EVOLUTION OF MARINE RESOURCES MANAGEMENT : A SCIENTOMETRIC ANALYSIS

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ABSTRACT

The field of marine resources management is very broad and diverse. It is also very dynamic as new and exiting research is being produced in emerging fields such as aquaculture and integrated management. This research proposes to evaluate the trends in research pertaining to the many fields within marine resources management and discover what areas of research exist. The goal of the article is to produce a portrait of the many research themes that come into play in marine resource management as is it commonly practiced now. In order to tackle the structure and the evolution of this field, we will use the method of associated words. The method exploits the occurrence and co-occurrence of keywords in order to construct a word-network which can represent the field of marine resources management. As it is not possible to represent a domain using only word-networks, the method consists of using an index of association to bring out the most significant associations (i.e. the word aggregates that are more strongly related among themselves than to other words in the network). These word aggregates (also called themes) are composed of a limited number of words that can be determined during the process. Each theme is constructed around a central word which serves as its definition and with which all the other words of the theme are in a statistical relationship. It is possible to see the evolution of research themes through time and therefore have an overview of the development of the field of study, especially with regard to important themes, and the appearance of new themes. All the papers which are relative to marine resources management and included in bibliographic databases (ABI-INFORM, EBSCO Host and Science Direct) to 2006 have been analyzed. In this paper, we will present some results of this study and a special focus will be placed on decision making tools which have been developed and implemented in this field of interests.

Keywords: scientometric analysis, marine resource management, keywords, trends

INTRODUCTION

The field of marine resource management (thereafter referred to MRM) has seen some sweeping changes in the last decades. It is a fast evolving field that comprises a wide array of scientific disciplines and therefore defining its "true" composition and following the evolving changes in every discipline is quite challenging. The overarching goal of this research is to collect the information in scientific papers provided by the numerous fields of science that make up MRM and transform them into knowledge that empowers the scientific community. The three fundamental questions that are addressed are: 1) what knowledge is being produced in the field of MRM? (what broad concepts are present and what is emerging) 2) who is producing that knowledge? 3) where is that knowledge being produced (which journals)?

The process of sieving through large volume of information to extract knowledge is known as datamining. The rise in importance and popularity of this procedure has resulted in the development of multiples software's that allow these analyses. Datamining is used in a great number of activities; in the pharmaceutical industry where it helps in identifying the most promising cures for specific diseases, in banks to study the characteristics of fraud and many more applications (Solveig Vidal, 2004 MSc thesis).

A database that provided an accurate representation of the current situation and trends in knowledge in MRM was built. Like any major research field, some themes will occupy great amount of importance; reflected by the volume of publications they command and the number of dedicated journals. Nevertheless, in order to detect emerging fields and subjects matters that have not yet received a significant amount of attention it is necessary to focus on week signals. Through the study of these signals, it is possible to detect the up and coming themes and the future trends setters for the field of MRM. Strap up your seatbelt as we are about to embark on an historical review of marine sciences and play a scientific Nostradamus prediction game which will hopefully lend itself to very rewarding findings.

Materials and Methods

In order to address the question of the evolution of MRM and provide an accurate picture of the field, the focus of the analysis was put on keywords presented within scientific articles. The simultaneous use of two keywords within an article translates a link in the meaning of the two words and present the principal notions discussed in the communication (Urli and Nadeau, 1999). The multiple occurrences of these keywords will then be used to construct a word-network which brings out the most significant associations (the word aggregates that are the most strongly related among themselves). Each of these word-network created can then be defined in term of its centrality and density. An emerging concept would be characterized by a strong density and a weak centrality; indicating that it is out of the central word-network forming the majority of the defined field of research and represents a new quasi independent research area (reflected by the high density).

To allow for the coverage of a field as broad in nature as MRM, a data collection encompassing all the pertinent scientific fields related to MRM was developed. Published papers present in three electronic databases were collected: ABI/INFORM (3800 business and management journals), EBSCOhost (12 000 journals) and ScienceDirect (>1840 journals). A list of the selected journals found within each of the databases was then circulated among a panel of expert in MRM. Based on their knowledge and input, selected journals which were not yet part of the build data collection were then added individually to provide a coverage, as extensive and complete as possible, of the studied field. The same keywords and research procedure were used in all three databases to avoid any possible bias. The completion of the various steps assured that all the main journals pertaining to MRM were included in this research. The overall database that was analyzed contained 4524 articles emerging from 674 journals. At this point, it is important to point out that our focus was on academic knowledge, our database was formed exclusively from published papers.

The software used for the extraction and the interpretation of the keywords was Lexiquest Mine™ a SPSS' text mining software based on a Natural Language Processing (NLP) technology. The software employs "a combination of dictionary-based linguistic analysis and statistical proximity matching to identify key concepts, including multi-word concepts" (Martin et al. 2004). A linguistic analysis based on the context and semantic nature of the words then allows to identify the degree of relationship between the various multi-words concepts and other concepts all arousing from the co-occurring keywords. The various trends and changes in the literature will be reflected through the changes in the keywords used.

Once the analysis is completed, the trends and the various research fields within MRM will be obtained. The obtained results will then be presented to a panel of expert in MRM. From the ensuing discussion, it is hoped that trends and signals perceived in the analysis can be explained and reasoned by experts in their field of expertise. For example, if a sudden peak in a particular subject is observed (identified by a sharp increase in the frequency of a given keyword) what caused that sudden rise in interest for that

particular subject matter? New legislations, a particular oil spill, a new biomolecule? These interpretations thus allow to make sense out of the many perceived signals and providing clues as to what lies ahead. The interpretation by a committee of expert has not been performed yet and therefore, this research is still a work in progress.

Analysis of the database

One of the fundamental questions asked earlier, is where does the knowledge in MRM get produced? In order to answer this question, a review of the database is required.
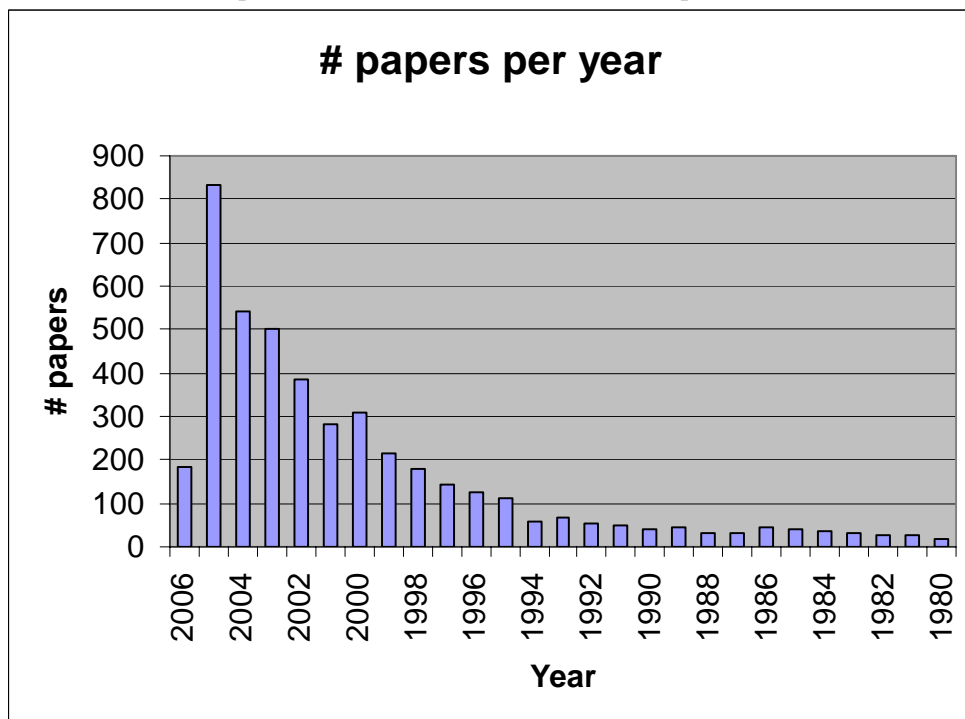
papers per year

Figure 1. Evolution of publication in MRM per year.
Note 1. 2006 contains the papers from January to March only.
Note 2. The number of papers per year prior to 1980 were simply too small and eratic to add to figure 1.

As can be observed from figure 1, the field of MRM is in a state of expansion. From the year 1980 to 1994 a constant amount of literature is generated with minimal fluctuation. After 1994, an exponential rate of increase is setting in. There is no sign that this trend is about to change, in 2006, with only three months of literature collected, the number of publications is already higher than anything observed prior to 1998. It is important to keep in mind that exponentially increasing trend as it will occur again in further analysis.

The main themes in MRM

From the analysis of the database, the main themes can be extracted. Table 1 illustrates the main concepts present within each theme. The vast majority of the themes contain concepts that are only found within a particular theme, the number of duplication is low indicating that the themes are discrete.

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Table I. 10 most important concepts present within each main theme for the complete database.

Fisheries (1168)	Aquaculture (462)	Shipping (291)	Coastal zone management (232)
			un convention on the maritime legislation unclos
fishery economics	phosphorus	container transportation	
fish populations	farm management	Cartels	Seashore
Management	Antibiotics	marine service	beach erosion
fish	Diseases	Rates	shore protection
			coastal zone engineering
Fishing	Treatment	international trade	
aquatic resources	fish culture	Transportation	coastal zone
fishery management	Effluents	Competition	coastal zone ecology
natural resources	Fish	freight & freightage	geographic information system
		Transportation economics	
Agriculture	Agriculture		marine policy
united states	Feeds	trade policy	actions & defenses

Aquatic resources (192)	Ports (172)	Economic models (161)	Salmon (157)
fish populations	infrastructure	economic rent	m74 syndrome
biotic communities	quality of services	demand curves	grey seal
Management	competition	Variables	stock forecasts
life sciences	supply chains	production functions	mixed-stock fishery
Agriculture	container transportation	Economic theory	Genetics
natural resources	Logistics	fishery economics	salmon farming
wildlife management	transportation	Equilibrium	Diseases
fishery management	international trade	statistical analysis	fishery closures
Aquatic sports	Shipping	elasticity of demand	rive monitoring
conservation of natural resources	performance evaluation	input output analysis	subdivided population

Models (109)	Resource management (105)	Economics (94)	Marine protected areas (92)
Raceway	Conflict	economic models	aquarium fish
Design	Shutdowns	Jurisdiction	sea cucumber
dolphins & porpoises	land use	Resources	Trophic
energy economics	renewable resources	commercial fishing	protected areas
computer simulation	government regulation	Biological	national parks & reserves
celtic sea cod	Zone	greenhouse effect	management areas
Optimization	Resources	fishery economics	Bioeconomics
fluid dymanics	business failures	Demand	Keystone
Recreation	pearl culture	Tradeoffs	invariance analysis
Costs	fishery economics	Economic impact	sea raven

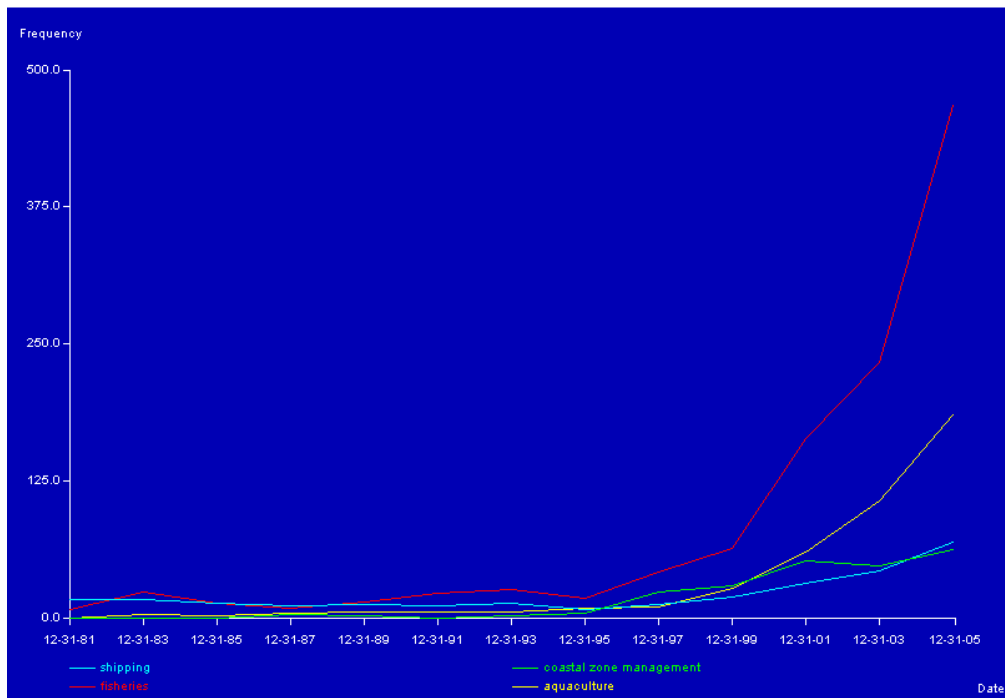Table I. was obtained from the analysis performed with Lexiquest Mine[TM].

Figure 2. Evolution of the main themes over the period of 1980 to 2005 inclusively.

As can be observed in figure 2, all the themes are following the general trend of increasing publication, the selected keywords appear more frequently in papers. The themes of "fisheries" and "aquaculture" are the one experiencing the strongest increase (which is not surprising) while the frequency of appearance of the theme "coastal zone management" and "shipping" are not increasing as steeply. From 1999 onward, fisheries and aquaculture become increasingly more important every year. It is possible to obtain the global frequency of the entire majors theme present in the database. By combining them, a rough statistical approximation of the importance of every theme can be obtained as illustrated in figure 3.

Slightly over a quarter of the articles are pertaining to the fisheries. While 10.5% and 6.6% are dealing with "aquaculture" and "shipping" respectively. This figure provides a general view of what constitutes the field of MRM. The large importance of aquaculture and coastal zone management are a testimony to the rapidly changing nature of MRM. Both are relatively new concepts, which have undergone an explosion in importance in the last decades, from keywords virtually unused prior to 1997, they now represent the second and third most important themes for the overall period of 1948 to 2005.

Another way to characterize the major themes of MRM is to look at the variables of centrality and density. The density is the average value of the internal ties between the words within a theme. A high density value indicates that the words are closely linked therefore, the papers from which the keywords emerge and form those links are specialized and deal with repetitive subjects. On the other hand, the centrality measures the average value of the external ties of a given theme. The centrality is higher when a given theme is a passage opening up the door to the other themes of the domain (Urli and Nadeau, 1999).
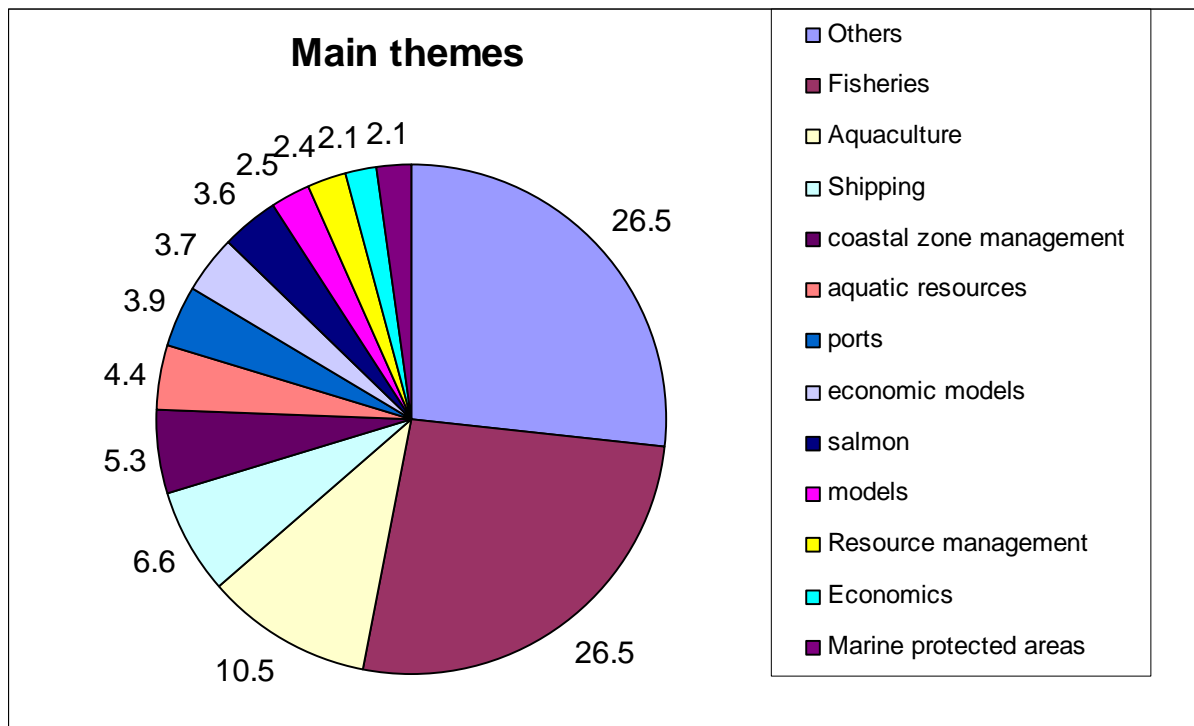
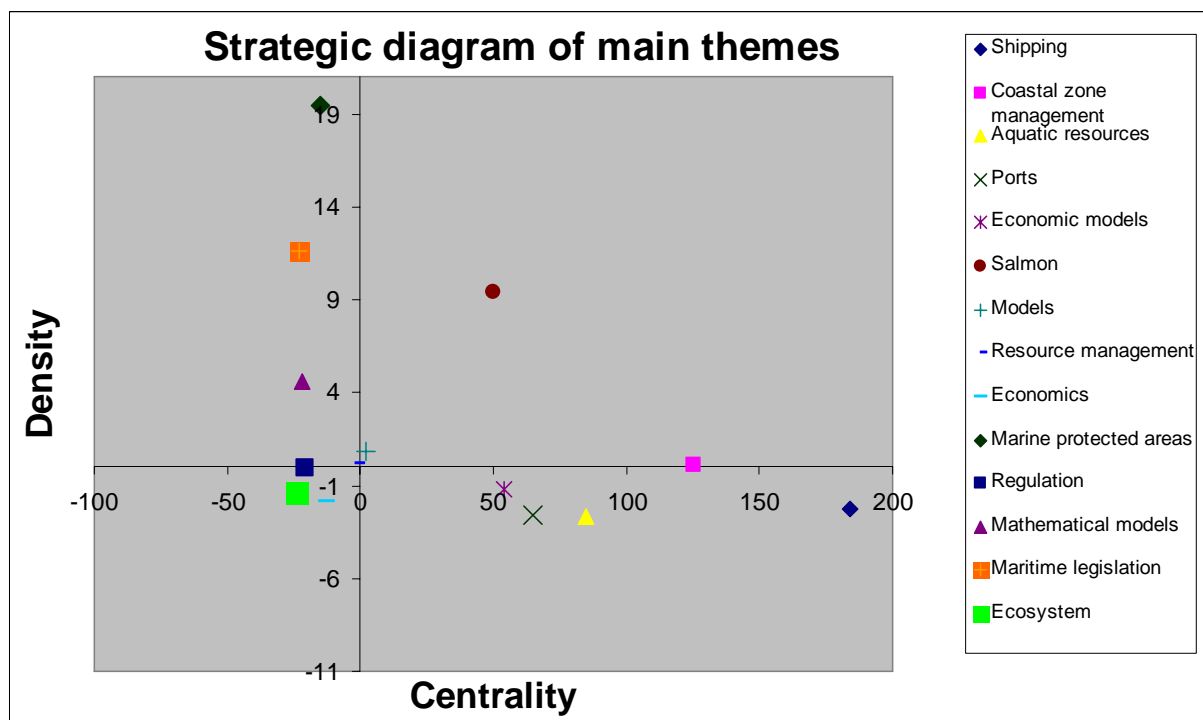Figure 3. Relative importance of the major themes in MRM.

Figure 4. Centrality and density of the main themes of the database.
Note the theme Fisheries and Aquaculture were not included as their very high centrality value prevented having a clear view of the remaining themes.

A quick study of figure 4 illustrates the main themes and their relative importance in MRM. The themes with a high value of centrality are the core theme of MRM. These include fisheries, aquaculture, coastal zone management, aquatic resources, ports, economic models, models, resource management and shipping. So far no surprises, one would expect these themes to be important and at the hearth of MRM. What is even more interesting are those themes having a low centrality and a high density values. They represent new emerging themes that are quite self sustained that have sprung up from the general more core themes (stronger centrality values). The strongest emerging theme is "marine protected areas", which is now developing a whole new research field within itself. Following closely behind are the themes of "maritime legislation" and "mathematical models" which are also both considered as emerging.
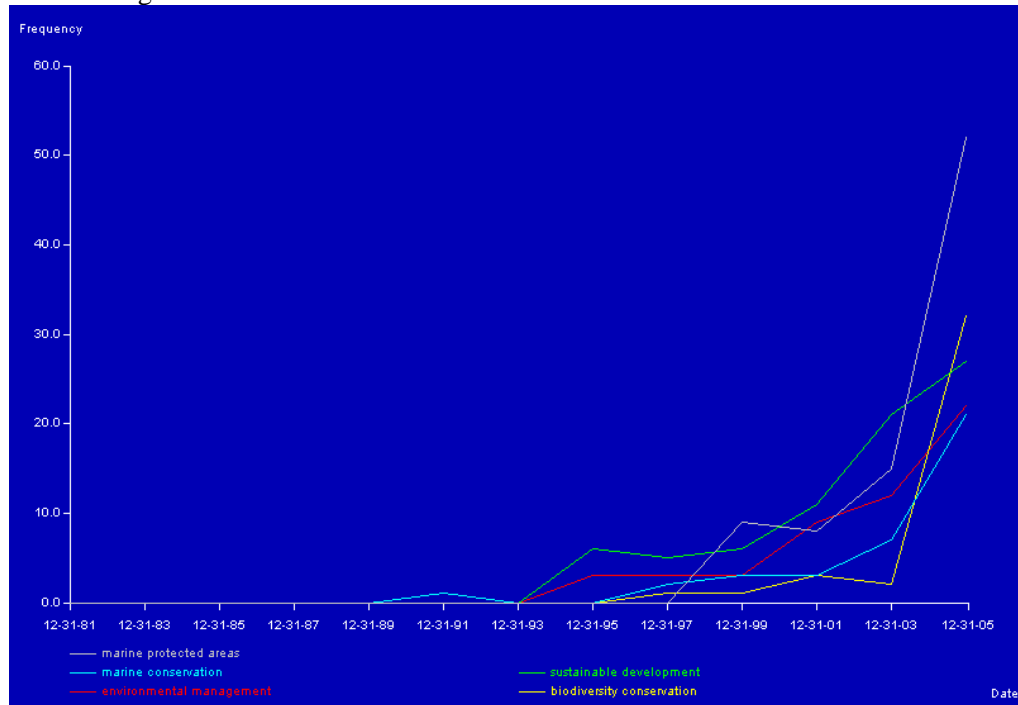

Figure 5. Emerging trends in MRM.

The results illustrated in figure 5 corroborate the findings of the diagram of centrality and density. The theme of "marine protected areas" undergoes a sharp rise in frequency of citing at the end of 2003. Another encouraging note is the sharp increase in publications concerning the environmental terms which are taking greater importance in the last decades. These environmental themes were of overall importance too low to be included in the main themes of the database (table I) but with their recent frequency of appearances they might just become dominant themes of MRM in the years to come (hence the adjective emerging fields).

The author's network

The scientometric analysis allows to graphically represent a map of co-publication among the various authors as illustrated in figure 6. This is an interesting finding in itself but it is nevertheless limited as it does not permit to see what each of these network of co-publishing authors are publishing about; their research interests which translate into the various themes explored through out this paper (please consult the discussion and conclusion for a further discussions of these limitations and the next steps to be
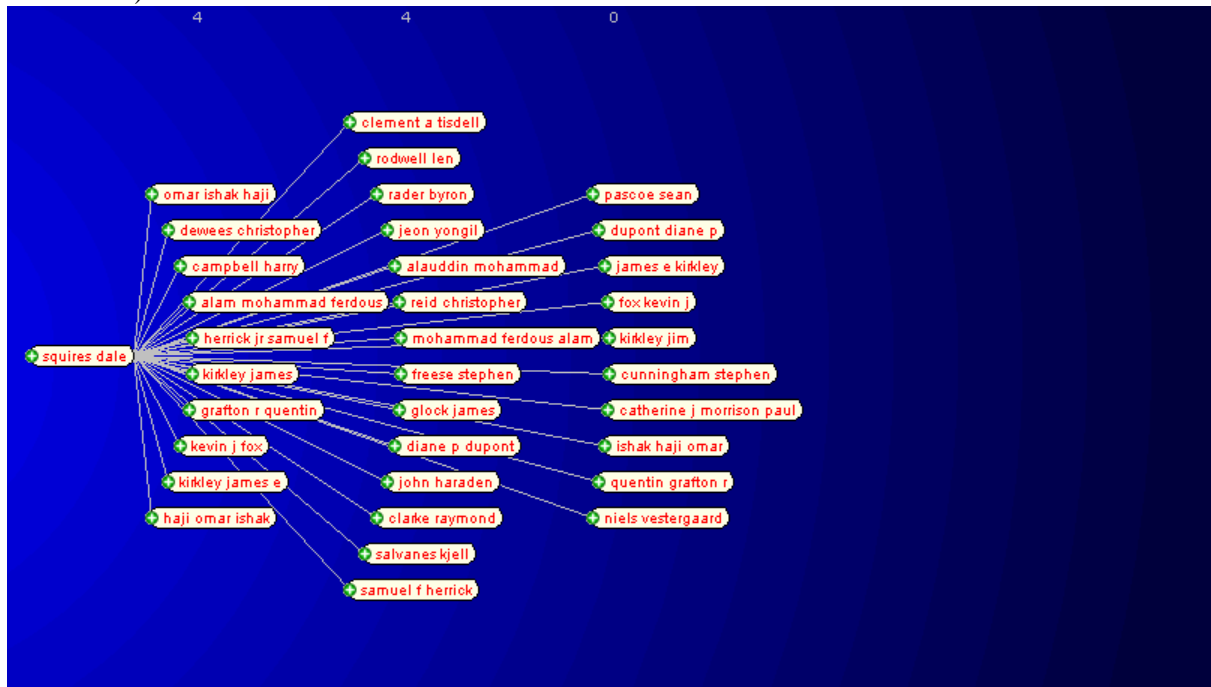
undertaken).

Figure 6. Authors co-publication networks (this particular map is for Squires Dale).

The impact of the selected journals

There were 674 scientific journals included in the database. Out of these 674, some journals accounted for a significant amount of the total publication as illustrated in table 2.

Table II. Most important journals in term of number of papers published in MRM.

# publications between 1948-2005	Journals
62	Aquaculture Research
70	American Journal of Agricultural Economics
70	Land Economics
85	Canadian Journal of Fisheries & Aquatic Sciences
87	Maritime Policy & Management
99	Aquaculture
117	Fisheries Management & Ecology
126	Journal of Environmental Economics & Management
180	ICES Journal of Marine Science
297	Fisheries Research
486	Marine Policy

It is important to acknowledge the importance of the various scientific publications as each specializes in its own domain. The overall picture of a database will be greatly impacted by the journals selected. While acquiring knowledge on a given field of research, it is also necessary to obtain all the information possible on the journals through which the knowledge is produced. The following figures illustrate the major

themes relating to MRM discussed in the two scientific journals that contained the most papers published in MRM.
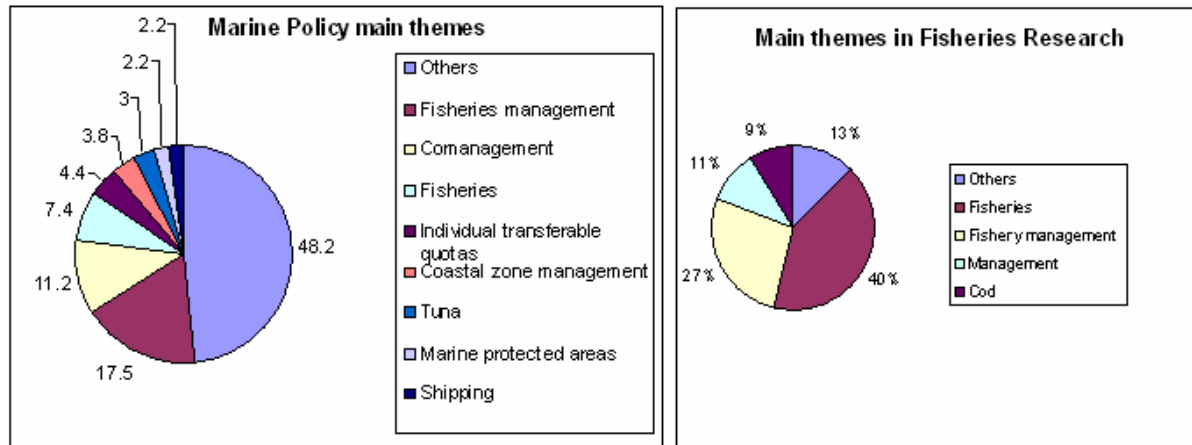

Figure 7. Main themes in *Marine Policy* and *Fisheries Research.*

Figure 7 clearly illustrates the difference in themes that both journal focus on. The journal of *Fisheries Research* is more specialized as reflected by the very high percentage of coverage that is achieved by simply considering the two main themes; "fisheries" and "fishery management"(over 50% of the themes). The papers published in *Marine Policy* are more diverse, as illustrated by the multiple major themes represented in the figure, which all occupy a much smaller percentage of the overall published material when compared to *Fisheries Research*. It is also interesting to notice that both of these journals focus on different fish species, tuna for *Marine Policy* and cod for *Fisheries Research*.

The latest trends and unexpected events impacts

Through the scientometric analysis of the field of MRM, it is possible to clearly identify when new concepts and themes appear in publications. This then allows to stay on top of what is current, relevant and with a bit of intuition; what is to come. For a dynamic field of research such as MRM this can prove crucial in producing "good" and up to date research. Figure 8 illustrates the most recent changes that have taken place in the literature reflecting the new interests in research.

It is very interesting to see what the scientific community is perceiving and writing about as an environmental concerns as time evolves. The observed peak for the concept "accident" occurs in 1989, the year of the Exxon Valdez accident. This concept then virtually disappears from the radar for a long period of time. 1995 seems to be the awakening call concerning the problem of overfishing and as figure 8 shows, this concept as since then constantly attracted more literature; to remain up to 2005 the leading environmental issue. Another latecomer that has come to capture a vast number of papers is the "invasive species" problem. From a virtual unknown prior to 2001, it becomes within two years the most frequently cited environmental issue with the problem of "overfishing".
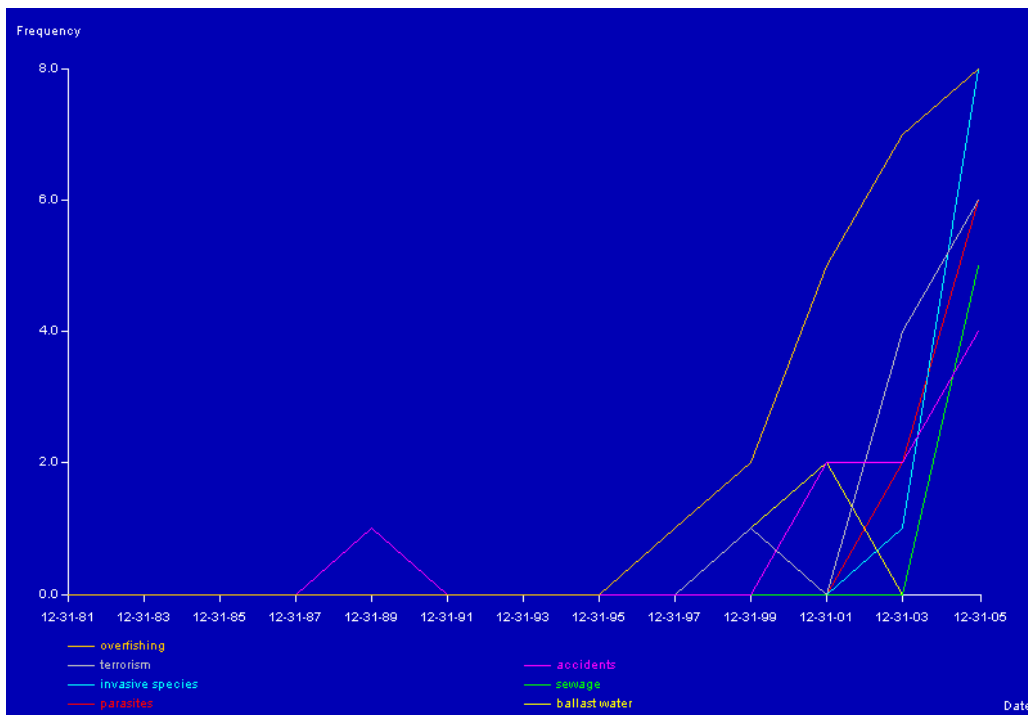
Figure 8. Emergence of new trends pertaining to new environmental concerns.

It would nevertheless be unwise to simple rely on previous years trends to predict which issues will go on increasing in their frequency of citation and therefore represent an active research theme as illustrated by figure 9.

Prior to 2001, the amount of papers discussing legislations and regulations pertaining to the environmental and maritime subject are reaching record levels never seen in 20 years. Past the terrorist attack on the United-States in 2001, the biggest drop in frequency related to the regulatory and environmental concepts takes place, this sharp decrease lasts two years. Then the environmental regulations and the international legislations go back on the increasing trend while the maritime legislations stagnate. This particular example is quite interesting as it illustrates that the scientific world can be greatly influenced by events far from its usual realm of interests but nevertheless have a very strong impact. It proves that it might be pertinent to look outside of the scientific community as well to see what will be the influences guiding the new directions taken by scientific research.
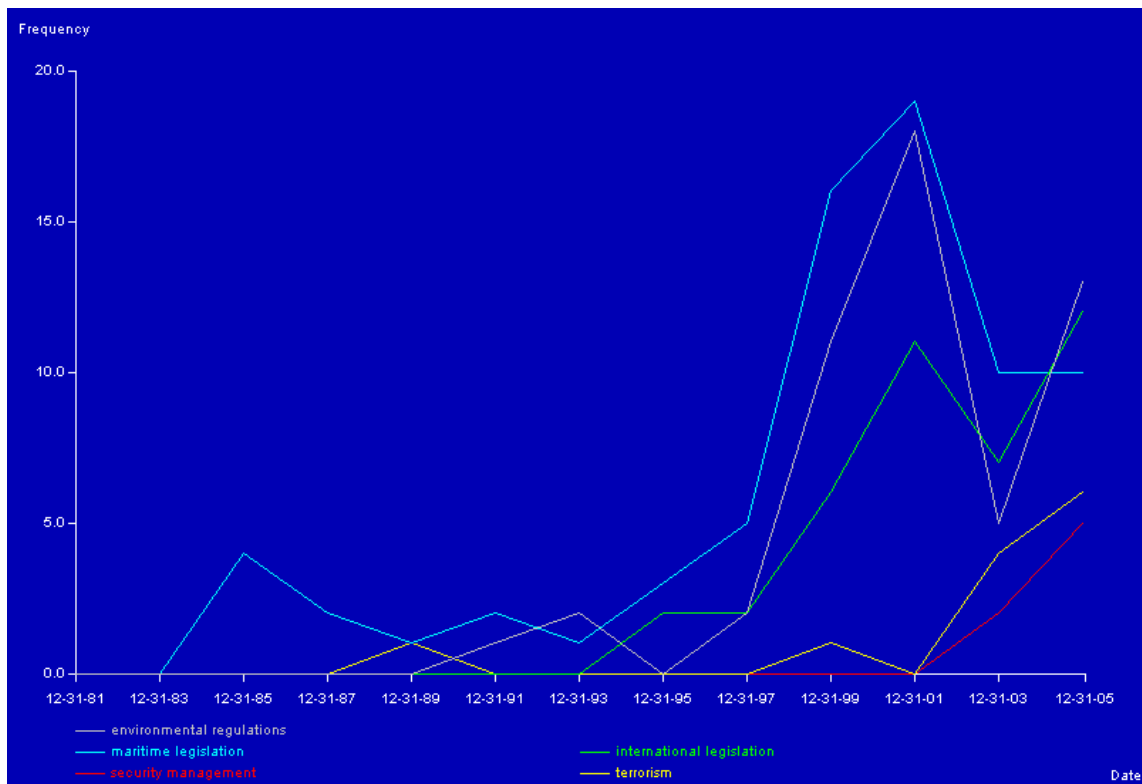
Figure 9. The impact of uncertainty on the regulatory world.

Conclusion and discussion

This research is still a work in progress and only the early analyses have been presented in the present paper. The upcoming work requires consultation with a committee of experts and the use of another software which will be discussed shortly.

The procedure previously described in this research is quite valuable to provide insight into a field of scientific knowledge. By researching all the pertinent journals that are used in the field of MRM it was thus assured that the field was accurately represented. The selected approach is devout of preconception. The definition of the themes and concepts making up MRM were not pre-conceived but rather emerge from the literature itself. It therefore provides a complete portrait of MRM not from a given expert's standpoint but rather it objectively emerges from the analyses. The help of a committee of experts will nevertheless be required. It is proposed to present these results to a committee which will then provide the knowledge to more fully interpret them. According to them, is the current portrait provided accurate? Have they themselves perceived the same changes that were discussed here in their specific research interests? Only through their input will the results exposed here be validated.

Often in the literature, a great amount of recognition is given to an author that possesses a large number of publications. With the analyses that were performed in this paper it is possible to assess the impact of a given author on the rest of the scientific community. With the software used in this research, it is feasible to graphically represent the publishing network (who publishes with whom). It is therefore possible to see which scientists work together and which scientific group exists. The next step that will be undertaken is to link together the publishing network with the themes network. This way it will be possible to link a given research group to a particular research theme and see how a particular knowledge spread through

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the scientific community and how and where emerging themes arise. By graphically representing these concepts, it will become possible to answer all the fundamental questions asked in the introduction; who is producing the knowledge; what knowledge and where. It will also allow seeing if the authors are as multidisciplinary as the discipline of MRM is; or if authors are experts in their own field of expertise and do not venture out of it.

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