Laurie J Hunter. A Trend Analysis of the Journal of Mathematical Analysis and Application, 1960 to 2010. A Master's Paper for the M.S. in L.S degree. April 2011. 35 pages. Advisor: Diane Kelly

It is well known that mathematics is a unique field, somewhere between the sciences and humanities. It is not well known, however, how researchers within the mathematics community use mathematical literature. In this study, I have examined 450 articles from the *Journal of Mathematical Analysis and Application* from 1960, 1970, 1980, 1990, 2000 and 2010 in order to discover how publishing has changed over time as well as country, institution, author and topic representation within the journal. From the data gathered, I have found that there has been a large amount of growth in the number of published articles as well as the number of countries represented. It was also seen that this journal follows Lotka's law: a small number of authors publish the most papers while a large group of authors publish few papers. This work has provided insight and inspiration for future research in mathematical publishing and literature.

Headings:

Bibliometrics

Bibliometrics-Trend Analysis

Publishers and publishing/Mathematical Literature

Periodicals, Mathematical

A TREND ANALYSIS OF THE JOURNAL OF MATHEMATICAL ANALYSIS AND APPLICATION, 1960 TO 2010

by
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Approved by

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INTRODUCTION

Bibliometrics, as described by Farideh Osareh (1996), is a research method typically used to evaluate literature in a specific discipline and to compare literature across disciplines. Many researchers have developed different definitions of and purposes for bibliometrics since it was first used in the 1890s, and possibly earlier (Osareh 1996). Pritchard has described the purpose of bibliometrics as "to shed light on the processes of written communication and of the nature and course of development of a discipline […] by means of counting and analyzing the various facets of written communication" (as cited in Osareh 1999). Bibliometrics can be applied at different levels of literature, ranging from individual authors or journals to a discipline as a whole to evaluate and identify researchers, articles, or journals that have been highly cited, and observe how researchers communicate with others in their field through references (Osareh 1996). In addition, Borgman, as cited by Farideh (1996), describes bibliometrics as allowing the study of scholarly communication through "three theoretical variables: producers of the communication, artifacts of the communication, and communication concepts" (150). This study focuses on the artifacts of communication, published original research articles.

In this study, I have collected data on 450 entries in the *Journal of Mathematical Analysis and Application*. This data will be used to evaluate publishing

trends within the journal and gain insight into mathematical literature publishing. Specifically, I am looking at the change in the number of articles published per year, the number of authors per article, and the number of citations per article. By examining these aspects of articles from the years 1960, 1970, 1980, 1990, 2000 and 2010, I will see a snapshot of how the journal has changed over time, how collaboration has increased or decreased and how mathematicians' citing trends have changed, possibly in response to an increase in electronic resources.

Until recently, analysis of mathematical literature has been included with the natural and physical sciences. Mathematics is a unique field outside that realm. Few studies have been completed on strictly mathematical literature to discover its differences from the natural and physical sciences (Bensman, Smolinsky & Pudovkin 2010; Glänzel & Schoepflin 1999). It has also been noted that popular bibliometric measures, such as impact factor, have not been accurate measures of the impact of mathematics literature; however, very few researchers have suggested other indicators that would more accurately describe mathematics literature or even indicators that could be applied to multiple disciplines for comparison (Bensman, Smolinsky & Pudovkin 2010; Glänzel & Schoepflin 2009; White et al. 2009).

This research project will identify publishing trends in mathematical literature that will lead to a better understanding of the field. Since mathematicians use previous research differently than most other scholars and conduct their research in different ways, investigating this difference could help develop new ways of evaluating mathematics literature and researchers' contributions to the field as well as the nature of the discipline.

A better understanding of mathematics professional communication will also contribute to the development of other fields. Mathematics is a very interdisciplinary field that is used throughout different subject areas including biology, chemistry, physics and engineering. Understanding the literature is not only important to the mathematicians contributing new research, but to the other researchers who will use the literature to explain a phenomenon in their entirely different field.

Although mathematics research is used across many disciplines often by a team of researchers, mathematics has remained largely an independent subject. It has been seen, however, that this is changing. Wuchty, Jones & Uzzi (2007) evaluate the increase in collaboration within different subjects including science and engineering, social sciences, humanities and patents. To their surprise, mathematicians are also working in teams more than previously (Wuchty et al. 2007, 1037). This study will look at the change in co-authorship and illustrate the working patterns of mathematicians over time.

Librarians who are responsible for mathematics collections, most likely in large research libraries, may gain increased knowledge from this research. Insight into the publishing and citing trends of mathematicians could alter the way mathematical resources are selected for inclusion in a collection.

After recognizing contributions this research may make to the understanding and management of mathematical literature, I will answer the following research questions to provide some insight to the *Journal of Mathematical Analysis and Application*.

During the period 1960-2010:

- How has the number of articles published changed?
- How has the number of authors per article changed?
- How has the number of citations per article changed?
- Who have been the most published authors within each year? Over all selected years?
- Which country has been highly represented within each year? Over all selected years?
- How has country representation changed?

Answers to these questions will begin the exploration of mathematics literature, showing first how publishing trends of a math-focused, but interdisciplinary journal have evolved from its establishment in 1960. Understanding publishing will help provide direction for future studies into citation trends of mathematicians and mappings of the field.

LITERATURE REVIEW

The first set of studies included in the literature review illustrate what other researchers have discovered about professional communication in mathematical literature; what makes it different from natural and physical sciences and the humanities and social sciences. The literature review also examines different bibliometric techniques that can be used to map fields and compares bibliometric measures across disciplines.

Studies on literature outside of mathematics

The basis of this research will focus on the characteristics that make professional communication within mathematics unique, set apart from the realms of sciences, the humanities and social sciences. To realize what makes mathematics unique, we first need to understand the literature in the sciences, humanities and social sciences. Wolfgang Glänzel and Urs Schoepflin (1999) described in their bibliometric study how subjects that rely on dissemination of information through monographs and books are not accurately described by the current, widely used bibliometric measures. In this study, the authors hoped to better describe how literature is used in the areas where serial publications are not referenced as widely. These areas also happen to include "slowly aging" literature, a term that has been used to describe mathematics, soft science and technology (Glänzel & Schoepflin 1999). A body of literature described as slow aging often includes articles that are cited for many years following publication; conversely, quickly aging literature

includes articles that are cited for only a limited number of years following publication.

White and McCain (1998) have developed a series of visualizations of the information and library science field over a 23 year period. The analysis they completed maps out the two major subfields of information and library science, bibliometrics and retrieval. It also shows how authors included have moved through the field and indicates that there is no central author to unite the two subfields, similar to mathematical literature's lack of core journals (White & McCain 1998). Although there is a larger number subfields in mathematics, a similar mapping of the field would indicate whether a slowly maturing discipline aids in the longevity of researchers, keeping them active in the field for a longer time than other quickly maturing fields.

One of the major differences between mathematics and the sciences is how its literature ages. Glänzel and Schoepflin (1995), looked at the aging of scientific literature. In this study, the authors looked at journals reflective of seven different areas of science: sociology, psychology, chemistry, general and internal medicine (two journals), statistics and probability theory (Glänzel & Schoepflin 1995). The authors were able to compare journals in different disciplines based on their citation behavior over time. Although math is often classified with the hard or physical sciences, it was found that the literature of this discipline behaves more like the literature of the social sciences. More often scholars in these areas publish new findings in monographs and books, preventing journals devoted to that field from achieving high Journal Impact Factors (White et al. 2009). The areas listed above

could benefit from a completely different metric to gauge impact (White et al. 2009). White, Boell, Yu, Davis, Wilson, and Cole (2009) suggest that a new metric entitled "libcitations" should be used to compare the impacts of monographs and books in the humanities and social sciences. Libcitations are based on the average number of libraries holding a title in a union catalog (White et al. 2009). This alternative technique may benefit the humanities and social sciences, but it is unclear if it would be beneficial to mathematical literature since many mathematical publications are serials. Although mathematical literature may mimic how literature in the humanities and social sciences ages, the modes of publication are not equivalent and thus cannot be compared or generalized for the two disciplines.

Studies on current measures

Because of the slow aging of mathematical literature, like that of the social sciences, traditional measures like impact factors over a two year period may not be an accurate measure of how important different journals are to the field of mathematics. Glänzel and Schoepflin (1995) suggest that a four-year impact factor should be used instead, citing Rousseau (1988). Bensman, Smolinsky, and Pudovkin (2010) go a step further to evaluate math literature; the authors look at the mean citation rate per article measures, which include the two and five year impact factors and a five-year article influence score, all calculated by the *Science Citation Index Journal Citation Reports*. Their purpose was to compare the nature of mathematical literature to the literature of the sciences. As a field where literature matures quickly, the sciences are accurately described by the mean citation rate per

article measures. The authors discovered that most of the citations to an article occurred during the two-year time span covered by impact factor whereas the majority of citations to mathematical articles fell outside of that time frame. The five-year impact factor, in this case, was more accurate for describing mathematical literature (Bensman et al. 2010). From both of these studies, it can be seen that measures covering a greater period of time will describe mathematics literature more effectively since the literature ages more slowly than that in the science realm.

Lancho-Barrantes, Guerrero-Bote and Noya-Aegon (2010) discuss the shortfalls of the metrics that Glänzel and Schoepflin (1995) and Bensman, Smolinsky, and Pudovkin (2010) have criticized as not accurately reflecting mathematical literature. The data used by Lancho-Barrantes et al. (2010) was retrieved from Reed Elsevier's *Scopus*, a database of bibliometric statistics also discussed by Archambault, Campbell, Gingras, and Larivière (2009). The authors' findings agree with Glänzel and Schoepflin's (1995) and Bensman, Smolinsky, and Pudovkin's (2010) recommendations that longer time periods would yield more accurate measures of mathematical literature's impact. Lancho-Barrantes et al. (2010), through their analysis, discovered that the Journal Impact Factor actually favors disciplines that reference young research articles over historical studies that could be cornerstones of the field. Also of note, the size of a discipline does not affect the statistical significances of bibliometric indicators (Lancho-Barrantes et al. 2010). With this finding in mind, it may be possible to analyze a small subfield of mathematics and obtain a clear and accurate visualization of the literature in that one area, although comparison across other subfields may be challenging.

Both Glänzel and Schoepflin (1995) and Bensman, Smolinsky, and Pudovkin (2010) used data gathered from ISI's *Journal Citation Report*, as ISI was previously the only source for a large quantities of bibliometric data. A 2009 study by Archambault, Campbell, Gingras and Larivière incorporates the newly available bibliometric data available from Reed Elsevier's *Scopus*. Although this study was concerned with a country's production of knowledge based on data from both ISI and *Scopus*, they do provide some insight to future study of mathematical literature. It was found that data gathered from the *Journal Citation Index* and *Scopus* are comparable, indicating that the data is stable across both sources (Archambault et al. 2009). In applying this to mathematical literature, it could be said that neither the *Journal Citation Index* nor *Scopus* provide accurate measures of the impact of mathematical articles. However, *Journal Citation Index* and *Scopus* do not cover the same publications. This could pose problems for comparing disciplines that include more journals in one database than another.

Studies on bibliomteric techniques and measures

Smith (2009) employs bibliometric measures that may be helpful when evaluating the mathematical literature, especially when trying to compare long-term trends of the literature in mathematics and the quickly aging sciences, occupational health in this case. Smith (2009) chose to evaluate the journal using four different measures: citable items, citations received, immediacy indices, and impact factors for the journal over the 30-year time span. Because so much focus has been placed on how mathematical literature ages and how that makes the literature unique, the

immediacy indices would be most interesting since it would show how soon and often an article is cited. This measure "represents the average number of times an article published in a certain journal in a certain year is cited over the course of that same year" (Smith 2009, 45). This measure is defined by Thomson Reuters, the publishing company responsible for *Journal Citation Index*, but it is unclear whether a similar or the same measurement is employed by other databases. As Glänzel and Schoepflin (1995) and Bensman, Smolinsky, and Pudovkin (2010) both indicated, journal impact factors over a relatively short time period (two-years in these cases) did not accurately reflect mathematical literature and it is possible that the immediacy indices' short period of analysis will not accurately reflect the literature either. However, this measure has not been applied to mathematical literature and could shed light on new, unique, and interesting characteristics of the discipline.

Bensman, Smolinsky, and Pudovkin (2010) mention in their study's findings that math is a very disjoint discipline, with many subfields isolating themselves from others. This structure has prevented the field from being mapped previously, one potential outcome of a bibliometric study of mathematical literature. White and McCain (1998) used author co-citation analysis to create visualizations of the field of information science, looking at two disjoint subfields. Although the information science study only contained two subfields as opposed to a minimum of five subfields in mathematics, the techniques could be transferred to a future study on mapping mathematical literature. The authors analyzed twelve significant journals in the field of information science over the years 1972 through 1995. By breaking this large time period into three smaller spans of time, the authors were able to

visualize how highly cited, and thus important, authors moved into different subfields over time. These authors could bridge the gaps between subfields, and who might have been instrumental in a paradigm shift across the entire discipline (1998).

Similarly, Glänzel (2002) looks at coauthorship patterns in three fields indentified in the *Science Citation Index*: biomedical research, chemistry, and mathematics. As mentioned by Bensman, Smolinsky, and Pudovkin (2010) above, mathematics is a disjoint field and, unlike other science fields, does not always promote collaboration between researchers. Glänzel (2002) has found in this study that, although mathematics is still an isolated discipline, collaboration has greatly increased over the period of time he analyzed (2002). This discovery indicates a change in the field of mathematics. Wuchty et al. (2007) also recognized this change in a larger study of collaboration within science and engineering, social sciences, humanities and patents (2007). The authors in this study note: "Surprisingly, even mathematics, long thought the domain of the loner scientist […], showed a marked increase in the fraction of work done in teams, from 19% to 57%" (1037). The methods used by White and McCain (1998) could be used to decipher which publishing mathematicians have been responsible for, or at least representative in, bringing about this change.

Often, bibliometric measures of journals and articles are assumed to evaluate the performance of researchers and the progress that has been made in certain fields. Wook Nah, Dai-Shin Kang, Dae-Hee Lee, and Yun-Chul Chung (2009), evaluated research studies being completed at the Korea Institute of Science and

Technology using normalized Impact Factors from ISI. Although studies published in mathematical journals were not included in this analysis, the technique of normalization that is proposed seems to provide a level playing ground for different disciplines (Nah et al. 2009). As mentioned elsewhere, Impact Factor does not accurately describe journals integral in the realm of mathematical professional communication (Glänzel & Schoepflin 2009; Bensman et al. 2010); perhaps the techniques used in this study to construct normalized Impact Factors could aid in allowing for better comparisons between Impact Factors across disciplines. Lancho-Barrantes et al. (2010) point out the ways that citation-based indicators do not accurately reflect a discipline's contribution to the general field of knowledge. One of the downfalls they cited was the lack of normalization, unlike the indicators used by Nah et al. (2009). Normalization can be seen here as an alternative to developing a new bibliometric measure that accounts for historical documents and relatively small or isolated disciplines.

From the research that has been presented in this literature review, it is clear that mathematical literature has a unique structure. It is unlike the natural and physical sciences, but also unlike the humanities and social sciences. The measurements that are in place at this time to evaluate the impact of publications do not accurately reflect the impact of an article on the field of mathematics due to the slow aging of the literature. Articles do not usually enter the mainstream of mathematical literature quickly, instead becoming highly cited after a decade or more following publication. The uniqueness of mathematics may have prevented a great deal of research from being completed on the nature of the literature. A

bibliometric study of mathematical literature is necessary at this point to inform collection managers of the changing literature, suggesting key pieces of the literature that should be acquired and maintained in an academic library.

The measurements in place also do not accurately represent mathematical literature because of the lack of a central canon of journals. Disjoint and isolated subfields prevent review journals from becoming highly cited publications. Instead, small, specialized, and not very highly read journals are cited more often and prevent researchers focusing on different subfields from coming together to study a common topic or problem. This isolation also furthers the expectation that mathematical research and publication is an individual task, although that may be changing; over the last twenty years, the number of published articles with more than three authors has greatly increased (Glänzel 2002). This change may indicate that the isolation is fading and that the breakthrough of review journals is imminent, but the field as it is needs to be understood.

Although none of the studies examined map mathematics or a subfield of mathematics, the techniques that are employed could be used in future studies to provide insight into different bibliometric techniques of citation analysis. Finally, since mathematical literature is so unique, the studies presented discuss how measures that are currently used for bibliometric analysis do not accurately reflect the body of mathematical literature and the possible factors that could increase accuracy of evaluation.

Through this research, I will begin to look at the publishing trends of one mathematical journal, the *Journal of Mathematical Analysis and Application*. By

starting with the publishing trends, information on what is being published, from whom and from where will be gathered. Knowing first what is available will then help to inform future studies on what is being cited, when articles are cited, and by whom.

METHOD

Sampling

To gain an understanding of mathematicians' publishing trends, I decided to examine the original research articles published in the *Journal of Mathematical Analysis and Application*. The reasons for choosing this journal were two-fold. With a focus on applications and analysis, there would be variety within the topics of published articles. Also, the University of North Carolina at Chapel Hill (UNC) had electronic access to all of the published issues from the inception of the journal in 1960. In case that mode of access failed, it was noted that North Carolina State University (NCSU) had all issues in print at D.H. Hill Library, while many back issues were in storage at UNC.

The *Journal of Mathematical Analysis and Application* has a 2009 impact factor of 1.225, indicating that a given article in the journal has been cited an average of 1.225 times during 2009. The aggregate impact factor for mathematics journals is 0.777; applied mathematics journals have a higher impact factor of 1.071. Because 1.225 is not much greater than 1.071, the *Journal of Mathematical Analysis and Application* is a fair representation of journals within applied mathematics.

In addition to easy access and the fair representation provided by this journal, it also represents many areas of mathematics and could be considered more of a cornerstone than a small, niche journal. Choosing a widely-read journal would increase the chances of drawing conclusions that could be applied to the wider mathematics community.

From the first issue of this journal in 1960 through 2010, 20,448 articles have been published. 10% of that total would have been too many articles to include in this study due to time constraints. It was decided that, instead of examining each year the journal has been published, to look at the years 1960, 1970, 1980, 1990, 2000, and 2010 specifically. These years would provide benchmarks of the journal's publishing trends. The total number of articles for those six years is 2,243. Sampling 20% of the total articles for each year would further refine the number of articles examined. This resulted in the examination of 450 entries in the journal.

To choose the sample of articles, I first constructed a list of all the articles published in 1960, 1970, 1980, 1990, 2000, and 2010. The volume, issue, and page number for each entry were recorded in an Excel spreadsheet with a different sheet for each year. Using the random number generator known as the Research Randomizer available at http://www.randomizer.org/form.htm randomly chose which entries to include in the sample. For each year, I requested one set of numbers and set parameters for how many numbers I wanted in the set and the range of numbers to include. The number of numbers in the set was 20% of the articles for that year and the range was from 2 through the number of articles plus 1; for example, if there was a total of 56 articles, I would request numbers between 2 and 57. That range was selected because the list of articles in Excel started with 2 since the first row contained headings for each column. By starting at 2 and adding one to the number of articles, I was able to use the numbers as generated by the random number generator instead of subtracting one from each number to select the correct corresponding article. The random number generator displayed a list of

random numbers in a new window that I then exported and saved to my hard drive as a .txt file.

Because the list of articles contained all publications present within a specific issue, front matter, editorial board rosters, redaction notices, indexes, corrigendums, erratums, and lists of forthcoming articles could be selected for analysis. In these cases, the type of publication was noted and available data was gathered. These entries in the journal, however, will not be included in the data analysis of original research articles.

Data was collected on 450 articles in the *Journal of Mathematical Analysis and Application*. Of those 450 articles, 422 (92.7%) were original research articles and contained all necessary data for analysis. The total number selected and number of original research articles is displayed in table 1 below.

Year	Total Number Selected	Number Used
1960	7	6
1970	46	41
1980	56	51
1990	81	79
2000	98	95
2010	162	150
Totals	450	422

Table 1: Number of Articles by Year

The publications excluded from analysis fell into one of the following classifications: forthcoming papers; contents; erratum; editorial board information; author index; dedication; retraction notices; or corrigendum.

Data Collection and Analysis

To analyze the selected articles, the follow data was collected for each article: title, volume, issue, date of publication, keywords (if any), number of authors, and number of references. Also, the names, institution affiliations, and country were collected for each author. For the years 1960, 1970, and 1980, print versions of the journal were used at D.H. Hill due to scheduled maintenance of Science Direct, the database that allows electronic access to the *Journal of Mathematical Analysis and Application*. Articles from the years 1990, 2000, and 2010 were accessed electronically through Science Direct once access to the database was restored.

When using the print volumes, volume, issue and date were collected from the cover of the issue. Title, number of authors, and all information about the authors were collected from the first page of the article. The number of references was collected from the last page of the article. Using the electronic version, all information was collected from the first page devoted to that article, reached by clicking on the title of the article examined. These variables were also recorded in an Excel spreadsheet, one tab for the article information collected and another for the author information collected. To ensure that each author was affiliated with their articles, articles were defined unique identifiers that were also listed in the author information spreadsheet. The identifiers contained year, volume, issue, and page; for example, 1990v148no1p202.

Data collected on each article was initially recorded as printed in the journal or listed on the webpage. This resulted in author names, institution names, and countries (i.e. China and PR China) being non-uniform. To aid in data analysis, I tried to standardize the data collected. For analysis of the institution affiliation,

departments have been stripped so that only the larger institution, either colleges, universities or corporations, can be examined. When authors have been affiliated with multiple institutions or countries, all were recorded, but only the first affiliation was used for analysis.

RESULTS

From the data in figure, it can be seen that over time the size of the journal has grown greatly. The change from 1960 to 1970 seems more drastic than it truly is; this can be attributed to the fact that the journal was first published in July 1960 and only includes the final six months of that year.

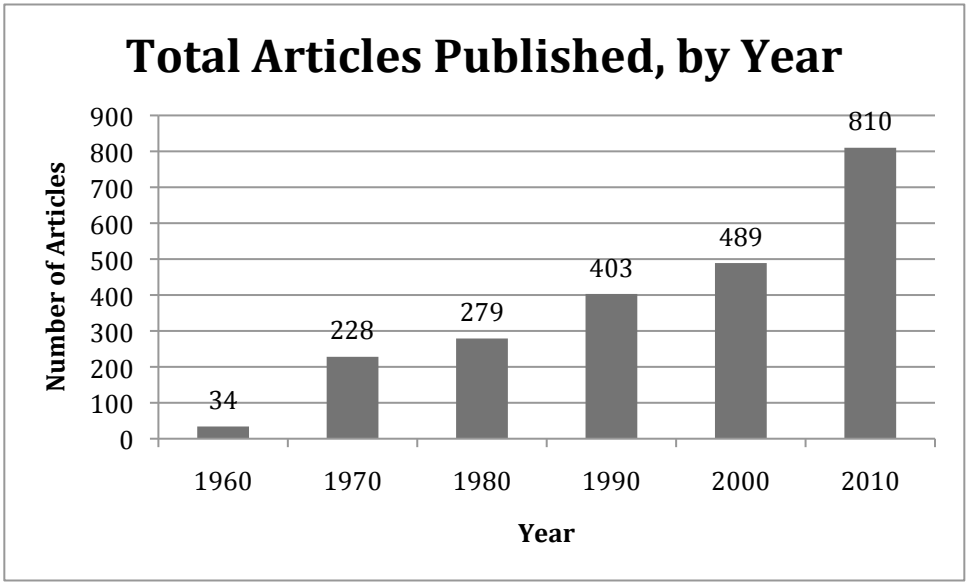

Figure 1: Total Published Articles in Journal of Mathematical Analysis and Application

This change in the number of published journals could be attributed to the natural growth of a journal; as the journal became better known, more mathematicians sought to publish their research here. Perhaps funding increased, through fees paid by authors or subscription fees, and that allowed for more issues and more articles.

Using the sample collected, information on 720 authors was collected including name, affiliation and country. Of these 720 authors, 688 were unique authors, appearing as an author of only one article examined. The frequency of published articles by an author is shown below.

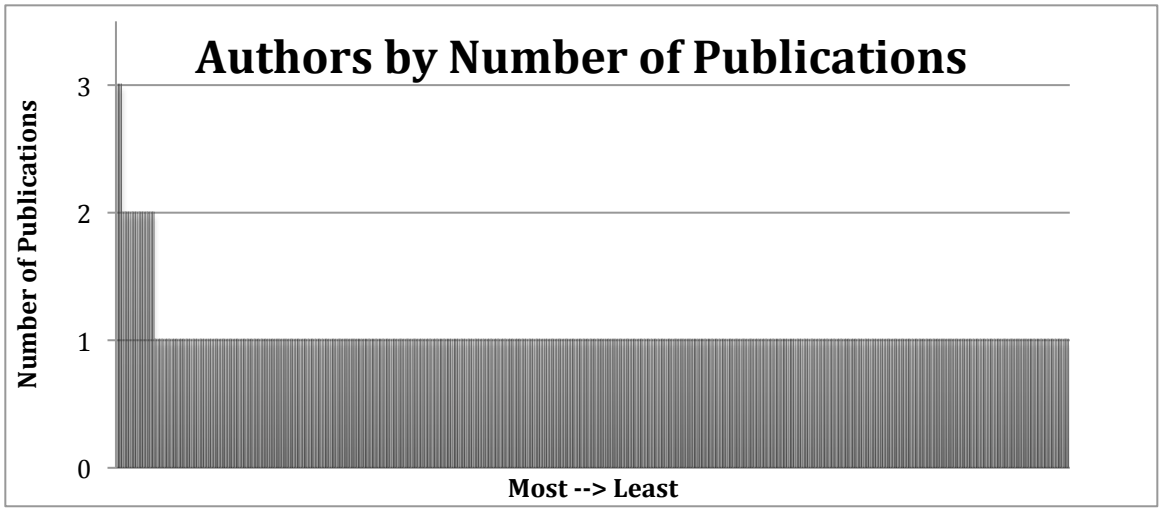

Figure 2: Frequency Chart, Authors' Publications

The authors publishing more than one paper were authors on a minimum of two papers and a maximum of three papers. The authors with either two or three published papers are listed in the following table.

	Name	Number of Articles Published
1.	Donal O'Regan	3
2.	J.F. Colombeau	3
3.	P.G.L. Leach	3
4.	Richard Bellman	3
5.	Young Ho Kim	3
6.	A. Belleni-Morante	2
7.	A. Inoue	2
8.	Abdelkhalek El Arni	2
9.	Bhagat Singh	2
10.	Chun-Lei Tang	2
11.	G. Ladas	2
12.	H.M. Srivastava	2
13.	Harold J. Kushner	2
14.	J. Rissanen	2
15.	J.L. Menaldi	2
16.	Jibin Li	2
17.	K.N. Murty	2
18.	Marko Razpet	2
19.	Moshe Marcus	2
20.	Paul Binding	2
21.	Pei-Kee Lin	2
22.	R.C. MacCamy	2
23.	Radu Zaharopol	2
24.	Ravi P. Agarwal	2
25.	Richard Datko	2
26.	Thomas W. Reiland	2
27.	W.L. Chan	2
28.	Yongsheng Li	2

Table 2: List of Top Published Authors

An aspect of publishing in the mathematical realm that I wanted to examine was collaboration on publications. For this, I collected the number of authors per article for the 422 original research articles. Mathematics is generally thought of as solitary work and the small average number of authors per article clearly reflects that. However, many of the articles examined contained two or more authors. The maximum number of authors per article is four. The following table contains the average number of authors per article by year.

Year	Average Number of Authors Per Article
1960	1.667
1970	1.243
1980	1.353
1990	1.608
2000	1.842
2010	2.18

Table 3: Average Number of Authors Per Article By Year

As seen in Table 3, the average number of authors per article has increased over time. This increase in the average number of authors per article over time indicates that collaboration is increasing in the mathematics community, possibly influenced by the spread of electronic communication between states, countries and continents.

Although a citation analysis was not conducted in this study, I collected the number of references per article to gain insight into basic citing patterns of mathematicians. This variable had a large range, expanding from zero references in one article to 64 references in another article. The average number of references per article by year is displayed in the following table.

Year	Average Number of References Per Article
1960	5.833
1970	8.390
1980	12.725
1990	12.873
2000	17.463
2010	19.96

Table 4: Average Number of References Per Article By Year

There has been an increase in the average number of references, beginning with less than six in 1960 and ending will nearly 20 references per article in 2010,

shown above. It is possible that the increase in electronic access to both new and historical sources has influenced this change.

To understand publishing trends within mathematics better, affiliation and country were collected for each author. This will show which institutions and regions are most active in this journal. Although many authors provided departmental affiliation, I will compare the larger organization for each author to allow for more effective comparison.

The comparison of represented countries is slightly more difficult because of changes in names over time. Many authors are from the Eastern European area and are affiliated with a country that is either previously or presently known by a different name. For example, many authors publishing were at institutions in West Germany during 1970 and 1980. During the years 1990, 2000 and 2010, authors of the same institution were publishing in Germany or the Republic of Germany. To account for this, I analyzed the representation of institution affiliation in addition to country affiliation; this allowed me to focus on institution because that name did not change over the time under analysis.

The charts below show the distribution of published authors from highly represented countries over time. The United States and People's Republic of China have been removed from the first chart and are instead presented separately to better illustrate the great difference between the numbers of published authors in the *Journal of Mathematical Analysis and Application*.

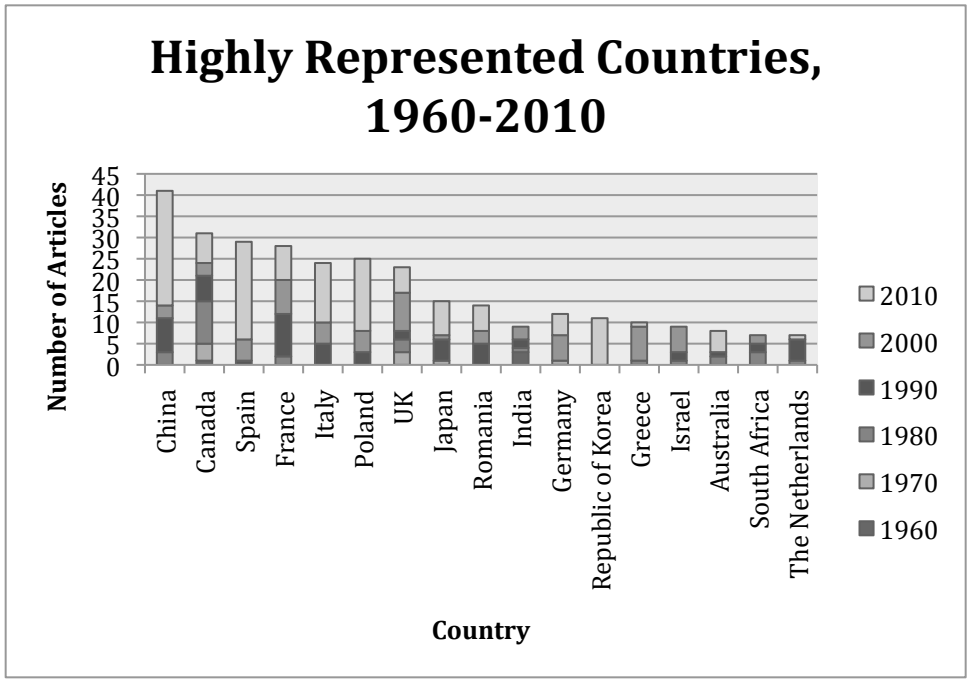

Figure 3: Highly Represented Countries by Year (Numbers for the USA and People's Republic of China have been removed to better illustrate the change over time of country representation)

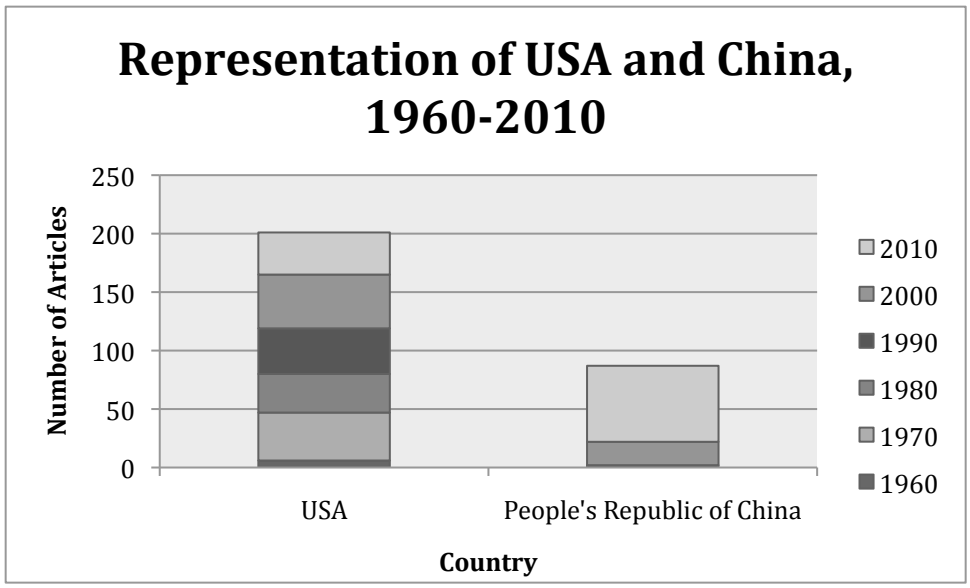

Figure 4: USA and People's Republic of China Representation Over Time

Articles within this journal represent 68 countries. Duplicate authors were included in the country count because I was concerned with the number of articles from each country as opposed to unique authors. Combining variations of countries'

names could reduce the number of countries. Authors from China illustrate this, for example. Based on the year the article was published and the institution affiliation, variations included China, People's Republic of China (represented by PR China), and Republic of China. China and the People's Republic of China represented 33 and 86 affiliated articles, respectively. Combined, these two variations would account for 119 affiliated articles. Taiwan and Hong Kong were also included but not considered variations of China.

Another example is Germany. The country name depended greatly on the year that the article was published. Variations for Germany included Germany, West Germany, Federal Republic for Germany, Bundesrepublik Deutschland, and German Democratic Republic. Individually, these variations account for few articles in the sample; collectively, that number increases to 21, making Germany the 10th greatest represented country within the sample.

Seen in Figure 3, the United States is the most highly represented country with 202 affiliated articles; the combined articles for all variations of China would still not equal this number. This high representation is most likely due to the place of publication. This journal is based in the United States; the founding editor, Richard Bellman, worked at the University of Southern California when the journal began. Many early articles were submitted by Bellman. The large number of US authors published in early issues could have influenced more US authors to submit their research to this journal for publication.

Looking at the countries represented over time, it can be seen that later articles are very likely to include at least one author outside the United States. Many

other highly represented countries gained a large number of published articles in 2000 and 2010 compared to previous years. The United States, however, contributed roughly the same number of articles, or slightly fewer, as previous years. Similar to the growth in the number of references per article, this could be attributed to the increase in electronic access to resources, specifically the *Journal of Mathematical Analysis and Application* and instructions for authors wishing to publish their research in this journal from other countries or continents.

To gather data on the popular topics during each year, I collected any keywords assigned to articles. Unfortunately, no keywords were used within the print volumes for 1960, 1970 and 1980, none were used online during 1990, and some articles were assigned keywords in 2000. Only in 2010 were all articles examined assigned keywords by either an author or indexer for Science Direct. This lack of assigned keywords raises the question: how are these articles searched? Although not a focus of this study, searching impacts findability and future citing of published articles. Even when examining the assigned keywords from 2000 and 2010, very few keywords are assigned to more than one article. This indicates that the keywords are very specific to each article or topic and could hinder a researcher discovering a resource unless he or she knew the precise keyword to use within the Science Direct search feature.

In addition to the article features, data was collected about each author of the articles examined. As mentioned earlier, there were 720 total authors including duplicates; 688 were unique. I recorded each author's name, affiliation as listed on the title page of the article and the country they were working in. In some cases,

authors had multiple affiliations, either with many institutions within the same country or in multiple countries. For this study, multiple affiliations were noted but the first affiliation was used for analysis.

Once again there were 720 affiliations including duplicates. 550 affiliations were unique when using department and institution affiliations. Institutions only, college, university or corporation, for example, accounted for 472 unique affiliations. The table below shows the top 10 affiliations by department represented in the sample.

Department and Institution Affiliation	# articles
Department of Applied Mathematics, Andrha University, Waltair, India	5
Department of Mathematics, University of Rhode Island, Kingston, Rhode Island	5
Center for Cybernetic Studies, College of Business Administration, The University of Texas at Austin, Austin, Texas	4
Department of Mathematics, The Chinese University of Hong Kong, Shatin, N.T., Hong Kong	4
Department of Mathematics, Yunnan Normal University, Kunming	4
UER de Mathematiques et d'Informatique, Universite de Boedeaux I, 351 cours de la Liberation, 33405 Talence	4
Carnegie Mellon University, Pittsburgh, Pennsylvania	3
Center for Nonlinear Science Studies, Kunming University of Science and Technology, Kunming, Yunnan	3
Centre de Recherches Mathematiques, Universite de Montreal, Montreal, Quebec	3
College of Applied Sciences, Beijing University of Technology, Beijing	3

Table 5: Top Ten Departmental Affiliations

Because this journal focuses on mathematical applications, the authors represent many different types of departments. Some of the different disciplines included were: mechanical engineering, electrical engineering, economics, and one author from a department of process and food science. The integration of more departments outside of mathematics could be influenced by the increase in collaboration among researchers as a whole, not just mathematicians (Wuchty et al. 2007).

CONCLUSION

The purpose of this study was to gain insight into the publishing trends of mathematicians and mathematics journals. The data gathered and conclusions drawn provide a small view of the larger mathematical community. Because of the nature of this study, there were some limitations that are discussed below. Also, recommendations for further research are discussed.

Limitations

The narrowness and size of the sample influence how the results can be generalized. To ensure that this study would be manageable within the time frame given, the population under consideration was very specific. Only articles from the *Journal of Mathematical Analysis and Application* were included and that was further refined to only represent the years 1960, 1970, 1980, 1990, 2000 and 2010. It is possible that the view of published research gained from this study favors applied mathematics in the United States during those specific years. Performing a more in depth study of each decade would be a much greater endeavor, but would allow for broadly applied conclusions. To gain an even better understanding of the international mathematics community, studying additional journals from multiple countries would be beneficial.

In addition to the specific population, only 20% of each year examined was included in the sample. With this fraction of the articles examined, there is a high margin of error meaning the results may not be applied to all years within the journal's publication range. This small sample was necessary to complete the study

within the time frame allowed for a master's paper and shows trends within this journal, but the conclusions cannot be applied to other populations within the mathematics community with much confidence.

The data is limited and thus the results may not be generalizable to the large body of mathematical literature. In this case, only one journal, the *Journal of Mathematical Analysis and Application* has been analyzed. There are many small, niche math journals that are not be included in this population that may provide a different view of publishing trends.

Further Research

As discussed above, the present study was limited to a very specific population in time. To overcome these limits further research should be conducted. To begin, using the same sample of articles here, a citation analysis should be completed to discover what articles, journals, authors, and other resources are being cited. This would better illustrate how mathematicians are using mathematical literature in their research and published articles.

In addition, these techniques for looking at publishing trends could be applied to a larger, more diverse population. With more time, a sample of all mathematical articles indexed by Science Direct or MathSciNet from the time period 1960 to 2010 could be examined to see if the trends discovered here hold true across multiple mathematical journals.

Examining the population described above, a citation analysis would be helpful to determine more broadly what are the seminal works within mathematics.

This would also aid in potentially mapping the field to see how mathematicians have contributed, inspired, changed, and altered different subfields of mathematics.

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