Jointly published by Elsevier Science B. V., Amsterdam and Akadémiai Kiadó, Budapest

Scientometrics, Vol. 32, No. 3 (1995) 227-236

INDICES OF JOURNAL CITATION RELATEDNESS AND CITATION RELATIONSHIPS AMONG AQUATIC BIOLOGY JOURNALS

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(Received September 7, 1994)

Simple quantitative indices of pair-wise journal citation relatedness (based on the numbers of references given to and received from a journal title, which are provided by Science Citation Index database) are translated by an automatic clustering procedure into a meaningful map diagram reflecting topical relatedness of journals within a field of science. Such a map for 60 journals in marine and freshwater biology and related sciences published in 1987 reveals a tight cluster of marine biology journals quite distinct from the freshwater biology journal cluster and from the fisheries cluster. The journals within the marine biology cluster and those with strongest pair-wise links with them can be regarded as the core journals in marine biology. Indices of unilateral citation relatedness are used to obtain diagrams, which we term citograms. The citograms visualize patterns of citation relatedness of a journal (its citing and being cited). Journal self-citation can be meaningfully estimated using the bilateral index of relatedness. Self-citation is high in specialized or regional journal titles. It also appears to be quite substantial in journals of broader scope, which possibly reflect authors' subjective preferences.

Introduction

The Institute for Scientific Information (ISI, Philadelphia, USA) runs a computer routine, which can be termed monitoring of world-wide journal literature, in different fields of science. The results of bibliometric studies based on this monitoring appeared in a series of essays by Dr. Eugene Garfield, the President of ISI, entitled "Journal Citation Studies", most recent of which is the 53rd in the series (*Garfield*[1]). This approach was also used by *Garfield*[2] in his analysis of marine biology literature. Garfield's conclusions were critically commented on by *Zhirmunsky*.[3] The subject was touched again by *Garfield*[4] in his essay on oceanographic literature. *Fuseler-McDowell*[5] considered in more detail ISI's procedure for determining the core marine biology journals.

0138-9130/95/US $ 9.50

Garfield[2, 4] stresses broad relationships of marine biology journals to those in other fields such as freshwater biology, fisheries sciences and oceanography and argues for considering the journals pertaining to the fields within a single specialty category of "aquatic sciences". *Zhirmunsky*[3] objects against this swamping of marine biology by other "aquatic sciences". He advocates autonomy of marine biology and thinks that Garfield's conclusions are a result of a heterogeneous core journal set used in the analysis. Were the core devoid of journals no specifically related to marine biology, the results of Garfield's analysis would have been different.

The present study is an attempt to quantitatively outline world-wide marine biology journal literature and its connections with related fields of biology, oceanography and environmental studies using citation data provided by ISI. This study was done at ISI during a six month stay of one of the authors (AIP) in Philadelphia in 1988 – 1989.

Methods

The journals considered here are those which gave the highest number of citations to the core marine and freshwater biology journals listed in ISI's *Journal Citation Reports* (JCR), which is derived from the Science Citation Index (SCI) database. The only exception was the inclusion of a Russian language journal *Okeanologiya* (*Oceanology*), which received few citations from the core. This journal was included to provide a comparison with another Russian language journal *Biologiya Morya* (*Marine Biology*), which was a core journal. The number of citations each journal receives from different specialty core journals is obtained annually by a computer routine (Hayne-Coulson) that is used to create the JCR database. The same routine provided citation scores the 60 journals gave to each other. The number of journals was limited to 60 due to technical limitations of the multi-dimensional scaling procedure used in the analysis (*Pudovkin*[6, 7]).

Figure 1 gives the citation relatedness of the 60 journals in 1977. This map was produced by the procedure of non-metric multi-dimensional scaling (*Kruskal*[8]) applied to a 60×60 matrix of pair-wise indices of citation relatedness (R_{A*B}) suggested by *Pudovkin*[6, 7]:

$$R_{A*B} = (R_{A>B} + R_{A<B})/2,$$
$$R_{A>B} = /(N_B{*}M_B){*}10^6 \text{ and } R_{A<B} = HA{<}B/(N_B{*}M_B){*}10^6,$$

where represents the number of references of journal A to journal B; $H_{A<B}$

represents the same for journal B to journal A; N_A and N_B represents the overall number of papers in year sets of journals A and B; M_A and M_B represents the same for cited references. Thus, the index R_{A*B} is independent of journal sizes, lengths of lists of cited references or periodicity of the journals. Each circle in the diagram represents a journal, its size being proportional to the journal size measured as the overall number of references in the yearly set of the journal.

To visual citation relationships of all the 60 journals we used non-metric multi-dimensional scaling (*Kruskal*[8]). We applied this procedure to a 60×60 metric of pair-wise of bilateral citation relatedness (R_{A*B}).

To locate the most tightly related journals we used another clustering procedure – the unweighted pair-group method (*Sneath* and *Sokal*[9]). The dendrogram was produced according to this methods with the help of NTSYS-pc package (*Rohlf*[10]).

Results

Figure 1 gives the citation relatedness of the 60 journals in 1977 produced by the procedure of non-metric multi-dimensional scaling (see Methods). Each circle in Fig. 1. represents a journal, its size is proportional to the journal size measured as the overall number of references in the yearly set of the journal.

One can see that the pattern of arrangement of the journals on the diagram is quite meaningful – the journals of related scope are placed by the scaling procedure adjacent to each other. For instance, five algology journals – *Botanica Marina* (11), *British Phycological Journal* (12), *Journal of Phycology* (39), *Aquatic Botany* (42), and *Phycologia* (54) – are all grouped together in the bottom right of the diagram. The journals that are predominantly zoological in scope – *Journal of Molluscan Studies* (38), *Veliger* (59), *Journal of Crustacean Biology* (31), and *Crustaceana* (16) – are in the middle left. To emphasize this topical arrangement of journals, the authors drew lines around the related journals and gave tentative names to each group.

To better understand the diagram created by the scaling procedure consider the position (in the bottom margin) of two Russian language journals – *Okeanologiya* (60) and *Biologiya Morya* (10). They are the only Russian language journals in our journal set. As more than 50% of their citations refer to Russian publications, which are not considered here, and because these 2 Russian language journals are rarely cited by other journals in the set, their indices of citation relatedness with other journals are extremely low. Hence, they are moved out to the periphery of the map.

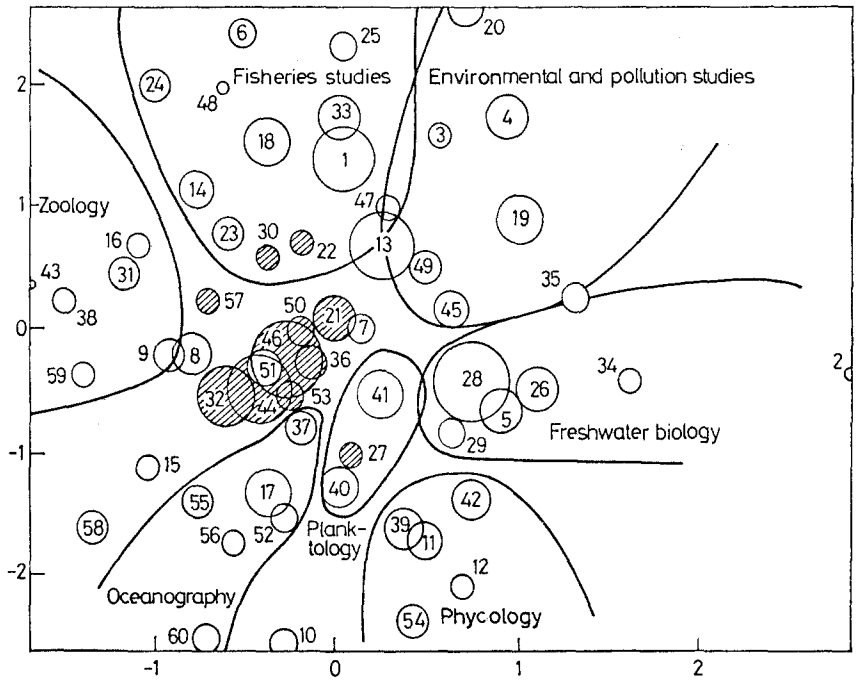

Fig. 1. Citation relationships of 60 journals in marine biology and related fields. Each circle represents a journal, and the circle size is proportional to the overall number of references in the year set of the journal. The axes show first (abscissa) and second (ordinate) principle components. The journals suggested as core ones in marine biology are indicated by hatching. Lines connecting circles indicate 20 most tight citation links among the journals. The journals are indicated with numbers:

1. Aquaculture, 2. Aquatic Insects, 3. Aquatic Toxicology, 4. Archives of Environmental Contamination and Toxicology, 5. Archiv fur Hydrobiologie, 6. Arctic, 7. Australian Journal of Marine and Freshwater Research, 8. Bulletin of Marine Science, 9. Biological Bulletin, 10. Biologiya Morya (Marine Biology, Vladivostok), 11. Botanica Marina, 12. British Phycological Journal, 13. Canadian Journal of Fisheries and Aquatic Sciences, 14. Continental Shelf Research, 15. Coral Reefs, 16. Crustaceana, 17. Deep-sea Research, 18. Environmental Biology of Fishes, 19. Environmental Pollution, 20. Environmental Toxicology and Chemistry, 21. Estuarine Coastal and Shelf Science, 22. Estuaries, 23. Fishery Bulletin, 24. Fish Physiology and Biochemistry, 25. Fisheries Research, 26. Freshwater Biology, 27. Helgolander Meeresuntersuchungen, 28. Hydrobiologia, 29. International Revue der Gesamten Hydrobiologie, 30. Journal du Conseil, 31. Journal of Crustacean Biology, 32. Journal of Experimental Marine Biology and Ecology, 33. Journal of Fish Biology, 34. Journal of Freshwater Ecology, 35. Journal of Great Lakes Research, 36. Biological Association of the UK, 37. Journal of Marine Research, 38. Journal of Molluscan Studies, 39. Journal of Phycology, 40. Journal of Plankton Research, 41. Limnology and Oceanography, 42. Aquatic Botany, 43. Marine Behaviour and Physiology, 44. Marine Biology, 45. Marine Chemistry, 46. Marine Ecology – Progress Series, 47. Marine Environmental Research, 48. Marine Fisheries Review, 49. Marine Pollution Bulletin, 50. Netherlands Journal of Sea Research, 51. Oceanography and Marine Biology, 52. Oceanologica Acta, 53. Ophelia, 54. Phycologia, 55. Polar Biology, 56. Marine Ecology: Publicazioni della Stazione Zoologica di Napoli, 57. Sarsia, 58. Symbiosis, 59. Veliger, 60. Okeanologiya (Oceanology, Moscow)

Being Russian, the journals give a few citations to each other and thus are placed by the scaling procedure close to each other, although they are only weakly related. Another similar example is the position of the journal *Aquatic Insects* (2). It cites and is infrequently cited by freshwater journals only; thus, it is placed in the far periphery of the diagram behind the freshwater journal cluster. It is also interesting to note the position of the *Journal of Great Lakes Research* (35). It is placed on the border between two adjacent clusters – freshwater biology journals (5, 26, 28, 29, and 34) and those related to environmental monitoring and pollution studies: *Marine Chemistry* (45), *Marine Pollution Bulletin* (49), *Marine Environmental Research* (47), *Environmental Pollution* (19), *Aquatic Toxicology* (3), *Archives of Environmental Contamination and Toxicology* (4), and *Environmental Toxicology and Chemistry* (20).

In the center of the diagram there is a tight group of seven marine biology publications – *Marine Ecology – Progress Series* (46), *Marine Biology* (44), *Journal of the Marine Biological Association of the UK* (36), *Netherlands Journal of Sea Research* (50), *Ophelia* (53), *Journal of Experimental Marine Biology and Ecology* (32) and the annual *Oceanography and Marine Biology* (51). Evidently, the central position of the journals is determined by their broad multi-disciplinary scope and high quality of papers, which in its turn results in high citation rates to them from almost all of the 60 journals considered.

It is interesting to note that freshwater biology journals – *Archive fur Hydrobiologie* (5), *Freshwater Biology* (26), *Hydrobiologia* (28), *International Revue der Gesamten Hydrobiologie* (29), *Journal of Freshwater Ecology* (34) – form a separate tight group, quite distinct from the main marine biology journals.

It should be emphasized that proximity of journals in the diagram does not necessarily mean their highest pair-wise relatedness, as was seen for the two Russian journals. The proximity is a cumulative result of relatedness of the journals to all the other journals of the considered set. Thus, two weakly related journals may be placed by the clustering procedure adjacent to each other just because they are even weaker related to all the other journals. On the contrary, two strongly related journals maybe placed at a distance from each other, if one of them is tightly linked with a group of journals, but the other is unrelated to them. The latter situation is observed for *Fishery Bulletin* (23) and *Marine Fisheries Review* (48), which reveal the highest pair-wise relatedness. The first one is related to many journals, hence it is placed by the scaling procedure in the central area of the map. *Marine Fisheries Review* (48) is cited (and cites) mostly by the *Fisheries Bulletin* (23). Accordingly, *Marine Fisheries Review* (48) is displaced to the periphery of the map, but remains within the fisheries cluster.

A similar situation occurs with the position in the map of the *Helgolander Meeresuntersuchungen* (27). This journal is tightly linked with the marine biology publications forming the central cluster (32, 44, 51, 53, 46, 36, 50). At the same time it is very closely linked with three phycology journals (12, 39, 54). Hence, it is pulled away from the central cluster towards the phycology cluster. Twenty strongest pair-wise citation links between the 60 journals are shown by lines in the Fig. 1.

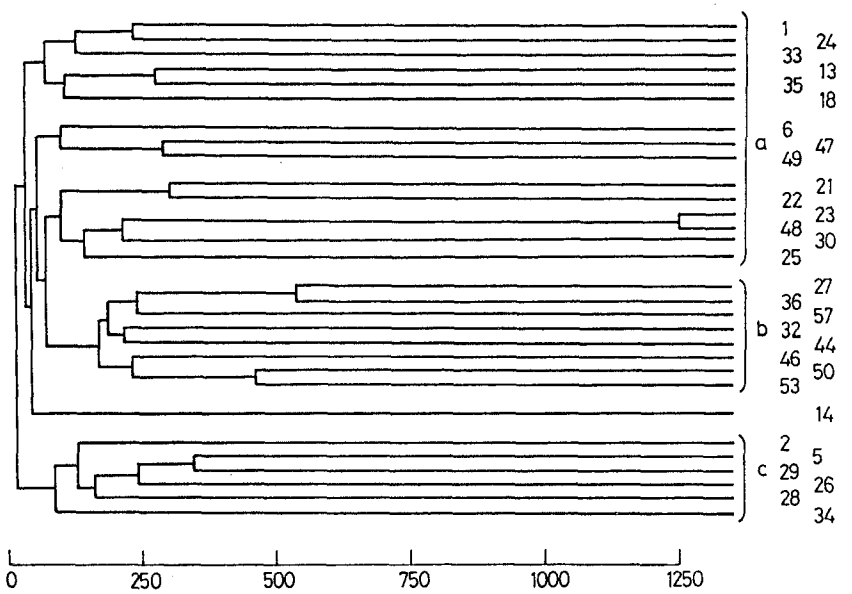

Fig. 2. Thirty journals in marine biology, fisheries and freshwater biology, clustered by unweighted pair-group method. Numbers on the right indicate the journals (for the titles see Fig. 1). The abscissa – citation relatedness of the linked journals. a – fisheries journals, b – marine biology journals, c – freshwater biology journals

The dendogram-like diagram in Fig. 2 visuals citation relationships of 30 journal making up the three clusters revealed by multidimensional scaling. It is produced by unweighted pair-group method (see Methods). The procedure looks for a pair of journals with the strongest tie between them, the it links to them the next strongly related journal, and so on. It can be seen here that the seven marine biology publications forming the tight cluster in Fig. 1 are within one cluster here as well [the *Helgolander Meeresuntersuchungen* (27) being added to them]. Fisheries journals form a group of loosely tied clusters, tending to link with marine biology journals. The freshwater biology journals form quite a distinct group. Thus, two quite different

clustering procedures reveal that marine biology journals are isolated from freshwater biology ones. Thus, it does not seem reasonable to regard them as representing a single specialty as is done in the *Journal Citation Reports* of the *Science Citation Index*.

Discussion

It seems reasonable to regard the six journals of the central cluster and the other five journals most closely linked to them by pair-wise ties as the core marine biology journals. These 11 journals arranged alphabetically are: *Estuarine Coastal and Shelf Science* (21), *Estuary* (22), *Helgolander Meeresuntersuchungen* (27), *Journal du Conseil* (30), *Journal of Experimental Marine Biology and Ecology* (32), *Journal of the Marine Biological Association of the UK* (36), *Marine Biology* (44), *Marine Ecology – Progress Series* (46), *Netherlands Journal of Sea Research* (50), *Ophelia* (53), and *Sarsia* (57). These journals are marked with hatching in Fig. 1.

The suggested bilateral index R_{A*B} can be used to characterize self-relatedness of journals. The JCR provides scores of self-citation for each journal. It gives two percentages: first is the self-citation of all the citations given by the journal to all other sources; the second is the same but relative to all the citations received by the journals (from those covered by the JCR). Our index of self-relatedness is a single index and it is quite different from indices provided by the JCR. To make it clear let us consider self-citation and self-relatedness of two publications – the journal *Marine Biology* (44) and the annual *Oceanography and Marine Biology* (51). The first cites itself 726 times, direct self-citation being 726/7661 = 9.46%. The second cites itself only 18 times, direct self-citation being 18/1839 = 0.98%, which is almost ten times less. On the contrary, indices of self-relatedness are 419 and 1007, being more than 2 times less for the *Marine Biology* (44) than for *Oceanography and Marine Biology* (51). This is easy to explain if one takes into consideration the difference in numbers of papers appearing in the publications during a year. These numbers are 226 for the *Marine Biology* (44) and 9 for the *Oceanography and Marine Biology* (51).

Almost all the journals have self-relatedness considerably stronger than relatedness with other journals. Among the 1770 pair-wise indices of citation relatedness there were only two which were higher than 750; among 60 indices of self-relatedness 34 were higher than that. To quantitatively express this we suggested an index of relative self-relatedness (IRCR), which is the ratio of self-relatedness to the average relatedness of the journal with the three journals most related to it. For

the 60 journals the IRCR range from 0.9 to 32.9, the median being 2.9. Thus, self-relatedness of the considered journals is, on the average, almost 3 times stronger than their relatedness with the 3 most closely linked ones. The highest values of IRCR are obtained for more specialized and regional journals: 32.9 for *Marine Behaviour and Physiology* (43), 15.8 for *Australian Journal of Marine and Freshwater Research* (7), 14.6 for the *Journal of Great Lakes Research* (35). These high values are easy to interpret. Indeed, the authors studying the Great Lakes often publish their data in the *Journal of Great Lakes Research* (35); correspondingly, they cite the journal more frequently. It is more difficult to explain high values of IRCR for journals of broader scope, e.g. the *Journal of Marine Biological Association of the UK* (36) (IRCR = 4.7) or the *Internationale Revue der Gesamten Hydrobiologie* (29) (IRCR = 2.9). This may reflect some authors' or/and editors' preferences.

The diagram in Fig. 3 is a citogram, which visualizes unilateral citation relatedness ($R_{A>B}$ and $R_{A<B}$) of 3 core marine biology journals – *Helgolander Meeresuntersuchungen* (27), *Journal of the Marine Biological Association of the UK* (36), and *Marine Biology* (44) – to all the 60 considered journals. Specific patterns of citations by the journals are shown in the citogram. There are journals, which are cited and cite with more or less equal frequency, for example *Marine Biology* (44), average R_A > all = 85.4 and R_A < all = 103.2. Other journals can be predominantly cited [e.g. the *Journal of the Marine Biological Association of the UK* (36), the same indices being 49.0 and 165.5] or predominantly cite other journals [e.g. *Continental Shelf Research* (14), the indices being 58.5 and 2.6].

Values of impact factor (IF) for the 11 core marine biology journals range from 0.431 to 1.867, the median being 0.924. Although these values seem low in comparison with IF for the highest impact publications – 35.1 for the *Annual Review of Biochemistry*, 25.2 for the *Annual Review of Immunology*, they are in fact not low. Seven of the 11 journals have IF higher than 0.888, which is the median for all the 4159 journals covered by the *Journal Citation Reports* in 1987. Three of them have IF higher than 1.159 (which is the upper quartile), that is they are within the upper quarter of all the journals. None of them has a lower value than 0.233, which is the lower quartile of the overall distribution of IF values.

Low IF values of many highly specialized journals can be a result of the small number of publishing authors in the field. For instance, the journal *Crustaceana* (16), well-known among crustacean zoologists, has a very low IF of 0.236. But it is by no means ignored by other journals, which also publish papers on crustaceans – *Journal of Crustacean Biology* (31), *Bulletin of Marine Science* (8). They reveal quite high values of forward relatedness to Crustaceana, $R_{A>B}$ for them are 476 and 217.

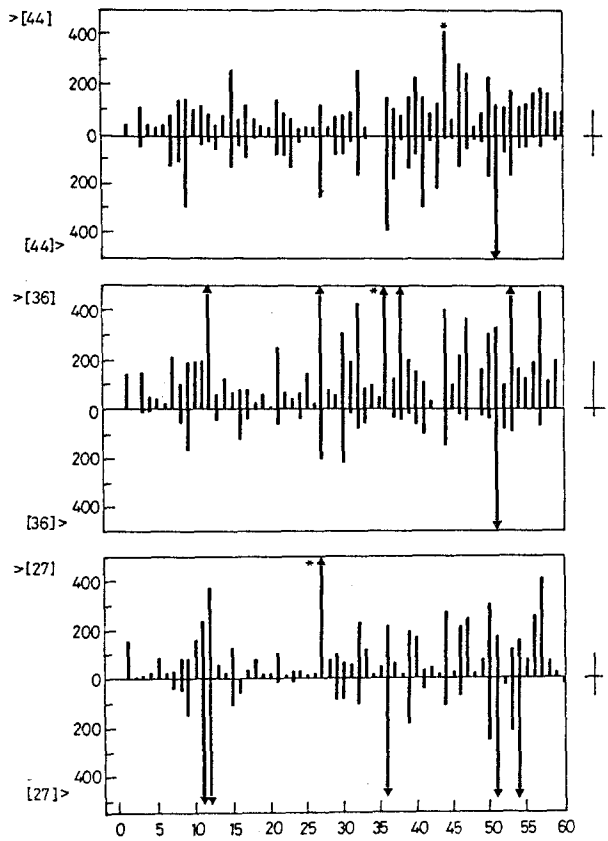

Fig. 3. Citogram reflecting unilateral citation relatedness of three core marine biology journals – *Helgolander Meeresuntersuchungen* (27), *Journal of the Marine Biological Association of the UK* (36), and *Marine Biology* (44) – to all the sixty journals under consideration.
On the abscissa – order numbers of journals, which cite the three journals and being cited by them; the ordinate – values of citation relatedness ($R_{A<B}$ above, $R_{A>B}$ below zero line). Arrows indicate the values exceeding 500; asterisks indicate self-citedness

Fisheries journals have lower IF values: the median is 0.636, the range is 0.127 to 1.507. Only two journals of the 13 are within the upper quarter and three are within the lower quarter of the overall IF range. This is possibly due to different priorities among scientists working in basic (marine biology) and applied (fisheries) fields. Publishing activity is less among the latter, hence their papers receive fewer citations. Besides, fisheries scientists seem to publish more frequently in publications (conference proceedings, collection of papers, etc.) which are not included in the Science Citation Index database.

It should be stressed that this study is only a pilot one. The authors used a very simple index of relatedness, but there certainly may be other and more adequate ones. For instance, the present index R_{A*B} is the arithmetic mean of two unilateral indices of journal relatedness, $R_{A>B}$ and $R_{A<B}$. Now it seems that geometric mean might be better, as it would take into account reciprocity of citation, being higher when the two journals cite each other with equal frequency. Or just the contrary, the index $R_{A*B} = \max (R_{A>B}, R_{A<B})$, which equals the highest of the unilateral indices, may be preferred. This index would remove the disadvantages of recently established journals, which do not yet receive many citations, but reveal their relatedness to other journals giving citations to them. It would also increase relatedness of non-English language journals, which intensively cite English language journals, but receive few citations from them. In the future we would like to see this method applied to other subjects.

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The authors greatly appreciate continuing interest and encouragement to this study from Dr. A. V. *Zhirmunsky* (Institute of Marine Biology, Vladivostok, Russia) and Dr. E. *Garfield* (Institute for Scientific Information, Philadelphia, USA). The Institute for Scientific Information provided funds for A. I. Pudovkin's sojourn in Philadelphia and use of its databases and facilities.

References

1. E. GARFIELD, 1990. Journal citation studies. 53. Agricultural sciences: most fruitful journals and high yield research fields. *Current Contents*, No. 51, p. 5–18. Reprinted in: *Essays of an Information Scientist*, Vol. 13. ISI Press, 1991, p. 455–467.
2. E. GARFIELD, 1980. The literature of marine biology. *Biologiya Morya*, No. 3, p. 3–20. In Russian. (Also published in: *Soviet Journal of Marine Biology*, 7 (1981) 137–152.
3. A. V. ZHIRMUNSKY, 1980. Comments of the Editor on the paper by E. Garfield. *Biologiya Morya*, No. 3, p. 20–22. (In Russian) (Also published in: *Soviet Journal of Marine Biology*, 7 (1981) 152–153.
4. E. GARFIELD, 1987. Journal citation studies. 47. What oceanography journals make the biggest waves? – *Current Contents*, Vol. 30, No. 48, pp. 3–11. Reprinted in: *Essays of an Information Scientist*, Vol. 10. ISI Press, 1989, p. 361–369.
5. E. FUSELER-MCDOWELL, 1988. Documenting the literature of marine biology. In: *Marine Science Information Throughout the World*. WINN, BURKHART, BURKHART (Eds), IAMSLIC, pp. 45–60.
6. A. I. PUDOVKIN, 1993a. Citation relationships among marine biology journals and those in related fields. *Marine Ecology Progress Series*, 100: 207–209.
7. A. I. PUDOVKIN, 1993b. Journals in marine biology and adjacent area: a bibliometric study of citation links among the journals. (In Russian), Vladivostok, Institute of Marine Biology Deposited in VINITY (Moscow), p. 68.
8. J. B. KRUSKAL, 1964. Multidimensional scaling by optimizing goodness-of-fit to a non-metric hypothesis. *Psychometrica*, Vol. 29, pp. 1–27.
9. P. H. A. SNEATH, R. R. SOKAL, 1973. *Numerical Taxonomy*. San Francisco, Freeman. p. 573.
10. F. G. ROHLF, 1988. *NTSYS-pc: Numerical Taxonomy and Multivariate Analysis System*. New York, Exeter Publishing, Ltd.