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

MAJA JOKIĆ
Nacional and University Library
Av. Hrvatske bratske zajednice b.b.
10000 Zagreb
Croatia

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 institutions 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-indexed 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, 833 (98.9%) did not author any SCI-indexed paper. Surprisingly, 87% of the scientists selected

Received September 2, 1999.

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 interdisciplinary 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 its 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) 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 them 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 1981 - 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 (BIO-
SIS). Scientific impact was evaluated by citation analy-
sis. The specific differences between biological disci-
plines concerning publication rates and citation dynam-
ics 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 1959 by Eugen Garfield to provide researchers with access to current research information of the highest quality Today, ISI maintains the most comprehensive, multidisciplinary, bibliographic data-
base of research information in the world. The ISI data-
base 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 im-
mediate desktop access to the most significant scientif-
ic literature. ISI’s Citation databases Arts & Humanities Citation Index®, Biochemistry & Biophysics Citation Index(TM), Biotechnology Citation Index(TM), Chem-
istry 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 Ci-
tation Index® are indispensable tools for uncovering
current research and tracking retrospective information.
At this moment, ISI’s publications cover following jour-
als that are published in Croatia: Chemical and Bio-
chemical Engineering Quarterly, Croatian Chemical Acta, Food Technology and Biotechnology, Neurologia Croatia, 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 refer-
ces 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 influ-

ent research journals indexed. If the author is cited in works outside of this group, those citations will not be retrieved (5).

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

The Current Contents Search® (CC Search®) data-
base provides access to the tables of contents and bib-
liographic data from current issues of the world’s lead-
ing scholarly research journals in the natural sciences, social sciences, and arts and humanities. Cover-to-cov-
er indexing of journal articles, reviews, meeting ab-
stracts, editorials, etc., is provided for more than 7,000 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, Key-
Words Plus®, and ISSNIs are provided. The Current Contents (CC) databases provide thorough, multidisci-
plinary 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 approxi-
ately 1,030 journals), Social & Behavioral Sciences (covers approximately 1,570 journals) and Arts & Hu-
mnities (covers about 1,130 journals; delivered bi-week-
ly in print). Each of the approximately 7,000 journals and
2,000 books have to meet stringent qualitative and quanti-
tative measures in order to be included in the ISI data-
bases. Criteria such as the journal’s impact factor, tim-
eliness, editorial integrity, and current depth and breadth of coverage assure that the database contains high-cal-
iber, relevant publications (4).

The Biological Abstracts database (BIOSIS Previews, BA), Philadelphia, USA, contains more than 10.5 million references, with abstracts (for approximately 90 percent of the records), to the worldwide literature on research in the life sciences, microbiology, plant and animal sci-
ence, experimental medicine, agriculture, pharmaco-
ology, ecology, biochemistry, bioengineering and biophys-
ics, covering original research reports, reviews of origi-
nal research, the history and philosophy of biology and biomedicine, and the documentation and retrieval of biological information. The primary sources include

Period Biol Vol 102, No 1, 2000

131
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 48 (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 investigator 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 82 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 1.55 (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 Rudjer Bošković Institute. The remaining 289 papers were published by 298 scientists. The resulting productivity outside the Rudjer 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>
<thead>
<tr>
<th>Institution</th>
<th>Number of projects</th>
<th>Number of papers indexed in SCI</th>
<th>Number of papers indexed in BIOGIS</th>
<th>Number of researchers by the projects</th>
<th>Average number of papers per researcher in the SCI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Faculty of Forestry</td>
<td>1</td>
<td>0</td>
<td>10</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>Forestry Institute Jastrebarsko</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>3</td>
<td>0</td>
</tr>
<tr>
<td>Faculty of Natural Sciences, Split</td>
<td>1</td>
<td>0</td>
<td>3</td>
<td>6</td>
<td>0</td>
</tr>
<tr>
<td>Croatian Academy of Science and Arts, Osijek</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>4</td>
<td>0</td>
</tr>
<tr>
<td>Croatian Academy of Science and Arts, Zagreb</td>
<td>2</td>
<td>0</td>
<td>11</td>
<td>8</td>
<td>0</td>
</tr>
<tr>
<td>Faculty of Agriculture</td>
<td>2</td>
<td>3</td>
<td>22</td>
<td>31</td>
<td>0.096</td>
</tr>
<tr>
<td>School of Medicine, Rijeka</td>
<td>2</td>
<td>1</td>
<td>7</td>
<td>7</td>
<td>0.14</td>
</tr>
<tr>
<td>Faculty of Education, Osijek</td>
<td>4</td>
<td>2</td>
<td>13</td>
<td>12</td>
<td>0.16</td>
</tr>
<tr>
<td>Faculty of Natural Sciences, Zagreb, Department of Botany</td>
<td>10</td>
<td>10</td>
<td>88</td>
<td>42</td>
<td>0.238</td>
</tr>
<tr>
<td>B.C. Institute for Plant Breeding and Production</td>
<td>1</td>
<td>2</td>
<td>6</td>
<td>7</td>
<td>0.285</td>
</tr>
<tr>
<td>PLIWA Research Institute</td>
<td>2</td>
<td>4</td>
<td>11</td>
<td>12</td>
<td>0.33</td>
</tr>
<tr>
<td>Croatian Museum of Natural History</td>
<td>1</td>
<td>3</td>
<td>12</td>
<td>20</td>
<td>0.45</td>
</tr>
<tr>
<td>Faculty of Natural Sciences, Zagreb, Department of Zoology</td>
<td>8</td>
<td>26</td>
<td>51</td>
<td>38</td>
<td>0.68</td>
</tr>
<tr>
<td>Faculty of Natural Sciences, Zagreb, Department of Animal Physiology</td>
<td>3</td>
<td>9</td>
<td>22</td>
<td>10</td>
<td>0.9</td>
</tr>
<tr>
<td>Faculty of Natural Sciences, Zagreb, Department of Molecular Biology</td>
<td>4</td>
<td>21</td>
<td>54</td>
<td>18</td>
<td>1.16</td>
</tr>
<tr>
<td>Faculty of Veterinary Science</td>
<td>5</td>
<td>31</td>
<td>59</td>
<td>22</td>
<td>1.409</td>
</tr>
<tr>
<td>Institution</td>
<td>Number of projects</td>
<td>Number of papers indexed in SCI</td>
<td>Number of papers indexed in BIOSIS</td>
<td>Number of researchers by the projects</td>
<td>Average number of papers per researcher in the SCI</td>
</tr>
<tr>
<td>-------------------------------------------------</td>
<td>--------------------</td>
<td>---------------------------------</td>
<td>-------------------------------------</td>
<td>---------------------------------------</td>
<td>-------------------------------------------------</td>
</tr>
<tr>
<td>School of Medicine, Zagreb</td>
<td>3</td>
<td>27</td>
<td>39</td>
<td>12</td>
<td>2.25</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(1=13)</td>
<td>(1=25)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>(2=7)</td>
<td>(3=6)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>(3=7)</td>
<td>(3=8)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Institute of Oceanography &amp; Fisheries, Split</td>
<td>7</td>
<td>52</td>
<td>64</td>
<td>20</td>
<td>2.26</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(1=11)</td>
<td>(1=14)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>(2=7)</td>
<td>(2=9)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>(3=3)</td>
<td>(3=4)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>(4=4)</td>
<td>(4=5)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>(5=3)</td>
<td>(5=4)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>(6=16)</td>
<td>(6=18)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>(7=11)</td>
<td>(7=13)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Institute for Medical Research, Zagreb</td>
<td>2</td>
<td>25</td>
<td>32</td>
<td>11</td>
<td>2.27</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(1=20)</td>
<td>(1=23)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>(2=5)</td>
<td>(2=9)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Institute Ruder Bošković (Zagreb and Rovinj)</td>
<td>27</td>
<td>406</td>
<td>542</td>
<td>186</td>
<td>2.66</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(1=9)</td>
<td>(1=10)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>(2=29)</td>
<td>(2=33)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>(3=11)</td>
<td>(3=13)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>(4=20)</td>
<td>(4=22)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>(5=20)</td>
<td>(5=23)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>(6=21)</td>
<td>(6=24)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>(7=38)</td>
<td>(7=41)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>(8=22)</td>
<td>(8=23)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>(9=29)</td>
<td>(9=32)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>(10=0)</td>
<td>(10=0)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>(11=12)</td>
<td>(11=14)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>(12=6)</td>
<td>(12=7)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>(13=27)</td>
<td>(13=29)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>(14=2)</td>
<td>(14=9)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>(15=62)</td>
<td>(13=66)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>(16=31)</td>
<td>(16=32)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>(17=2)</td>
<td>(17=3)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>(18=38)</td>
<td>(18=38)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>(19=13)</td>
<td>(19=15)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>(20=22)</td>
<td>(20=23)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>(21=17)</td>
<td>(21=18)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>(22=6)</td>
<td>(22=9)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>(23=15)</td>
<td>(23=16)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>(24=13)</td>
<td>(24=14)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>(25=10)</td>
<td>(25=11)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>(26=2)</td>
<td>(26=3)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>(27=13)</td>
<td>(27=14)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Faculty of Food Science &amp; Biotechnology</td>
<td>3</td>
<td>37</td>
<td>35</td>
<td>13</td>
<td>2.84</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(1=15)</td>
<td>(1=12)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>(2=22)</td>
<td>(2=19)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>(3=3)</td>
<td>(3=4)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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-

indexed by BIOSIS are to be considered unproductive. Such projects include: 2 projects granted to the Department of Animal Physiology of the Zagreb Faculty of Natural Sciences, 1 project granted to the Department of Molecular Biology of the same faculty, and 2 projects granted to the Faculty of Education in Osijek.

Faculties

As detailed above, this study covers 9 faculties, or 12 scientific units, because the Zagreb Faculty of Natural Sciences contributes 4 departments with independent research programs. Out of 46 projects awarded to these institutions, 21 (45.65%) did not publish a single paper covered by the SCI. The scientific output of the faculties in SCI-indexed journals, as compared to that of the other two categories of research institutions, is presented in Figure 2.

![Figure 2](image)

**FIGURE 2. Distribution of SCI indexed papers with respect to type of institutions.**

The productivity of the individual faculties (departments in the case of the Zagreb Faculty of Natural Sciences), in terms of SCI-registered publications in the 1991-1996 period, is summarized in Figure 3. As the Zagreb Faculty of Natural Sciences plays a central role in the education of biologists, the relative output of its four biological departments in detailed in Figure 4. In interpreting the data presented it should be borne in mind that "botany" did not appear in the 1993 Subject Category Listing of the SCI Journal Citation Reports. Journals covering, for example, applied botany thus had to be identified within the subject categories agriculture, biology, cytology & histology, ecology and plant sciences.

Institutes

Six institutes active in biological research, with 1 Institute for Forestry, Jastrebarsko and BC-Institute For Breeding and Plant Production) to 27 (Rudjer Bošković Institute) projects were registered with the Croatian Ministry of Science and Technology, in the 1991 - 1996 period. Their productivity per research professional is summarized in Figure 5. The three leading institutions were: the Rudjer Bošković Institute in Zagreb and Rovinj, the Institute of Oceanography & Fisheries in Split, and the Institute of Medical Research in Zagreb. The output of the two institutes with the largest number of projects, the Rudjer Bošković Institute, Zagreb/Rovinj (27 projects) and the Institute of Oceanography & Fisheries, Split (7 projects) is detailed in Figures 6 and 7.

Other biological research units

This category of institutions comprises the Croatian Academy of Science and Arts in Zagreb and Osijek, and the Croatian Museum of Natural History in Zagreb. As shown in Table 1, the two departments of the academy did not publish any SCI registered articles. The muse-
of Oceanography and Fisheries. The same level of productivity was accomplished by the following number of scientists participating in one of the 46 biological projects granted to the respective faculties of the University of Zagreb: 2 scientists (one of them working in the USA) at the Faculty of Biotechnology and Food Science, 1 scientist at the Medical School and, from the Zagreb Faculty of Natural Sciences, 2 scientists from the Department of Molecular Biology and 1 scientist from the Department of Zoology. The latter case is unusual, as the respective individual worked at a US research institution throughout the time period covered (and has continuously kept his foreign appointment up to the present date).

The above data do not include the output of the 90 principal investigators directing the projects under consideration; the productivity of these research leaders was analyzed separately. Within the time period considered, 31 (34.4%) principal investigators did not publish any SCI-indexed papers. Out of this group of individuals, 11 (12.2% of the total) did not publish in journals covered by BIOSIS either. The 32 (35.5%) principal investigators published 5 or more SCI-indexed papers in the 1991-1996 period. Out of this, highly productive, group of scientists, 15 (16.6% of the total) had an output of 10 or more papers.

### TABLE 2

List of the scientists participating in the Croatian biological projects funded during the 1991-1996 period, who are among the high-scoring Croatian scientists (top 2.5% for the 1980-1995 period).

<table>
<thead>
<tr>
<th>Author</th>
<th>Institution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kurelec, B.</td>
<td>Ruder Bošković Institute</td>
</tr>
<tr>
<td>Pavelić, K.</td>
<td>Ruder Bošković Institute</td>
</tr>
<tr>
<td>Luču, C.</td>
<td>Ruder Bošković Institute</td>
</tr>
<tr>
<td>Kršinić, F.</td>
<td>Institute of Oceanography &amp; Fisheries, Split</td>
</tr>
<tr>
<td>Osmački, M.</td>
<td>Ruder Bošković Institute</td>
</tr>
<tr>
<td>Ugaroškić, D.</td>
<td>Ruder Bošković Institute</td>
</tr>
<tr>
<td>Degobba, D.</td>
<td>Ruder Bošković Institute</td>
</tr>
<tr>
<td>Magnus, V.</td>
<td>Ruder Bošković Institute</td>
</tr>
<tr>
<td>Salaj-Štimac, E.</td>
<td>Ruder Bošković Institute</td>
</tr>
<tr>
<td>Trgovčić, Ž.</td>
<td>Ruder Bošković Institute</td>
</tr>
<tr>
<td>Belet, R.</td>
<td>Ruder Bošković Institute</td>
</tr>
<tr>
<td>Justić, D.</td>
<td>Faculty of Natural Sciences, Zagreb - Department of Zoology</td>
</tr>
<tr>
<td>Witscher, M.</td>
<td>Ruder Bošković Institute</td>
</tr>
<tr>
<td>Stojiljković, I.</td>
<td>Ruder Bošković Institute</td>
</tr>
</tbody>
</table>
Comparison of the most productive scientists in the sample analyzed here, and the data presented by Kavić (11) reveals that 14 (6.14%, Table 2) individuals are included in the top 2.5% high-scoring Croatian scientists, as listed for the 1990 - 1995 period.

**Citations**

As a measure of the impact of published research we chose citation analysis, even though we are aware of the fact that a few more years have to pass before this criterion will permit a complete evaluation of the significance (impact) of papers published in the 1991 - 1996 period. The SCI-citations accumulated from 1992 - 1996 by all scientists participating in the projects under consideration were attributed to the respective projects. The results are presented in Table 3. Citations were counted.

<table>
<thead>
<tr>
<th>Institution</th>
<th>Number of projects</th>
<th>Number of citations in the 1992-1996 period</th>
</tr>
</thead>
<tbody>
<tr>
<td>Croat. Acad. Sci. &amp; Arts, Zagreb</td>
<td>2</td>
<td>(1=3)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(2=2)</td>
</tr>
<tr>
<td>Croat. Acad. Sci. &amp; Arts, Osijek</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Fac. Food Sci. &amp; Biotech.</td>
<td>3</td>
<td>63</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(10=12)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(2=1)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(3=50)</td>
</tr>
<tr>
<td>Fac. Forest.</td>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(1=5)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(2=6)</td>
</tr>
<tr>
<td>Fac. Agricul.</td>
<td>2</td>
<td>11</td>
</tr>
<tr>
<td>Fac. Educat., Osijek</td>
<td>4</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(1=4)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(2=0)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(3=3)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(1=16)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(2=0)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(3=12)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(4=0)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(5=0)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(6=8)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(7=0)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(3=3)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(9=0)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(10=1)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(1=8)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(2=5)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(3=1)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(4=5)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(5=5)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(6=13)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(7=0)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(8=47)(justić)</td>
</tr>
</tbody>
</table>

**Table 3**

*Number of citations with respect to projects, in the 1992-1996 period (Data collected at the end of 1997).*

- Fac. Natur. Sci., Split 5 0
- Fac. Vet. Med. 2 66
- School Med., Rijeka 3 0
- School Med., Zagreb 87
- Inst. Med. Res. 2 39
- Ruder Bošković Institute 27 1839

Period biol, Vol 102, No 1, 2000

137
ed starting in 1992 because publications resulting from a project initiated in 1991 are extremely unlikely to be quoted at an earlier date. Depending on the subject, three months up to more than a year will pass before a manuscript received by the editor of a scientific journal appears in print. According to the author's experience, one more year, at the average, is likely to pass before that article is quoted for the first time.

For how many years a research paper is usually cited, depends on the dynamics of the individual scientific discipline. In molecular biology for example, a publication not quoted within the first two years following its publication has little chance to be quoted within five years. For disciplines such as botany and zoology, citations accumulate at a slower pace, and a sampling period of five years is considered more appropriate.

Communication of the principal investigator with the scientists participating in his project

In this section we discuss to what extent the principal investigators collaborated with the members of their research teams, and how these members communicated with one another. As a quantitative criterion for this kind of communication, we adopted co-authorship of joint publications. As the analysis of all projects under consideration afforded an overwhelming amount of data, we only present, as an example, the results obtained for the Zagreb Faculty of Natural Sciences, the most diverse university institution with four biological departments which, to a large extent, coordinate the academic education of biology students and junior research biologists. Efficient communication between the principal investigator and the senior and junior participants in their projects is thus of particular relevance.

Department of Molecular Biology - Four projects directed by three principal investigators were funded. For one project, the principal investigator was the only research professional included, and no papers were published. A second principal investigator directed 2 projects including 11 research professionals. These collaborated in the work published in 14 (41.6%) out of a total output of 36 papers. Out of the 14 research articles authored by the principal investigator, 8 (57.1%) included other participants in one of the two projects as co-authors. The fourth project in the department included 6 participants, in addition to the principal investigator. Three (50%) of the collaborating scientists did not appear on any publications. The principal investigator published two papers, each of which included one of the members of his group as a co-author.

Department of Animal Physiology - Out of three funded projects, two included only one research professional; the third project was granted to a group of nine individuals. Concerning the communication within the latter project: three (33.3%) members of the team did not author any publications. In the total output of 22 articles, only two members of the team published in co-authorship with the principal investigator; two papers contain contributions by two participants in the project.

Department of Botany - Ten projects including a total of 42 research professionals were analyzed. Three projects were granted to individual scientists. Two projects were assigned to groups of three research professionals. In one of those, there was no communication between the individual members of the team; in the second project, the total output of seven papers included two (28.6%) co-authored by all three scientists assigned to the project and one article by two members of the team excluding the principal investigator. Two further projects included four scientists each. In one of those, 3 (50%) papers were authored by more than one member of the team, but one member was without publications. In the second four-member project, there was no communication through joint publications. In a further project with a six-member team, four (26.6%) papers were published in co-authorship, one including the principal investigator. In a project including ten research professionals, 50% (12) of the collaborators did not author a single paper and the principal investigator did not publish in co-authorship with the other members of his project. The last project to be mentioned comprised nine individuals. 11 (34.4%) articles were published in mutual co-authorship. The principal investigator published two (6.2%) papers in collaboration with one of the other members of the team.

Department of Zoology - Eight projects were funded, i.e. 1) two projects with two scientists each, one of which projects accomplished one (55%) joint paper out of a total of three publications while, in the other project, three (37.7%) out of eight research articles were joint ventures; 2) a project assigned to three scientists who cooperated in the research presented in six (55.7%) papers; 3) a four-member team without collaboration including two members (principal investigator) without publications; 4) two projects assigned to five scientists each, both with three (60%) members not included in any publication, one with the principal investigator appearing on only one (20%) publication co-authored by one of his co-workers; 5) a seven-member project with two (28.5%) participants without publications, and the remaining four sharing authorship on three papers with the principal investigator; 6) a project assigned to nine scientists with the name of the principal investigator on only 2 (23.3%) papers, and more than 50% of all publications presenting the results of one author who, while listed as a member of the team, did (does) not work in Croatia.

Selection of Principal Investigators for the 1997-1999 period

The following pertains to 62 projects in the field of biology registered with the Ministry of Science and Technology by April 1997, and funded accordingly. To what extent did the newly appointed principal investigators show the outstanding research productivity in the 1991-1996 grant period which was supposed to be one of the factors to determine the level of support in the current funding cycle? Surprisingly, 13 (20.9%) of the newly appointed principal investigators did not publish a single SCI registered paper in the above period.
Unexpectedly, out of 19 biological projects granted to the Zagreb Faculty of Natural Sciences, none was awarded to the Department of Animal Physiology. The following numbers of projects were approved for the other three biological departments: Zoology, 8; Botany, 5; Molecular Biology, 6.

**DISCUSSION**

The 21 Croatian institutions (research units) engaged in biological research were, for the purposes of this study, classified into three groups reflecting the specific circumstances in which they perform their activities: faculties, institutes, and "other institutions". It would be unrealistic to expect the same level of productivity for the research-oriented institutes as well as for the faculties of the university and for institutions such as museums. However, as all 91 projects considered here were funded, during the 1991-1996 period, by the Ministry of Science and Technology, it was of interest to which extent productivity during the previous funding cycle influenced the distribution of funds in the current grant period. Figures 1 and 2 clearly show that the majority of the 1991-1996 projects were granted to the faculties, while their productivity was considerably less than that of the institutes. The difference is much larger than can be accounted for by the fact that faculty employees can devote only 50% of their time to research. Figure 2 is, however, based on the SCI, a highly selective secondary source which does not provide equal coverage for all scientific disciplines. Also, smaller fields, such as botany or mathematics, do not generate as many articles or citations as, say, biotechnology or genetics (3). We thus chose the Biological Abstracts (BIOSIS) as a second, less selective, secondary source. Research biologists whose papers are not included in the latter source (Table 1) remain virtually unknown to the international scientific community.

**Faculties**

The professional productivity of the 12 research units which are parts of one of the faculties of a university, is summarized in Figures 3 and 4. The fact that 21 (44.3%) out of a total of 46 biological projects did not produce a single SCI indexed paper, in the 1991-1996 period, calls for further analysis. Modest output is understandable in cases such as the Faculty of Education in Osijek (3 out of 4 projects without SCI registered publications) which directly suffered from the war and war related difficulties. What is surprising is that, within the Zagreb Faculty of Natural Sciences, two out of three projects in the Department of Animal Physiology, two out of eight projects in the Department of Zoology, three out of ten projects in the Department of Botany, and one out of four projects in the Department of Molecular Biology all failed to publish their results in any SCI registered journal (Table 1). The situation improves to some extent if the articles indexed in BIOSIS are also considered: only 6 out of 46 were without publications. Surprisingly, this group of truly unproductive projects includes two projects in the Department of Animal Physiology, and one project in the Department of Molecular Biology. Both Departments are in the Faculty of Natural Sciences which coordinates the education of biologists at the University of Zagreb. The research productivity of its departments (Figure 4) is thus of particular relevance. To start with the Department of Zoology, the average output of 0.68 SCI registered articles per research professional, in the 1991-1996 period, does unfortunately not reflect the real situation. In fact, one scientist was registered as a participant in one of the departmental projects, but worked in the U.S. A. and his papers were not related to the title of the Zagreb project. The Department of Animal Physiology had a satisfactory average output, but out of three projects only one resulted in publications (SCI, 9; BIOSIS, 22). The Department of Botany produced the smallest number of articles in professional journals. It may be argued that its research is primarily of national significance (flora croatica) and thus unfit for presentation in international journals. However, Croatia is well known in professional circles as one of the botanically most diverse European countries. Data on the influence of geographical, geological, and ecological factors on local plant life should thus be of concern for the international scientific community. The Department of Molecular Biology was the most productive biology department within the Zagreb Faculty of Natural Sciences. The average output of this department would further improve if the project without publications registered by SCI or BIOSIS was excluded.

According to Klaic (11), the annual number of SCI indexed publications per research professional, in the 1980-1995 period, amounts to 0.180, on the condition that the partial authorship of each publishing scientist is 1.00, i.e. all papers are published by single authors. Taking into account that there are, on the average, 3.02 authors per SCI registered article, the average world productivity is 3.02 x 0.180 = 0.543. In comparison, the productivity per research professional participating in the projects of the biological departments of the Zagreb Faculty of Natural Sciences was 0.232 (less than 50% of the world average) for the Department of Molecular Biology, 0.180 for the Department of Animal Physiology, 0.136 for the Department of Zoology, and 0.047 for the Department of Botany.

While these numbers are based on SCI indexed publications, Table 1 shows that the BIOSIS database includes a much larger number of papers authored by members of the biological departments of the Zagreb Faculty of Natural Sciences. This is because the latter database covers a larger number of Croatian journals (8).

The communication within the biological research teams at the Zagreb Faculty of Natural Sciences may be summarized as follows:

**Botany** - 33.3% of all projects were assigned to single scientists. In two projects, each with five research professionals, 60% of the publications were authored by the principal investigator, but not by any other participant in their projects. Only in one project (three research professionals) 85.7% of the publications presented the results of joint research.
Zoology. There were no one-person projects. In two projects, each with five participants, 60% of the members of the research teams were not included as co-authors of the articles published. Only in one project (three participants), 87.5% of the papers were published in mutual co-authorship.

Animal Physiology. Two out of three projects were assigned to single scientists. For the third project (nine research professionals), one-third of all papers did not contain joint results. Only two members of the team published in co-authorship with the principal investigator.

Molecular Biology. For two projects, the common principal investigator and his two research teams published 97.1% of the six research professionals included were not among the authors of any publication.

The output of the most productive biological departments of other faculties (Figure 4) was larger, and closer to the world average, than for the Zagreb Faculty of Natural Sciences. Thus, in the report period, the Faculty of Biotechnology and Food Science published 2.84 (0.568 per annum) SCI registered articles per research professional which is, according to Klaic (11), above the world average. This excellent performance appears to be due to a field of interest (mutagenesis, toxicology) which is in the focus of contemporary biological research and to well-developed international contacts. One member of the team works in the U.S.A. At the Zagreb School of Medicine, the average annual productivity per research professional was 0.45 SCI covered papers, which is slightly below the world average. The biological research teams at the Faculty of Veterinary Medicine publishes 0.28 SCI indexed articles annually per research professional. This is only about one-half the world average, but still well above the average for Croatian faculty departments. The outstanding performance may in part be due to the fact that one of the principal investigators collaborated with a US institution. His eight papers published in co-authorship with American colleagues represent about 25% of the total output of his faculty in the field of biology.

Institutes

As expected, the Rudjer Bošković Institute (1, 8, 9, 10) was the most productive Croatian institute engaged in biological research (Figure 5). Surprisingly, however, one of the 1991-1996 projects did not result in any SCI registered publications. Four projects (14.2%) published less than five SCI-indexed papers, i.e. less than one paper per year. On the other hand, the Rudjer Bošković Institute comprised the largest number of principal investigators and collaborators (Table 1) with more than five publications in the report period. The average annual number of SCI-indexed papers per professional engaged in biological research was 3.32. This is very close to the world average and about twice the productivity averaged for all departments of the Rudjer Bošković Institute (0.277 papers annually per research profession-
al. The high research profile of the Rudjer Bošković Institute is further corroborated by the fact that out of the 14 biologists included among the top 228 (2.5%) high-scoring Croatian Scientists (evaluation period: 1980-1995 (11), 12 (85.6%) are its employees (Table 2).

Two further institutes highly productive in biological research were: the Institute of Medical Research with an average annual output of 0.454 SCI-indexed papers per research professional, and the Institute of Oceanography and Fisheries with a productivity of 0.452, in the same units. Both results are quite close to the world average and by far above the productivity of an average Croatian research institution.

Citations

The conclusions reached in this article are only to a minor extent based on the number of citations for the papers summarizing the results of the research projects studied herein. This approach was necessary because many of these papers have not been available to the public long enough to be evaluated (and cited accordingly) by the research community. In certain fields it may take 10 or more years for an article to attract a meaningful number of citations, while in other research areas citations typically peak after only a few years. It should always be stressed that citation data must be carefully interpreted - and these limitations clearly understood - when they are used for evaluation purposes. For example, the number of authors and journals varies greatly between and within disciplines, as do their citation levels and rates. Smaller fields like botany or mathematics do not generate as many articles or citations as, say, biotechnology or genetics (3).

The citations generated in the 1992-1996 period were counted separately for each author, and for all his papers, regardless of the date of publication. Not all citations thus relate to the projects studied herein. Also, citations were counted regardless of the type of the items published in journals: articles, research reviews, letters, notes, and editorials. This approach was chosen in accordance with Garfield's results. In 1986 Garfield studied 40 leading medical journals and compared the so-called "items-by-items" impacts. Review articles had the highest impact in four of the top five journals. Original research articles were the impact leader in one, and second in two of the top five journals. Interestingly, proceedings ranked second in impact. The impact of letters, editorials, and proceedings argues in favor of comprehensive coverage of all items, as ISI provides, and against limiting coverage to articles and reviews only (4).

The purpose of our citation analysis was to present conceptually independent, even though preliminary, criteria for the scientific impact of individual authors and particular institutions (Table 3). Further research will be required before more detailed conclusions can be presented. In most cases, the following (only seemingly obvious) correlation appears to apply: the more SCI registered papers, the more citations.

140
Selection of principal investigators for the 1997 - 1999 period

In the current funding cycle (data collected in April, 1997), the number of approved biological projects was reduced by about one-third, compared to the 1991 - 1996 period. This may, to some extent, be due to a reduction of the research funds available to the Ministry of Science and Technology. How were the remaining funds distributed? The declared policy was to pay due attention to the past scientific output, or related scientometric parameters, of the principal investigators to be funded. In reality, however, 57% of the principal investigators selected in the new funding cycle published no more than zero to one SCI registered papers in the 1991 - 1996 period.

Foreign government agencies responsible for research politics widely use scientometrics as a numerical method not subject to personal bias. Peer reviews are frequently used, in addition to such statistical data, to evaluate the specific conditions in which the proposed research will be done. In this respect, peer reviews are useful and necessary. However, if peer reviews are the only criterion, the author of this article tends to agree with the opinion of Irvine (6). There is little doubt that expert committees can function effectively in institutional assessment, especially where the research under review is in a single field (or in several related fields) and a disintegrated group of relevant experts can be drawn upon as evaluators. However, problems arise when institutions undertake a wide range of research activities (making it difficult to constitute a suitable committee), or in fields characterized by institutional oligopoly with a limited number of centers and a distinct lack of neutral peers. The absence of suitable peers is also a major problem in national evaluations of the relative performance of all institutions (or university departments) in a particular field because it is far from easy to establish a disinterested committee unless all the members are drawn from abroad. Consequently, when a domestic committee does carry out a comprehensive review of research strengths which has implications for future resource distribution, strong criticism is generally voiced as to its intrinsic "lack of neutrality" and "bias" towards established institutions from which the members are often drawn.

CONCLUSIONS

This study covers 91 research projects which were, during the 1991 - 1996 period, registered as biological projects and funded by the Croatian Ministry of Science and Technology. The institutions covered were classified in three groups: faculties of a university, research institutes, and "other institutions". The results of 70 (76.9%) of the above projects were published in one or more SCI-indexed articles. The remaining 21 (23.1%) projects were without SCI-registered productivity. 6.5% of all projects did not result in publications included in the BIOSIS database. The average annual output of SCI-indexed publications per research professional in the 1991 - 1995 period was 0.306, while the world average for the 1980 - 1990 period was 0.543.

The most productive biological research institution was the Faculty of Food Science and Biotechnology which, in the report period, published 0.688 SCI registered papers annually per research professional. This is, according to Klaic (10), above the world average. The Rudjer Boskovic Institute, ranked second with respect to productivity, had an annual output of 0.532 SCI indexed papers per research professional, which is very close to the world average.

At the Zagreb Faculty of Natural Sciences, which has a central role in the education of biologists, the Department of Molecular Biology performed relatively well (0.232 SCI registered papers annually per research professional), while the output of the other biological departments was more significantly below the world average. Lack of collaboration between the principal investigators and their groups indicates an unproductive research climate. Moreover, until April 1997, not a single project involving the Department of Animal Physiology was registered with the Ministry of Science and Technology.

233 (56.9%) participants in the projects studied here, and 31 (34.4%) of their principal investigators, were without SCI-indexed publications in the report period. The two numbers may well be closely correlated. With respect to the age distribution in the Croatian research hierarchy, the above 233 unproductive scientists undoubtedly include a large number of junior professionals who were not taught by their principal investigators how research should be organized to yield publishable results. In fact, our analyses of co-authorship clearly show that joint publications including both the principal investigator and his collaborators were the exception, rather than the rule.

REFERENCES

5. http://www.mrt.nin.hr/hr/nanostawiboar.html
8. JOKIĆ M 1994 Visibility of articles from Croatia in the Biological Abstracts Database. Period Biol 56: 504-505
11. KLAČIĆ B 1997 Analysis of scientific productivity of Croatia according to the Science Citation Index, Social Science Citation Index, and Arts & Humanities Citation Index for the 1980-1995 period. *Croat Med J* 38 (2): 88-99

12. PENAVA Z 1984 Odjek radova znanstvenih radnika SR Hrvatske iz biologije objavljenih u domaćim časopisima u Science Citation Index (SCI). *Acta Bot Croat* 43: 375-382

13. PENAVA Z, PRAVDIĆ N 1989a Citation based interrelationships of scientific journal in biology. *Period Biol* 91: 21-22


