tables of contents and bibliographic data from current issues of the world's leading scholarly research journals in the natural sciences, social sciences, and arts and humanities. Cover-to-cover indexing of journal articles, reviews, meeting abstracts, editorials, etc., is provided for more than 7500 international journals covering all disciplines. Complete bibliographic information, including English-language author abstracts (for approximately 85% of articles and reviews in the science editions), author keywords, KeyWords Plus®, and ISSNs are provided. The Current Contents (CC) databases provide thorough, multidisciplinary coverage of seven distinct areas of research. Each covers hundreds of the world's most respected, peer-reviewed journals, providing access to all of the critical information relevant to scientific work. The seven distinct areas are: Life Sciences (covers about 1.370 journals), Agriculture, Biology & Environmental Sciences (covers approximately 975 journals), Physical, Chemical & Earth Sciences (covers about 925 journals), Clinical Medicine (covers approximately 1.000 journals), Engineering, Computing & Technology (covers approximately 1.030 journals), Social & Behavioral Sciences (covers approximately 1.570 journals) and Arts & Humanities (covers about 1.130 journals; delivered bi-weekly in print). Each of the approximately 7,000 journals and 2,000 books have to meet stringent qualitative and quantitative measures in order to be included in the ISI databases. Criteria such as the journal's impact factor, timeliness, editorial integrity, and current depth and breadth of coverage assure that the database contains high-caliber, relevant publications *(4)*.

The Biological Abstracts database (BIOSIS Previews, BA), Philadelphia, USA, contains more than 10.5 million references, with abstracts (for approximately 50 percent of the records), to the worldwide literature on research in the life sciences, microbiology, plant and animal science, experimental medicine, agriculture, pharmacology, ecology, biochemistry, bioengineering and biophysics, covering original research reports, reviews of original research, the history and philosophy of biology and biomedicine, and the documentation and retrieval of biological information. The primary sources include

approximately 7000 periodicals, as well as books, monographs, conference proceedings, research communications, software reviews, symposia, reviews, notes and letters *(3)*. The Biological Abstracts database indexes 17 journals from Croatia. This corresponds to approximately 0,2% of the total number of journals indexed in this secondary source of scientific information in the domain of biology *(8)*.

All three secondary sources discussed above are available in printed and electronic editions, including magnetic tapes, CD-ROMs, and online service. The ISI citation indexes and Current Contents differ with respect to the number of journal covered and the bibliographic data presented. Depending on the scientific discipline, the journal coverage provided by CC and *e. g.* the SCI is about 90% identical. The most important difference between these two sources is that the SCI provides the references quoted by the author(s) of every article covered. These are the *citations* on which part of this study is based. Both CC and the SCI contain abstracts, in addition to the customary bibliographic data.

The ISI publications and BIOSIS, the second secondary source employed in this study, differ with respect to the selection of the publications covered. The fact that the Biological Abstracts includes more journals should not be interpreted to mean that a large number of low-quality publications are indexed. Rather, the Biological Abstracts represents the most complete and most widely distributed secondary source in the biological sciences, and every paper covered is accessible to a large scientific community. Thus, if CC and the SCI each index X journals from the discipline of botany, with the intention to include at least about 10 of the "most significant" ones, then BIOSIS covers approximately three times X journals from that discipline.

METHODOLOGY

The analyses presented here cover 21 scientific organizations and/or research units engaged in biological projects funded by the Croatian Ministry of Science and Technology, in the 1991 - 1996 period. At the university level, the following scientific organizations were considered: the Faculty of Natural Sciences of the University of Zagreb, with its Departments of Animal Physiology, Botany, Molecular Biology, and Zoology, the Faculty of Veterinary Science, the Faculty of Agriculture, the Faculty of Forestry, the Faculty of Food Science & Biotechnology, all in Zagreb, the Schools of Medicine in Zagreb and Rijeka, the Faculty of Education in Osijek, and the Faculty of Natural Sciences in Split. In addition, the following research institutes were covered: the Rudjer Bošković Institute in Zagreb and Rovinj, the Institute of Oceanography & Fisheries in Split, the Institute of Medical Research in Zagreb, the BC-Institute of Plant Breeding and Production in Zagreb, the Institute of Forestry in Jastrebarsko, and the PLIVA Research Institute. A third group of institutions considered included: the Croatian Museum of Natural History in Zagreb and the Croatian Academy of Science and Arts (HAZU) in Zagreb and Osijek. During the same period, there were 166 officially registered scientific organizations and units in Croatia; out of those 21 (12.65%) operated in the domain of biology *(5)*.

The total number of registered projects was 91 (one of the principal investigators selected supervised 2 projects) out of which 46 (50.5%) were granted to faculties of Croatian universities, 41 (45.1%) to institutes, and 4 (4.4%) to other institutions (the Croatian Academy of Science and Arts and the Croatian Museum of Natural History). During that period (1991-1996), the Croatian Ministry of Science and Technology funded 1365 projects, out of which 6.8% were in the domain of biological sciences (our sample) *(5)*. In our analysis, 494 scientists were included.

This study was performed using the CD-ROM's SCI and the BIOSIS databases, and online SCI database. The following data were collected: the overall productivity in terms of publications in scientific journals for each individual project and for each research professional included, the average number of publications per research professional in journals covered by the SCI and by BIOSIS, the number of citations for the research professionals included, but only for the cases in which their name appeared as the first author in the publication cited, the output of the principal investigators directing the projects, and the communication within the research teams responsible for the projects, as evidenced by joint publications.

We also scrutinized the past productivity (in terms of publications in professional journals) and scientific impact (total number of SCI citations), during the 1991 - 1996 period, of the principal investigators selected to direct the 62 biological projects in the current (1997 - 1999) funding cycle which were approved by the Croatian Ministry of Science and Technology until April, 1997, and attempted to understand the selection criteria.

RESULTS

The 91 projects considered here were directed by 90 principal investigators (*i. e.* one principal investigator simultaneously directed two projects) and were staffed by 494 research professionals who together published 1085 papers covered by BIOSIS, including 755 articles also indexed by the SCI. The mean productivity thus amounts to 2.24 (0.37 annually) BIOSIS-registered papers and 1.56 (0.26 annually) SCI-registered papers per scientist.

However, out of the total pool of SCI-indexed publications, 496 (2.26 per research professional) originated from the Ruđer Bošković Institute. The remaining 259 papers were published by 298 scientists. The resulting productivity outside the Ruđer Bošković Institute was thus only 0.869 articles per research professional (annually 0.14). Detailed data for the individual institutions covered by this study are presented in Table 1.

It should be realized that, out of the 21 institutions covered by this study, only the "institutes" are completely research-oriented, while the "faculties" and "other insti-

TABLE 1

Scientific productivity and numerical status of biological projects in the 1991-1996 period in the Republic of Croatia.

Institution	Number of projects	Number of papers indexed in SCI	Number of papers indexed in BIOSIS	Number of researchers by the projects	Average number of papers per researcher in the SCI
Faculty of Forestry	1	0	10	2	0
Forestry Institute Jastrebarsko	1	0	1	3	0
Faculty of Natural Sciences, Split	1	0	3	6	0
Croatian Academy of Science and Arts, Osijek	1	0	1	4	0
Croatian Academy of Science and Arts, Zagreb	2	0	11	8	0
Faculty of Agriculture	2	3	22 (1=7) (2=15)	31	0.096
School of Medicine, Rijeka	2	1 (1=1) (2=0)	7 (1=6) (2=1)	7	0.14
Faculty of Education, Osijek	4	2 (1=2) (2=0) (3=0) (4=0)	13 (1=6) (2=0) (3=7) (4=0)	12	0.16
Faculty of Natural Sciences, Zagreb, Department of Botany	10	10 (1=1) (2=0) (3=0) (4=2) (5=2) (6=2) (7=1) (8=0) (9=1) (10=1)	88 (1=32) (2=3) (3=3) (4=15) (5=13) (6=7) (7=6) (8=4) (9=1) (10=4)	42	0.238
B C- Institute for Plant Breeding and Production	1	2	8	7	0.285
PLIVA Research Institute	2	4 (1=1) (2=3)	11 (1=5) (2=6)	12	0.33
Croatian Museum of Natural History	1	9	12	20	0.45
Faculty of Natural Sciences, Zagreb, Department of Zoology	8	26 (1=1) (2=0) (3=6) (4=5) (5=0) (6=8) (7=1) (8=4)	51 (1=7) (2=3) (3=6) (4=4) (5=3) (6=15) (7=5) (8=8)	38	0.68
Faculty of Natural Sciences, Zagreb, Department of Animal Physiology	3	9 (1=9) (2=0) (3=0)	22 (1=22) (2=0) (3=0)	10	0.9
Faculty of Natural Sciences, Zagreb, Department of Molecular Biology	4	21 (1=13) (2=8) (3=0)	54 (1=36) (2=18) (3=0)	18	1.16
Faculty of Veterinary Science	5	31 (1=0) (2=5) (3=4) (4=22) (5=0)	59 (1=8) (2=8) (3=0) (4=39) (5=4)	22	1.409

Institution	Number of projects	Number of papers indexed in SCI	Number of papers indexed in BIOSIS	Number of researchers by the projects	Average number of papers per researcher in the SCI
School of Medicine, Zagreb	3	27	39	12	2.25
		(1=13)	(1=25)		
		(2=7)	(2=6)		
		(3=7)	(3=8)		
Institute of Oceanography & Fisheries, Split	7	52	64	20	2.26
		(1=11)	(1=14)		
		(2=7)	(2=9)		
		(3=3)	(3=4)		
		(4=4)	(4=5)		
		(5=3)	(5=4)		
		(6=16)	(6=18)		
	2	(7=11)	(7=13)		
Institute for Medical Research, Zagreb		25	32	11	2.27
		(1=20)	(1=23)		
		(2= 5)	(2=9)		
Institute Ruđer Bošković (Zagreb and Rovinj)	27	496	542	186	2.66
		(1=9)	(1=10)		
		(2=29)	(2=33)		
		(3=11)	(3=13)		
		(4=20)	(4=22)		
		(5=20)	(5=23)		
		(6=21)	(6=24)		
		(7=38)	(7=41)		
		(8=22)	(8=23)		
		(9=29)	(9=32)		
		(10=0)	(10=0)		
		(11=12)	(11=14)		
		(12=6)	(12=7)		
		(13=27)	(13=29)		
		(14=7)	(14=9)		
		(15=62)	(15=66)		
		(16=31)	(16=32)		
		(17=2)	(17=3)		
		(18=38)	(18=38)		
		(19=13)	(19=15)		
		(20=22)	(20=21)		
		(21=17)	(21=18)		
		(22=8)	(22=9)		
		(23=15)	(23=16)		
		(24=13)	(24=14)		
		(25=10)	(25=11)		
		(26=2)	(26=3)		
		(27=13)	(27=14)		
Faculty of Food Science & Biotechnology	3	37	35	13	2.84
		(1=13)	(1=12)		
		(2=22)	(2=19)		
		(3=2)	(3=4)		

tutions" (Croatian Museum of Natural History, Croatian Academy of Science and Arts in Zagreb and in Osijek) have additional obligations. The participation of each of these three categories of institutions in the pool of projects funded in the report period is summarized in Figure 1.

Six projects (6.5% of the total) did not result in a single publication covered by BIOSIS, while the output of 21 (23.07) projects did not enter the SCI. Academic research projects which did not result in publications in-

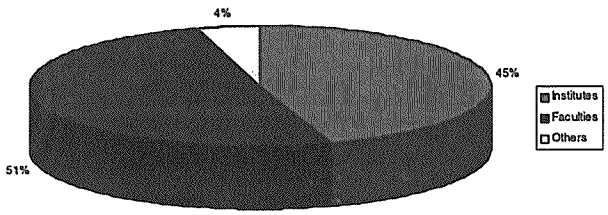

FIGURE 1. *Distribution of biological projects by type of institutions in the 1991-1996 period.*