MAPPING OF CORAL REEF RESEARCH LITERATURE : A GLOBAL PERSPECTIVE

A THESIS SUBMITTED TO THE PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE AWARD OF

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IN
LIBRARY AND INFORMATION SCIENCE

By

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CERTIFICATE

This is to certify that the thesis entitled **"Mapping of Coral Reef Research Literature: A Global Perspective"** is a bonafide record of research work done by **V. MOHAN,** Research Scholar, Annamalai University, under my guidance and supervision for the award of Ph.D., degree and that has not previously formed the basis for the award of any Degree, Diploma, Associateship or Similar title.

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DECLARATION

I hereby declare that the thesis, **"Mapping of coral reef research literature: a global perspective"** submitted to the Department of Library and Information Science, Annamalai University, is my original research work. It has not previously formed the basis for the award of any degree or any other similar title or recognition.

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Dedicated
to
my Grand Mother

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LIST OF ABBRIVATIONS

AIMS	**- Australian Institute of Marine Sciences**
APA	**- American Psychological Association**
ASFA	**- Aquatic Sciences & Fisheries Abstracts**
ASFIS	**- Aquatic Science Fisheries Information System**
BBCI	**- Biophysics and Biochemistry Citation Index**
BIOSIS	**- Biological Abstracts**
BTCI	**- Biotechnology Citation Index**
CA	**- Cluster Analysis**
CAB	**- Chemical Abstracts**
CDROM	**- Compact Disk Read Only Memory**
CMFRI	**- Central Marine Fisheries Research Institute**
CSCD	**- Chinese Scientific Citation Database**
CSIC	**- Spanish Council of Scientific Research**
DAE	**- Department of Atomic Energy**
DOD	**- Department of Ocean Development**
DRTC	**- Documentation Research & Training Centre**
FAO	**- Food and Agricultural Organisations**
GCRMN	**- Global Coral Reef Monitoring Network**
GDP	**- Gross Domestic Products**
GOI	**- Government of India**
HIV	**- Human Immunodeficiency Virus**
IASLIC	**- Indian Association of Special Libraries & Information Centres**
ICT	**- Information and Communication Technology**
IOC	**- Inter Governmental Ocenographic Commission**
ISI	**- Institute of Scientific Information**
JCR	**- Journal Citation Report**
LISA	**- Library and Information Science Abstracts**
MDS	**- Multi Dimensional Scaling**

MSCI	**- Material Science Citation Index**
NISC	**- National Information Service Corporation**
NPV	**- Net Per Value**
SAC	**- Space Application Centre**
SBI	**- Sugarcane Breeding Institute**
SCI	**- Science Citation Index**
SCUBA	**- Self Contained Underwater Breathing Apparatus**
SPSS	**- Statistical Packages Social Science**
SSCI	**- Social Science Citation Index**
UNDP	**- United Nations Development Programm**
UNEP	**- United Nations Environment Programme**
UNESCO	**- United Nations Educational Scientific Research Organisations**
UNOALOS	**- United Nations Office for Ocean Affairs and Law of the Sea**
WOS	**- Web of Science**

CHAPTER 1

INTRODUCTION

I. 1. Coral and coral reefs

Corals are living beings, belonging to marine **Invertebrata** under the Phylum **Coelenterata** or **Cnidaria** and are primitive animals occurring anywhere in the depth ranging from the low tide to 6000 metres mainly in the tropical regions of the oceans and seas. Although coral reef seems as rock or a plant, it is actually composed of tiny, fragile animals called coral polyps. Polyps, having a hollow cylindrical body with a ring of tentacles around the mouth, are sedentary. A coral polyp is a spineless animal. The Polyps are made of limestone viz. calcium carbonate which is extracted from the seawater.

The term '**cora**l' has been used to describe a variety of different invertebrate animals from the phylum **Cnidaria** including hard corals, soft corals, precious corals and hydrocorals. However, coral is most often used as the common name for hard corals from the order '**Scleractinia**'. Scleractinian corals are divided into reef building corals (Hermatypic corals), which form the primary structure of coral reefs, and non-reef building corals (Ahermatypic corals) that do not contribute significantly to reef formation (**Veron**, **2000**).

Coral reefs are defined as a complex organogenic framework of calcium carbonate, which form a rocky eminence on the seafloor and customarily grow upwards to the low-tide limit. They are also defined as marine biogenic, wave-resistant carbonate structures, also known as bioherms, composed of shells or skeletons of hermatypic or reef building organisms.

2. Origin of coral reefs

The origin of coral reefs has been debated by oceanographers for over a century. Coral reef first appeared and began diversifying in the **Ordovician**, peaked in the **Silurian** and vanished by end of **Permian** and early **Triassic** period (**Scrutton,1979**). Since corals do not grow below about 65 ft, they can survive only for brief period above water.

Charles Darwin (**1842)** put forward and referred to **'*subsidence theory*'** after his voyage around the world on the *R.M.S. Beagle* (1832–1836). Darwin propounded that the reef growth was made possible by the gradual minimum support of the pedestal upon which the reef first began to grow.

The reef organisms grew upward to compensate the gradual submergence of their platform. More recently, at the end of last Ice Age, gradual rising of the sea level, because of the melting of glaciers has added to the subsistence mechanism, is a possible explanation. The fringing reef becomes converted into barrier reefs

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Triassic = From 190 million to 230 million years ago; dinosaurs, marine reptiles; volcanic activity
Permian = From 230 million to 280 million years ago; reptiles
Silurian = From 405 million to 425 million years ago; first air-breathing animals
Ordovician = from 425 million to 500 million years ago; conodonts and ostracods and algae and seaweeds

and then into atolls, by slow gradual sinking of an island formation.

3. Age and growth of corals

A coral grows slowly by budding off new polyps. It may grow about half a centimetre to several centimetres in a year and a branch may have taken 15 years to grow and whole coral colony may be 30 to 50 years old. Encrusting and mound corals may grow a few millimeters only in diameter each year. A brain coral with 3 metres height may be over 1000 years old. Coral reefs flourish in the warm shallow waters of tropical seas and oceans that optimally have temperatures between 26° C and 27°C. Because of their precious gifts to sea life and to man, coral colonies should be protected and never damaged if possible by all means. It may take for a dynamite-shattered coral reef to take 30 to 40 years to half recover. Occasionally some fragments may start a new colony, but if the breakage is extensive, waves like ***Tsunami* 2004** may roll the pieces against the remaining live corals and smash them too (**Patterson *et al.*, 2005**). Freshwater and prolonged exposures to air kill corals. If a coral reef was killed by cloudy water or mud, the reef can grow back, if the source of cloudy water or mud is stopped.

Corals have sharp-edge tentacles. During the day the tentacles are closed. At night the tentacles open up like tiny

flowers, with which they snare plankton, for the food. Mangroves and sea-grasses provide nutrients to them. However, 4/5th of the coral energy comes from sunlight. The Zooxanthellae (algae and sea-plants) share their energy obtained from the sun. Most coral polyps have clear bodies and their skeletons are white, like human bones. Most corals get their color from the zoozanthellae inside them. Several million zooxanthellae live in just one square inch of coral and produce pigments. These pigments are visible through the clear body of the polyp and give the coral its beautiful color.

A coral often reproduce both sexually and asexually. Among corals some species are dimorphic and they reproduce when the water is warm and the full moon season in the tropics (**White**, **1987**).

4. Types of reefs

There have been many attempts to classify different types of reefs. All lack general agreement because there is continual variation from one reef type to another, also because they can be classified according to their geological history, their shape, their position relative to landmasses, and the nature of the material they are made of. In principle, these types of classification can be merged into three broad categories.

CORAL REEFS

Fringing reefs

This type of reef form a shallow shelf close inshore on rocky coastline or around offshore island. It's leaving only a narrow shallow lagoon between reef and land. The Fringing reefs grow to a substantial depth and usually exposed of low tide. **Guilcher** (**1988**) stated that some fringing reefs found in Mahe Island in the Seychelles contain the boat channel which is very shallow and also contain less sediment. In India some fringing reefs are common in the Gulf of Mannar and Andaman and Nicobar Islands.

Barrier reefs

Barrier reefs are at the edge of continental shelves and separated from land by deep coastal waters. The reef usually contains a substantial proportion of calcareous sediment of reef origin. It's typically developed to the length of 10- to 100s of kilometers from coastline. For example, the Great Barrier reef are dozens of kilometres wide extending about 2000 Km along the east coast of Australia and represent 3% of the total of the reefs in the world. Danajon barrier reefs lie between Bohol and Leyte Islands of Philippines. This type of reefs is found in Andaman and Nicobar Islands (**Pillai & Venkataraman, 1999**).

Atolls

Fringing reefs formed a circular barrier reef around a central lagoon and separated from island. The circular reef sometime

capped with small coral island, the island finally disappears and the entire island is enclosed by lagoon. The whole structure is called an atoll. It is also termed as coral island or atoll lagoon.

Stoddart (**1965**) recorded a total of about 425 atolls in the world and considered the Tuamoto Archipelago in Seychelles group of islands in the Indian Ocean as having seventy-six Atolls. In India, the Lakshadweep group of islands has 12 atolls surrounded by deep water.

Apart from these, the recent studies on the geography of coral reefs in various regions of the world indicate some more special reef types. These are named as Platform reef, Patch reef, Coral Pinnacle, reef flat, coralline shelf, Coral Heads and Live coral platform.

5. Worldwide distribution of coral reefs

Coral reefs composed of dead polyps cover about **2,84,300 sq.km**. (1,10,000 square miles) of the earth's surface (**Spalding *et. al.*, 2001**). About 100 countries are having coral reefs. **Figure 2** illustrates worldwide distribution of coral reefs. Indonesia is having largest reefs among the coral reef nations and its estimated total coral reef area is 51,020 sq. km. i.e. 17.95% of the world's total coral reef area, followed by Papua New Guinea, Fiji, Maldives, Saudi Arabia and Marshall Islands. India is the tenth largest reef nation i.e. 2.04% of the world total. U.K. is the 12th largest reef

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Archipelago=A group of many islands in a large body of water

nation and has over 5,510 sq.km. of coral reefs and USA is the 16th having over 3,770 sq.km. of reef area and all are located in its overseas territories. The reef areas have been rounded to the nearest 10sq.km., while for those countries with small areas of coral reefs, the terms of <100, <50 and <10 sq.km. have been used.

Kleypas (**1997**) has already studied the distribution of coral reefs of the world's major oceanic regions (**Table-1)**. The coral reef of the world covers an estimated area of **6,00,000 km²**. Over half of this (54%) lies in the Asiatic Mediterranean and the Indian Ocean regions. Of the remaining, Pacific reefs account for 25%, Caribbean reefs for 9%, Atlantic reefs for 6%, Red Sea reefs for 4% and Persian Gulf reefs for 2%. Elsewhere reefs occur where the water is warm and shallow and coastal environment is not dominated by river discharge and mud.

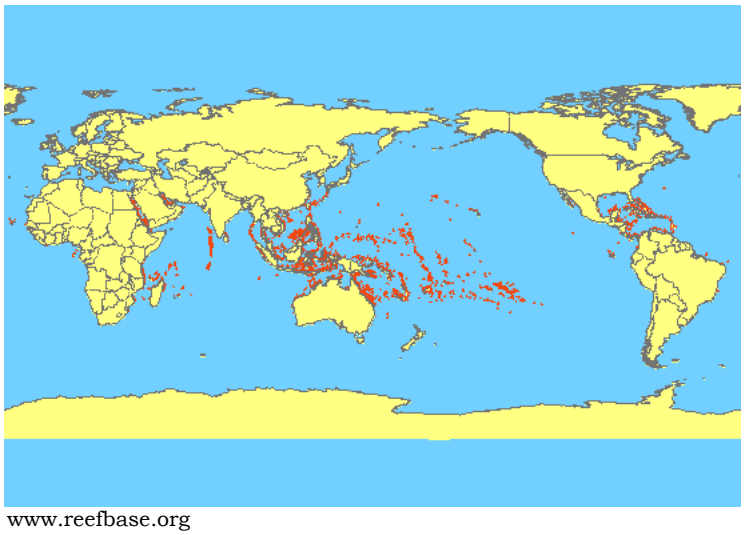
Table 1. Distribution of Coral reefs in the major oceanic regions.

Sl. No.	Oceanic Regions	Reef area X 1000 Km²	Percentage of Total reef Area
1.	Asiatic Mediterranean	182	30
2.	Indian ocean	146	24
3.	South Pacific	77	13
4.	North Pacific	76	12
5.	Caribbean	57	9
6.	North Atlantic	32	5
7.	Red Sea	27	4
8.	Persian Gulf	12	2
9.	South Atlantic	8	1
	Total	**617**	**100**

The marine scientists have taken lot of efforts to quantify the total number of species of reefs with remaining largely restricted to wild extrapolation and estimates. As may as 1,00,000 species may have been named and described worldwide.

The rich biodiversity of coral reefs occurs in Indonesia, Philippines, Malaysia and Papua New Guinea with reefs 500 to 600 species each. In India, more than 208 species of hard corals have been recorded from the Gulf of Mannar, Gulf of Kuchchh, Lakshadweep and Andaman and Nicobar Islands (**Venkataraman & Alfred 2002**).

Achitur & Dubizinsky (**1990**) have estimated that the Scleractinia (Hard corals) has first appeared in the middle Triassic and diversified in the upper Jurassic, Cretaceous and lower Tertiary. Many of the present genera expected to have evolved in the Jurassic or Cretaceous. They have pointed out by coral reefs of about 7500 species of present day corals in the world are in a decline with 5000 species having already died out.



www.reefbase.org

Figure 2. Global Level Distributions of Coral Reefs

5.1. Distribution of coral reefs in India

Indian subcontinent has its coastline of over 8000 km and its subtropical climatic condition has very few coral reef areas, when compared to other regions of the world. In India, the reefs are distributed along the east and west coasts viz. Palk Bay, Gulf of Mannar, Andaman and Nicobar Islands, Malvan, Lakshadweep Islands and Gulf of Kachch. All the three major reef types occur in India (**Pillai, 1996; DOD & SAC, 1997**), and this total area is **5,790 sq. km**., which is 2.04% of the world total reef area. India is the 10th largest reef nation in the world. More than 208 species of hard corals have been recorded from Indian reefs. C.S.G. Pillai first studied all Indian coral reefs except Gulf of Kuchchh area; 125 species belonging to 34 genera. The sub genus Acropora has studied in detail.

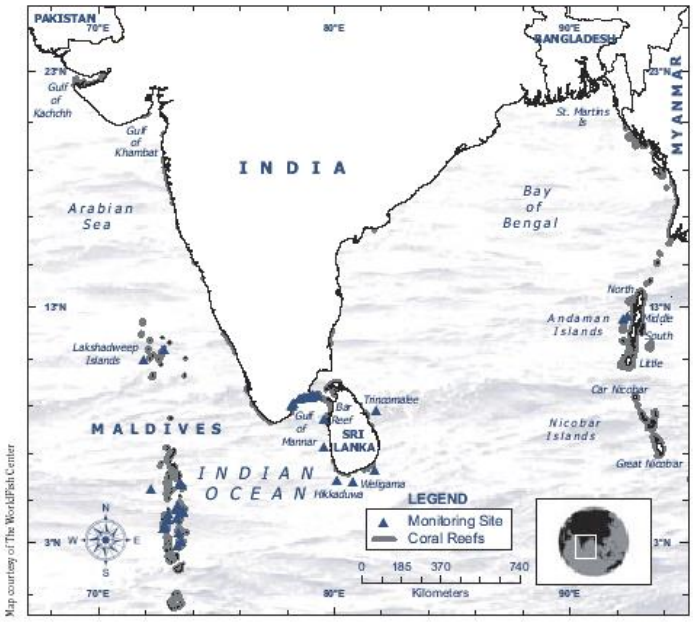


Figure 3. Distribution of coral reefs in India

6. Benefits of coral reefs

Coral reefs are extremely beneficial to humankind, providing a variety of ecological and physical services that are economically important.

- ✓ Make biologically diverse and productive ecosystems on the earth.
- ✓ Constitute feeding, breeding and nursery grounds for many fishes and invertebrates, thus supporting a unique coral reef ecosystem in the fisheries sector.
- ✓ Provides natural protection between the open seas and coastlines from tidal, water currents, winds etc.
- ✓ Act as wave breaks and effectively prevent coastal erosion
- ✓ Protect coastal areas from the consequences of predicated damages
- ✓ Potentially act as bio-indicators for climate changes
- ✓ Bio-indicators of coastal pollution
- ✓ Potential store house of medicinally valuable bio-active compounds
- ✓ Reef related aquarium and tourism plays an important role in the economics of many countries
- ✓ Ornamental purposes

- ✓ Some industries are exploiting the coral reefs illegally for industrial purposes such as cement production and wall paints.

The coral reefs provide a large variety of direct and indirect benefits to man, marine animals and society. The most valued uses and economically importance are as follows:

6.1 Environmental value of coral reefs

The coral reefs are a whole function as a community. Fish and other marine organisms in the quieter waters may consume food produced and dislodged in the shallow swift section, so that no more material is lost from the reef than is gained from adjacent ocean communities. This has been proved by the studies, which show that reefs export organic matter in large quantities that can substantiate energy requirements for zooplankton in adjacent oceanic waters (**Qasim & Sankaranarayanan, 1970**).

Coral reefs are the most biologically diverse, rich, stable and natural productive ecosystem on Earth. Coral reefs have been evolving for the last 240 million years and scientists estimates that, in total more than 1 million plant and animal species are linked with coral reef ecosystems associated with fish and invertebrates with along beaches, mangrove forest, lagoons and sea-grass beds. About 4000 species of fish eat corals, and they include fishes like parrotfishes, butterfly fishes and crown-of-thoms starfishes. 700

species of corals (**Groombridge & Jenkins**, **2000**) and thousands of coral reef fisheries components such as sponges, molluscs, boring mussels, Lithophaga that bore into the coral (**Appukuttan**, **1974**), crustaceans, echinoderms (Sea-cucumber) (**Kandan, 1996**) and fishes (**Pillai & Jasmine, 1989**; **James & Najmuddin, 1986**; **Anand, 1995**) constitute the reef-associated fauna.

As a source of lime production mining of living reef and back reef areas is still common in many part of the world. As coral reefs tend to position perpendicular to the mean direction of wind, hurricane, tsunami etc. thus generating swell currents flowing over the reef. They can weaken incoming waves, by minimizing erosion and coastal environmental hazards, behind the reef.

Coral reefs provide shelters for tiny sea animals from big waves, strong currents and to hide from predators. They filter the water sediments, release oxygen to breathe and absorbing carbon dioxide to stabilize the shoreline and filter pollutants from the land base.

6.2 Economical importance of coral reefs

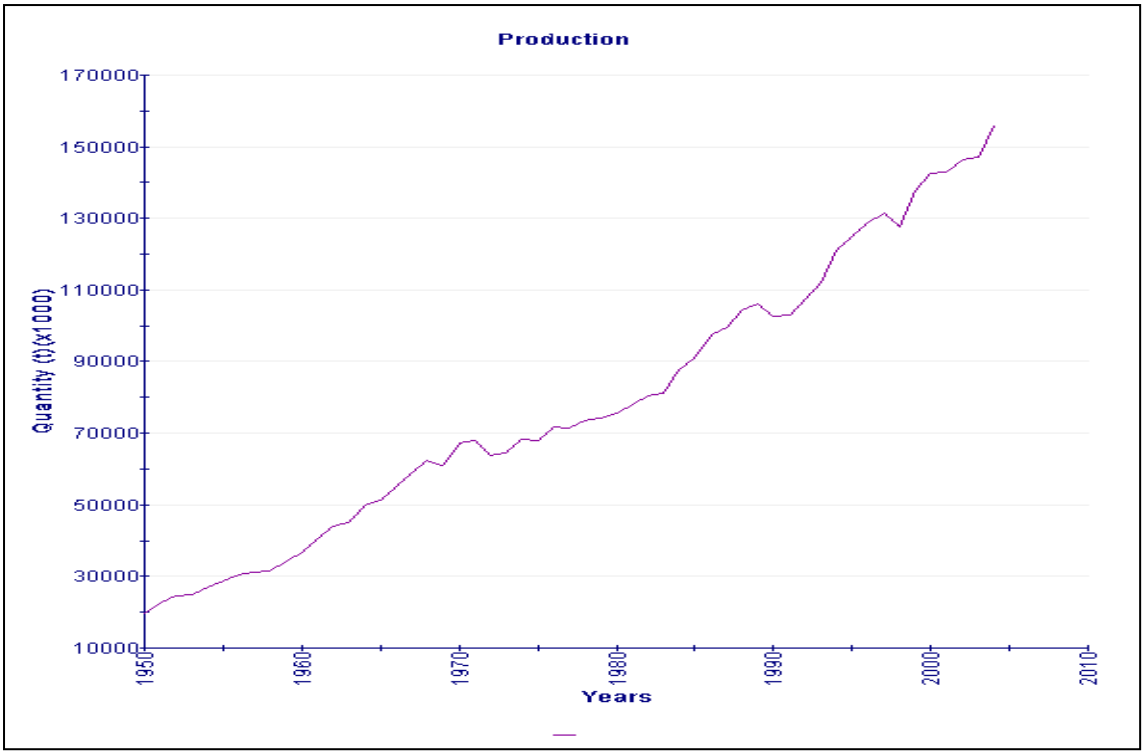
Coral reef fishery

Reef fishery is the major economic resource for people of many coral reef nations. One square kilometre of healthy coral reef helps to produces 20 to 35 metric tones of fishes each year, enough to feed 400-700 people. **Smith** (**1978**) have stated and estimated

to have a great potential in the total fish production of oceans, i.e. roughly $6x10^9$ kg y^{-1}, which is about 9% of the oceanic fish landing. The potential reef fishing benefits are estimated at US$5.7 billion annually (**Table 2)**, and so it is clear that coral reef contributes enormously to food and various other quantifiable benefits of coastal production, tourism, recreation, biodiversity value etc. The net potential benefits are estimated to nearly US$ 800 billion per year (**Cesar, *et. al.* 2003**).

Table 2. Potential net benefits per year and Net Present Value (NPV) Coral Reefs per region (in US$ million)

Economic Value of Coral Reefs	Southeast Asia	Caribbean	Indian Ocean	Pacific	Japan	USA	Australia	World
Reef Area (Km²)	***89,000***	***19,000***	***54,000***	***67,000***	***3,000***	***3,000***	***49,000***	***2,84,000***
Fisheries	2,281	391	969	1060	89	70	858	5,718
Coastal Protection	5,047	720	1,595	579	268	172	629	9,009
Tourism /Recreation	4,872	663	1,408	269	779	483	1,147	9,621
Biodiversity Value	458	79	199	172	529	401	3,645	5,483
Total	**12,658**	**1,853**	**4,171**	**2,079**	**1,665**	**1,126**	**6,278**	**29,830**
NPV (at 3%)	***3,38,348***	***49,527***	***1,11,484***	***55,584***	***44,500***	***30,097***	***1,67,819***	***7,97,359***



Source: FAO Fish Statistics

Figure 4. Fish Production global level

Coral reefs provide economic security to the millions of poor fisherfolks. In India the reefs provide 25% of the total fish catch (**Table 3)** and 75% of the animal protein consumed (**Venkataraman & Alfred, 2002**). They provide large harvests of fishes by-catch like sponges, seaweeds etc. and also help small fauna to hide from their predators**.**

The global marine aquarium trade involves about 1000 species of fish, 2000 species of coral, live rock and other reef invertebrates such as clams, worms and sea feathers. Indonesia is a major exporter of marine aquarium fishes to European Union (**Hodgson & Dixon, 1988**).

Table 3. Fish production and average annual growth rate in India (1988-2004)

YEAR	Fish Production (000 tons)	Average annual growth rate	Percentage
1987-1988	1658	0	0
1988-1989	1817	159	0.36
1989-1990	2275	458	1.04
1990-1991	2300	25	0.06
1991-1992	2447	147	0.33
1992-1993	2576	129	0.29
1993-1994	2649	73	0.17
1994-1995	2692	43	0.1
1995-1996	2707	15	0.03
1996-1997	2950	243	0.55
1997-1998	2696	-254	-0.58
1998-1999	2852	156	0.35
1999-2000	2811	-41	-0.09
2000-2001	2830	19	0.04
2002-2003	2990	160	0.36
2003-2004	2941	-49	-0.11
2004-2005	2778	-163	-0.37

Source: ICAR Fisheries Hand book 2006

Tourism

Tourism is the worlds largest industry, employing 199 million people and contributing US$ 3,500 billion (10%) to global GDP in 2002 (**World Travel & Tourism Council**, **2002**). Globally, tourism is one of the top five sources of foreign exchange for 83% of countries.

The reef related tourism of SCUBA diving and snorkeling plays an important role in the economy of many countries eg.

Bonaire, Netherland Antilles. Diving rates in this island are about 26,000 in 2001. **Spalding, *et. al.*** (**2001**) state that for better reef management fetches a potential income for 15million well trained SCUBA divers worldwide from 2500 dive centres of 91 countries. In December 1994, the waters of 38 islands in Malaysia were declared as Marine Parks of Malaysia. In India, **James & Pillai** (**1989)** suggested to establish a National Marine Park in Lakshadweep, with the components of underwater photography, swimming, observation and appreciation of aquatic flora and fauna.

6.3 Medicinal value of coral reefs

Coral reefs are the potential storehouse of medicinally valuable organisms. Several reef-dwelling organisms have been found to produce highly active biochemical compounds. The stony corals having pharmacological activities, and are helpful to cure for deadly disease like cancer (**Alam, N. *et. al.* 2002; & Iwashima, M. *et. al.* 2002**).

The soft corals produce potent anti-inflammatory and analgesic compounds to treat arthritis (**Poll & Faulkner, 1992**) and are also found to produce highly active biochemical compounds with antibiotic, anti-leukumic, anticoagulant and cardio active properties. Bioactive compound from soft coral has

been found to have anti HIV property (**Mayer & Hamann, 2004)** and still array of compounds are being discovered.

6.4 Social value of coral reefs

Coral reefs are one of the natural treasures of the countries. Not only are they very important for nature, but also they represent a very high value for humankind. They support millions of people, for their livelihood. They provide jobs to millions, earn foreign exchange, attract tourists etc.

Coral reef degradation may be attributed to poverty of coastal population, as they are very much related and dependent on their day-to-day life. Poverty is the important root cause for biodiversity loss and indiscriminate use of resources results in intertwining of poverty relief and unsustainability. In addition coral reef degradation leads to loss of livelihood in an indirect way to the coastal people and leads to impoverishment. So far 27% of coral reefs are permanently lost and with current trends, a further 30% is at risk of being lost in the next thirty years. With such devastating levels of destruction, the social and economical implications for the million of people who are dependent on coral reefs are of great concern.

7. Causes of coral reef decline

The major components of stress on reefs are storms and waves such as Hurricane, Tsunami, tropical storms, cyclones etc.

Varied human interferences include dredging, sample collection, blast fishing and cyanide fishing, pollution from industries, golf courses, effluents from oil refineries etc. (**Eakin, *et.al.* 1994).** Not only are the synergistic impacts of anthropogenic activities, but also natural, ecological and biological disturbances such as coral bleaching and coral disease (**Santary & Peters, 1997**) have also affected the coral reef communities.

It is increasingly evident that the following are the factors that influence to degradation of corals.

- Over development of the coastal area
- Destructive fishing practices
- Run off and land based pollution
- Global climate change
- Coral bleaching
- Coral disease and
- Tourism overuse.

8. Conservation and management of coral reefs

All who eat food from the sea and these, who draw breath on this planet, are responsible for the planets'. Coral reefs share spark of life with us. They have been surviving on this planet since 400 million years. Let's help them survive longer and altogether we also live longer as well as healthy. Marine scientists and environmentalist interact through international organizations and

bodies of different regions to monitor reefs of the world using a rapid assessment protocol. The organizations seek to provide baseline data on coral reef health by visual assessments of coral distribution, coral mortality, coral recruitment and its abundance and also reef fisheries. Consistency between observers is ensured through training, workshops support over a wide range of studies for effective coral reef conservation and management.

This is very useful to the members' network of regional marine laboratories, marine parks, marine tourists, SCUBA divers, etc. with the support of international maritime law and policy. A long-term variation in ecosystem structure and functions is monitored by the UN Organizations. The regional organizers control excess human interferences in coastal areas to convert them into dwelling places, farms, fishing grounds, thro Coastal Regulation Act that is an international protocol. The network also note on coral bleaching, coral disease, coral degradation and the natural calamities like cyclone, earthquake, hurricane, tsunami etc. The organizations are also having responsibilities for rehabilitation and recovery.

II. LIBRAMETRY TO SCIENTOMETRICS

1. Librametry to Bibliometrics

Application of quantitative techniques to library and bibliographical work was until recently known as statistical bibliography. **Witting** (**1978**) stated that the term 'statistical bibliography' was traced and used by Hulme in 1923. **Ranganathan** (**1948, 1969**) announced the term 'Librametry' on the lines of biometry, econometry, and pschometry and illustrated with a few examples of the application of statistics to library science. Prof. P.C. Mahalanobis, founder of the Indian Statistical institute, Calcutta stated that the statistics was the 'key technology' for all development and forecasting studies. The 'bibliometric' term was coined by **Pritchard (1969**) who described that bibliometrics was a simple statistical method of bibliography used to evaluate and quantify the growth of a subject. He also described the scope of the Librametry and defined Bibliometrics as the "statistical distribution of the processes relating to establish a theory for the structural aspects of a library". **Garfield (1970)** indicated that proper bibliometric analysis could identify the present focus of scientific research.

Ravichandra Rao (1981) stated that the information process and handling of information in libraries and information centres

were done by quantitatively analysing their characteristics and behaviour of documents by library staff and library users..

The British Standards Institution defines 'bibliometrics' as the study of the use of documents and patterns of publications in which mathematical and statistical methods have been applied. According to **Howkins (1981**) the term bibliometrics implies the "quantitative analysis of the bibliographical features of the body of a literature". More recently **Sengupta (1973)** has defined this term as the 'organisation, classification and quantitative evolution of publication pattern of all micro and macro level communication along with the authorship pattern by mathematical and statistical calculus".

2. Informatrics

The most recent metric term 'Informatrics' which comes from German. In 1979, Nacke first proposed the word 'informatrics' and described as to cover all parts of information science, dealing with the measurement of information phenomenon and the application of mathematical methods to the discipline's problems to parts of the information retrieval theory and bibliometrics.

In the second international conference on 'bibliometrics Scientometrics and informatrics' held at Canada, **Hemalatha Iyer, (1987**) pointed out that the late Prof. B.C. Brooke's suggestion about the term 'informatrics' was most meaningful to represent

bibliometrics, scientometrics and many other quantitative studies related to information science. In the third conference held at Bangalore, India in 1991, the term informatrics was used as a generic term and was described as "use and development of a variety of measures to study the several properties of information in general and documents in particular". Obviously this covers bibliometrics and Scientometrics.

3. Bibliometrics Laws

The bibliometric approach to Science and Technology is primarily based on quantitative characteristics and attributed to research publications such as article titles, authors, books, journals conference proceeding, reports etc. Research and development on social sciences and other sciences like Genetic Engineering, Bioinformatics, Aquaculture, etc. are growing rapidly and it can be easily observed that extensive co-operation is required among different research groups and countries. In view of using bibliometric techniques to identify the trends in a subject to study scientific communications and its distribution, the following three laws are characterized as positively skewed, long tailed and reverse J shaped.

- **Zipf's (1949)** law implies the frequency of occurrence of words in a text

- Lotka's law (1926) implies the productivity of authors in terms of scientific papers
- Bradford's law (1934) empirically depicts the scattering articles over different journals.

The bibliometric laws are regarded as milestones in bibliometrics. **Bookstein (1976)** briefly discussed that these different bibliometric distributions allowed one to understand them as being different version of a single theoretical distribution. He expressed the following function to describe the bibliometric processes.

$f(x) = k / x^{\infty}$

$X = 1, 2, 3 \ldots\ldots$

$K, \infty > 0$

This function can be used to describe the famous Zipf's law, Lotka's law and Bradford's law as follows:

- f (x) = the number of words occurring x times is proportional to $1/x^{\infty}$ $(\infty = 1)$
- f(x) = the number of authors who have published x papers is proportional to $1/x^{\infty}$ $(\infty > 1)$
- f(x) = the number of journals which contains x articles in a given subject is proportional to $1/x^{\infty}$ $(\infty > 1)$

3.1 Application of Bibliometrics

Bradford's law

Among the three classical bibliometrics laws, Bradford's law is very useful in determining the serial subscription and their contributions by subject during the study periods. The ranking based on that usage was first studied by **Gross** and **Gross (1927).** Other studies of this criterion with modifications are still in practice as have been cited by **Sengupta (1970)**. A rank list of scientific journals helps in serial management it can be tackled most effectively and efficiently by applying Bradford's law. It identifies the amount of users in a decade and checks whether the distribution of serials is as per the Bradford's law of scatter, considering the budgetary requirements for journals, the storage and space requirements. The size becomes the first choice; the circulation statistics and the coverage in databases speak of the 'visibility' of the journals.

Lotka's Law

A classic paper published by Lotka (1926) described the frequency distribution of scientific productivity. It presented an analysis of a number of publications listed in Chemical abstracts from 1907 to 1916 with the frequency of publications by particular authors. He excluded the names of corporate authors, but considered only the names of authors. If N is the total number of

authors, Ny1 in Lotka's equation, gives the number of authors who have published single paper each. Thus Lotka's equation is determined in its general form by three parameters:

- The number of authors with minimum productivity with single papers each (Ny1)
- The maximal productivity of an author (x max)
- The characteristic exponent ∞

Lotka's equation can also be written in the following form:

$$Yx = k / x^{\infty}$$

4. Scientific Productivity

There are other models, which are different from Lotka's Law. In recent years, **Narin (1976**) reviewed the early studies of scientific productivity and suggested that scientific talent was highly concentrated in a limited number of individuals. He also pointed out that the science policy should be designed to encourage the most productive scientists. Scientific productivity is frequently measured with regards to the state of science and technology in one-dimensional or scalar techniques are generally used. The scalar techniques are based on occurrence of specific bibliographic elements such as publications and patents. Similarly **Lotka (1926), Hersh (1942), Williams (1944), Shockley (1957), Murphy (1973), Schorr (1975)** and many others have used the study of productivity of authors and distribution of articles in

journals in different time. It can be considered in terms of indicators which throw light on the level of development in the scientific specialties. **Lawani (1986)** found a positive correlation between quantity and quality of research productivity. For instance, a highly productive researcher generally becomes more familiar with the literature of his/her specialization than scientists who publish infrequently.

Price (1971) directly made his first approach that the Lotka's law seemed to apply well to the productivity of the scientists in the 17th century as well as in the 20th century. He identifies a major proportion of publications that have often been written by a few scientists. **Shockley (1957)** has pointed out that the power law distribution as proposed by Lotka, exists in the case of patents also with a different index.

The analytical bibliometric procedures are not directed at obtaining characteristics, but to identify relations among constituting elements in a research field. The two dimensional or relational indicators are constructed from co-occurrences of specific items such as the number of times keywords, citations and authors are mentioned together with publications in a particular field.

5. Characteristics of bibliometric distributions

According to Price (1976) and many others, heuristic study characteristizes bibliometric distribution as they do the constitution of the research front. Price gives a few examples where such a phenomenon occurs in bibliometrics as follow:

- A journal that has been frequently used more is likely to be used again than an infrequently used journal
- An article in a journal, which has been cited many times, is more likely to be cited again than the one that has been rarely cited
- An author, who publishes many papers, is more likely to publish again than one who is less prolific.

However, in the above statements, Price also points out the time gap between the current date and the date of the occurrence of last event. For example, a journal no matter how many times it was used, which was used 50 years ago is unlikely to be used again in the immediate future. On the other hand a journal that might be used only once in a year, is likely to be used again in the immediate years. As such, there is no model which can predict the number of times an event can occur in the near future based on the number of times it occurred in the past and the date of the 'last it occurred'.

Bird (1977), Ravichandra Rao (1980) and **Tague (1981)** empirically argue that the above negative binomial distribution

describes the success breeds-success phenomenon. The phenomenon can also be explained by 80-20 rules. 20% of the most productive journals contribute approximately 80% of the total publications or total 20% of the authors contributes 80% of the total literature. **Egghe (1986)** also pointed out that 80-20 effect is much stronger if the underlying distribution is of Lotka type.

6. Scientometrics

Scientometrics means literally 'measurement of science'. In reality, it means the application of statistical indicators (especially bibliometric indicators) as the mean for the evaluation of scientific productivity. The term 'Scientometrics' derived from Russian (naukometria) was used mainly in the East and is defined as the study of the measurement of scientific and technological progress. Pritchard and Nalimov and Mulchenko almost simultaneously introduced the terms bibliometrics and scientometrics in 1969.

They defined Scientometrics as "the application of those quantitative methods which are dealing with the analysis of science viewed as an information process'. The Scientometrics foundation also explained as "application of statistical methods to organization of science and its productivity analysis"'. In 1978, the foundation started to publish a journal in the name of Scientometrics from Hungary. Now Scientometrics is one of the core journals and it has published 1062 papers till the end of 1999. **Persson** (**2000**)

revealed that D. Price and Eugene Garfield were the top most producer and founders of the Scientometric research field.

The idea that scientific knowledge could be organised deliberately and controlled from a mission perspective, can be considered as a result of experience from World War II. Before that time the intellectual organisation of knowledge had largely been left to the internal mechanisms of discipline formation and specialist communications (**Bush, 1945; Whitely 1984**). The military impact of Science and Technology through knowledge based development and mission oriented research during World War II (eg. The Manhattan Project) made it necessary in 1945 to formulate a new science and technology policy under peacetime conditions.

Garfield (1955) who has come of age in the online era, is being focused on monitoring, searching, accessing, liking, and analysing the research literature. Current Contents helped enfranchise scientists from the third world, as well as many from the less prosperous institutions of the first world. Gene made it possible to let their fingers do the walking. And Gene's other major contribution, The Science Citation Index (SCI) made it possible to monitor and measure productivity and impact. Gene Garfield did not invent the 'Publish or Perish' mode of productivity, but he fine-tuned it with the citation-ratio of papers, authors and journals helping to supply promotion/tenure committee such as library

serial selection committee, research funding committee etc. with a greater variety of indicators for research assessments (**Harnad, 1998)** such as peer-review system and citation analysis a way of exploring; the past, present and future course of research, sorting out the pedigrees of ideas and findings.

6.1 Scientometric indicators

Bibliometrics is a sub-domain of Scientometrics. Scientometric research is devoted to quantitative studies in science and technology. The Scientometric indicators, which are utilised in these studies, include input indicators like R&D fund, S & T manpower etc., and the output indicators are journal article, institutions, countries, etc. The output indicators are mainly addressed through bibliometrics.

The primary goal as well as the innate need for any individual or team doing scientific research is to contribute to the scientific information production. Consequently the evaluation of publications, both qualitative and quantitative may refer here to measuring the international impact of publications manifested in citations. The fundamentals of publication evaluation by means of Scientometric methods have been laid down by **Moravcsik (1988); Martin & Irvine (1983); Moed et. al. (1995) and Martin (1996)**. They described the real Scientometric systems, consisting of

several parts to be assessed and they identified that the main problem was caused by the difference in the following factors:

Publication productivity and citation characteristics Size (i.e. research capacity, number of staff)

Publication productivity with a dimension of:

= Number of papers /number of researcher X number of years

= Cited ness of papers – number of citations /number of papers

may be similar for research teams working on thematically homogeneous basic science field or subfield.

Martin (1996) pointed out the important factor to be considered in evaluating research organisation is their size, on the applicability of Scientometric evaluation indicators. **Persson (2000)** described the integration of scientometrics and sociology of science is not visible in the left part of the map, which contains mostly European researchers specializing in science indicators and science evaluation.

6.2 Scientometric Applications

It is not a surprise that a considerable part of Scientometric research is in fact devoted to the development and 'maintenance' of scientific information system on science and technology. Therefore, **Van Raan (1996)** mentioned this activity as the second main part of scientific research. With the know-how acquired in

the first-part, the Scientometric indicators work on all of its aspects, together with the basic data, must be systematically structured in what we could call a 'Bibliometric Information System'. So this system not only contains typical citation index data, but also data from other sources as well: key words, classification codes, abstract, etc. Based on that, the bibliometric information system 'grows' continuously by adding important practical knowledge, again in an encoded way in the form of variants of author names and address, information about institutional, regional or national infrastructure, and adding data from institutional research reports such as the many types of 'non-SCI publication'. Also the results of successive applications and based on experiences are the methodological improvements such as better standards for international comparison of impact.

7. Mapping of Science and Technology

The third area of Scientometric researches is the interaction between science and technology. Investigations include studies on author-inventor relation i.e. scientists who are active both in writing research publications as well as in creating technological breakthroughs. Citation analysis based approaches relational techniques or 'Mapping' represents the second main methodological development based on bibliometric data. Here, **Tijssen & Van Raan (1994), Garfield (1983; 1998)** and many

others experiences on information retrieval policy analysis. The research evaluation provides an introduction to co-citation analysis, clustering and research front identification and they described the new visualization techniques produce global maps of the recent scientific literature.

Basically, the following three techniques can be applied to the analysis of Scientometrics.

- Deviation of observations from expectation
- Calculation of distance and similarity measures
- Decomposition of the matrix.

The derived measures can be used as Scientometric indicator on the basis of multivariable analysis such as:

- ✓ Cluster Analysis
- ✓ Multidimensional Scaling (MDS) and related mathematical methods are applied and extended in order to develop a cartography of science and technology

8. Recent developments in Scientometrics

Recently, neural network based techniques are used to shape structures of scientific fields. Such 'abstract' landscapes of science with the position of major actors on the map are specific representations of scientific activities. This type of map is more or less philosophical, on 'ontological' level i.e. 'bibliometric

cartography'. The future of these mapping techniques will undoubtedly not lie in Scientometrics but in a much broader scope of generic technologies called 'data mining' and 'knowledge discovery'.

The interaction between application and basic work is necessary in the definition and operationalization of concepts such as relatedness of scientific or technological subfield, interdisciplinarity, internationality, 'ageing', 'growth' or rather and thus progress of knowledge.

9. Scope of the Scientometric Analysis

With the impact of Information and Communication Technology (ICT) the bibliometric research is now advanced in several instances to a level that can be characterized in methodologically and technologically sophisticated way in terms of variety of indicators applied to different aggregation levels and automation. The important work was done on the application of bibliometric analysis in social sciences, humanities, applied sciences, medicine and its subfields **Sylvain (1993); Dizon (1995); Dizon & Sadorra (1995); Freeman (1974); Fuseler-Mcdowell (1989; 1990)** and **Tapaswi & Maheswarappa (1999)** studied the publication work on interdisciplinary subject like marine science and oceanography using bibliometric indicators.

Following are the inferences made out of scientometric analysis were:

- Discipline – specific studies reveal the communication and collaboration characteristics on the national, regional and international level.
- Identification and evaluation of strengths and weaknesses in scientific achievements together with a clear, empirically supported set of conditions determining the applicability of bibliometric or scientometric indicators.
- The study emphasized that criticisms within the field and allied fields like social sciences are not able to contribute more than the improvement of bibliometric indicators stimulated by users.
- Additional of scientometric data, on human resources, infrastructure facilities and funding were obtained.
- Ranking and impact of the important publications in international conferences and scientific journals mark the state of the art in the study of the interaction between science and technology.
- Growth of socio-economical importance in the field of Science and Technology.
- Pioneering work led to important new approaches to clustering of data and imaging of the cluster similarities/dissimilarities is now being explored.
- Recent large-scale applications of bibliometric indicators leads to face challenging problems in inter and

multidisciplinary fields such as energy research, environmental research, information science (cognitive science). To identify how these fields are related to their different 'Mother Discipline', data on coral reef ecosystem research is taken for this study. As interdisciplinary fields are of increased social and economic importance, it is necessary to assess past, present and future of the performance of these fields.

- Evaluation of databases and creation of databases in each subject allow us to study the relation among production, distribution and 'consumption' of scientific information in a sophisticated way.

- Application of bibliometric methods may induce intended 'feed back' effects. The results will pursue studies aiming at 'induced' changes of publication practices and research scope.

- The development of scientometric studies of science and technology has a societal impact, and it is an important political issue, with large amount of money involved and the crucial influence of S & T on society.

- Scientometrics can play an important role in academic environment and it explores the whole domain of human knowledge.

10. Statement of the problem

It is well known that the world has only 3% of the freshwater and rest is seawater. As per the recent study, shallow coral reefs form 2,84,300 sq.km., an area about half the size of Madagascar. It supports 25% of marine animals. The reefs protect coastlines and provide reef fishes a source of nutrition. The potential reef fishing benefits are estimated at US$ 5.7 billion annually.

The impacts of modern fishing technologies and ever increasing human population have led to over fishing. These practices and damages to coral reef ecosystem result in decline in reef fisheries production. To avoid these economic implications, the coral reefs and their associated flora and fauna are to be protected, conserved and managed from the damage and stresses for sustainable fisheries production. In addition to create awareness about the coral reefs as our marine heritage, its function and benefits should be exposed to public in order to protect the reef ecosystem.

The literature on taxonomy and distribution of coral reefs was thoroughly investigated before 1950s. The studies on taxonomy of Indian coral reefs started as early as 1847 by Rink in Andaman & Nicobar Islands. The modern interdisciplinary studies such as Marine Science, Aquaculture, Biotechnology, Bioinformatics, Marine Geology and Hydrobiology started during the late 1960s with more information on corals and coral reef environments. The publications play a vital role in understanding

about more than 1,00,000 species of corals with their description and distribution through various survey methods by the agencies of United Nation Organization like United Nations Educational Scientific and Cultural Organization, United Nation Environmental Program, Intergovernmental Oceanographic Commission, Global Coral Reef Monitoring Network, Food and Agriculture Organization, Australian Institute of Marine Science etc. The publications are scattered in various forms of communication and easy access is not always possible. The present study of Scientometric mapping investigates the important characteristics focused mainly to review the state of the coral reefs based on the information available on coral reef. The study mainly aims to:

- Create awareness and promote further research on global Coastal Zone Management; Coral Reef Monitoring, to avoid destructive fishing practices;
- Prevent the land-Based Pollution by effluent discharge from Industrial Waste;
- Undertake responsible and judicial fishing techniques;
- Form artificial coral reefs (Fish aggregating Devices)
- Undertake intensive research on new fields of marine bioprospecting, biotechnology etc. and
- Enumerate solutions to protect the world's remaining reefs

So this problem was chosen to work on "**Mapping of coral reef research literature: a global perspective".**

11. Objectives of the study

The main objective of this study was to use Scientometric mapping and analyze the key features of coral reef research activities at global level. The fishes of the coral reef ecosystem contribute significantly for protein demand, thus playing vital role in food and nutritional security. They are strategically important world economy. This field has recently been identified as an area of considerable potential, social benefits and economic spin-offs. Most of the developing countries make it to focus their priority for development. As a matter of fact, Scientometric tools aids in mapping of the coral reef research literature, with an important role in influencing the decision-making authorities working in the fields of oceanography and fisheries research. Keeping above perspective in view, it was decided to undertake a study to evaluate a current trend and the future course of productivity on coral reef research and management using Aquatic Science & Fisheries Abstract database with the following objectives:

- ✓ To identify the overall perspective of coral reef productivity trend from the major oceanic regions of the world
- ✓ To depict the geographical and chronological growth rate of coral reef literature and its obsolescence.

- ✓ To find out languages in which maximum number of articles are published
- ✓ To note authorship pattern and identify most prominent authors
- ✓ To explore an overall perspective of channels of communication in which marine scientist preferred to publish their works
- ✓ To identify discipline and interdisciplinarity wise distribution of publications on coral reefs research
- ✓ To identify the core journals
- ✓ To identify worldwide distribution of most productive R & D organizations and academic institutions and their contributions.

From the above objectives, this study throw light on a worldwide distribution of coral reef literature exploring the global level structure of inherently heterogeneous disciplines and insight into the linkages with other subjects such as oceanography, marine geology and marine fisheries.

12. Hypothesis

The data were collected from ASFA database on coral reefs covering the worldwide literature in all interlinking areas of coral

reef research publications in journals, books, technical reports and conference proceedings. The method of "**keyword search"** was used to collect data. The following hypotheses have been formulated in fulfilling the above objectives of the study.

- The growth rate of coral reef literature significantly varies geographically and chronologically
- There is significant difference in languages in which maximum number of articles are published
- There has been an increasing trend in collaborative research
- Implications of Lotka's law related to author productivity in coral reef research
- The journal source of publication of coral reef research occupies the predominant place in comparison with other sources
- Significant differences in quantitative research performance of R & D organizations and academic institutions at global level
- There is a significant level of variation in coral reef research output in various branches of Science and Technology
- There is a significant difference in countries and subject wise research out put.

- There is a considerable variation in impact factor among the journals, which publish coral reef research work.

13. Scope of the study

In a broader context of innovation, the present study is to identify that the coral reefs have been used for various purposes including medicinal and nutritional value, besides food and shelter for tiny animals. However, the advent of the Scientometric mapping focused on the coral reef research and provides overall guideline about past present and the prospective future research output. The research activities and trends in coral reef research are of radically distinct in nature not only to the concerned researchers, but also to the academic and research institutions and policy makers as well.

It was found that coral reef research has exponential linkages with different disciplines like Medicine, Biotechnology, Marine Engineering, Aquaculture, etc. To creates awareness about coral reef resources to the developmental workers and fisherfolk; It obtains reliable information on corals to fulfill the requirement of the researchers; It reviews the strategic development of fishery production; It identifies life supporting systems such as medicinal and other bioactive compounds. It provides job to millions to earn foreign exchange and attract tourists. Hence a necessity was felt to

investigate the output performance of coral reef literature by using the ASFA database.

14. LIMITATIONS

The literatures on various aspects of coral reefs are presently available in a numerous publications on life science, marine science, and fisheries bibliographical databases such as Web of Sciences, BIOSIS (Biological Abstracts), CAB Abstracts (Chemical Abstracts), BBCI (Biophysics and Biochemistry Citation Index), BTCI (Biotechnology Citation Index). NISC databases on Fish & Fisheries Worldwide; Marine, Oceanography and Freshwater Resources, Fish Base, GCRMN South Asia Regional Coral Reef database and Reef base (A global information system on coral reefs).

To limit the chance of duplication, the researcher has recommended by the Guide, selecting one database.

1.8. ORGANIZATION OF THE THESIS

The following chapterization scheme has been adopted for preparation of the Thesis.

Chapter 1 Provides global status of coral reefs, origin, age and growth, benefit of Coral Reefs for ecosystem, economical importance including medicinal value, Librametrics to scientometrics, application of scientometrics, Scientometric indicators, mapping of science and technology, statement of the problem, objectives, hypothesis, scope of the study,. Limitations, and Organisation of the thesis

Chapter 2 Deals with the review of the related work

Chapter 3 Provides the research design, and description of the database. Methods adopted for data collection by applying appropriate search strategy for bibliographic retrieval

Chapter 4 Presents analysis and interpretation of the data.

Chapter 5 Discusses the findings of the study, suggestions and areas recommended for future research.

CHAPTER 2

REVIEW OF LITERATUE

Literature review on mapping of coral literature was done to know the insight about the relevant theories, conclusions and gaps on problem identification in order to avoid duplication of work. Considering the multidimensions of scientometric mapping studies, the researcher has classified them into 6 main categories as follows:

- General bibliometric and scientometric studies
- Mapping of S & T literature
- Authors' productivity
- Geographical and chronological growth rate
- Perspective of channels of communications
    - Journal productivity & its impact factor
- Subject and multidisciplinary studies
- Collaboration and visibility
    - Authors, National & International

General bibliometric and scientometric studies

There are number of studies dealing with different aspects of bibliometric analysis of literature. An ethical code is required to

analyse the general bibliometric and scientometrics review of earlier works, which are brought under this chapter. Some of bibliometric and scientometric methods of the study does not include the information publications and communications.

The bibliographical references taken for citation analysis are not standardized. This causes problem of ranking the authors on the basis of frequency of their citations. For instance, the author Dr. S. R. Ranganathan has been cited in different way as Siyali Ramamirita Ranganathan, Ranganathan S.R., Ranganathan, S.R. This causes scattering of citations of the same person's works. At the same time, it also possible that there may be more than one author under the same name and it may be difficult to distinguish them.

In the case of collaborated authors, the cited articles appear only under the name of the first author as listed in each article. Here one must determine the names with individual contributions with collaboration to get the actual rank of the authors. This is very difficult and tedious process. In spite of some limitations, bibliometric study is observed to be one of the best ways of getting scientific productivity of individual authors or scientists or institutions and journals and to study the pattern of growth of literature, nature of research publication and the age of literature used by the scientists.

In the long term, the course of research can be expected to produce various outcomes, for the benefit of the organizations/institutions or country etc. at large. The outcome of the research is really its impact on many types of research; the impact is a long-term affair. It is extremely difficult to evaluate the work of a particular research group by means of such long-term criteria.

Kalyane & Gadagimath (1991) identified in their early studies, publication activities of Sugarcane Breeding Institute (SBI), Coimbatore during the past 75 years from 1912 to 1987. It is observed through their study that they quantitatively documented for general characteristics, collaborations of core journals of publications and creativity of researchers. The main objective was to give a brief insight into productivity of researchers at SBI. Scientometrics study does not act as indicator of research performance. It can be regarded as a quinquennial review of research and its establishments.

Later, **Srivastava (1986)** in the Indian Agricultural Statistical Research Institute (IASRI) conducted the bibliometric study on research collaboration in the field of statistical science. In his study, the data regarding number of authors per paper was noted and tabulated over the period of 1965-85. The analysis was

made to identify the nature and pattern of multiple authorship and degree of collaboration in research.

Gadagimath & Lancaster (1991) analysed Science Citation Index (SCI) by direct citation, bibliographic coupling, and co-citation modes. The need for citation index for Arts and Humanities was felt as they started appearing from 1973 and 1978 respectively. Again Gadagimath and Kalyane examined the bibliometric study on research collaboration, publication trend and activities of the research group, to find an increasing trend of collaboration in research resulting in the publication of multiauthored research papers. The nature and magnitude of research collaboration varies.

Humayun Kabir (1988) studied on the publications of an Indian marine fisheries research laboratory shows that over 80% of their contributions had in the journals. The proceedings of conferences, seminars, workshops etc., were noticed to be the second choice (16.5%) of the scientist of the institute.

Sylvain's (1993) analysis of the Canadian publications in the field of aquaculture reveals the Canada's expertise in Science and Technology and it becomes the stimulus for funding by resource-based industries. Several bibliometric indicators were used to enlighten the peculiar features of the Canadian research system. The results showed that Canada displayed a better rank in

aquaculture (third among the G7), comparatively with its rank in all other sciences (sixth among the G7, seventh in the world). Large numbers of scientists were involved in production of Canadian publications in aquaculture, when compared with 13 institutions accounted for over 60% of output.

Macias-Chapula & Mijangos-Nolasco (2002) analysed the scientific productivity and case study of AIDS documents as produced on sub-Saharan African scientists. They publish a large proportion of their papers in English 84.50 percent and French 14.73 percent. Over 57 percent corresponded to journal articles covered by Science Citation Index through these journals have low impact factor. Few papers have also been on high impact factor in journals. The subject content of the documents was mainly focused on epidemiological, complications and prevention & control issues on 'HIV infections' and Acquired Immune Deficiency Syndrome.

Garg & Rao (1988) analysed the scientific productivity and case study of National Physics laboratory showed that the scientists of the cab gave more weightage for foreign journals to publish their papers rather than the Indian Journal. They publish a large proportion of their papers in India and foreign covered by Science Citation Index, though these journals have low impact factor. Few papers have also been on high impact factor in

journals. Both manpower and expenditure have positive relationship with all the output variables except the patents. High scientific productivity among these is manpower and papers published in Science Citation Index covering Indian Journals.

Subramaniam (1983) did the bibliometric studies of research collaboration to find in his review the scientific research was becoming an increasingly collaborative accomplishment. The nature and magnitude of collaboration vary from one discipline to another, and depend upon the structure, the research environment and demographic factors. Earlier studies have shown the high degree of collaboration and research productivity. The extent of collaboration cannot be easily determined by traditional methods of survey and observation. Bibliometric methods offer a commitment and reactive tool for studying collaboration in research. In this paper several types of collaboration have been identified and earlier research on collaboration has been reviewed.

Katz & Martin (1997) identified and analysed in their research on collaboration to measure it through co-authorship. Price presented data from chemical abstracts for the period from 1910 to 1960 to show that the number of multiple author papers increased from 20% in 1910 and over 60% in 1960. He found the number of three author papers; four authors papers and so on. The observation led Price to show that the proportion of multi-

authored papers has accelerated steadily and powerfully. His prediction was so large that in 1980 the single author paper might extinct.

Arunachalam & Gunasekaran (2002) made a bibliometric study on tuberculosis research in India and China identified that there is a tremendous mismatch between the share of the burden of the disease and the share of research efforts.

Other Bibliometric Studies are there in good number. Citation counting techniques are used in the evaluation of scientific activities for the last few years. The main objective of the citation analysis is to evaluate and interpret citation received by articles authors, institutions and other aggregates of scientific activities.

Sengupta (1974) in his paper on physiology periodicals observes that the rank distribution of journals in physiology conforms to Bradford's distribution. In another study **Sengupta (1973)** ranked journals in biochemistry by the absolute number of citations made to the 1969 volumes. He makes a logical connection with the number of words in each journal. He argues that identification of such relation, if any, may be useful in relation to the selection of journals and the study of research collaboration in the field of statistical science.

Weinstock (1971) observes the requirement of scientific tradition, as when a reputable scientist or technologist publishes an article he should refer to earlier articles, including his thesis. These references are supposed to identify those earlier researchers whose concepts, methods, apparatus etc are used by the author in developing his own article. There are many papers that discuss the reasons for citations, as the one by **Garfield (1976, 1977).**

Humayun Kabir (1995) observed in his studies of bibliometrics that, the single author distribution was the maximum and teamwork was not popular among the researchers in bibliometrics. There is increase in multi-authorship pattern which indicates that the research may shift from solo to team research by collaboration.

Sarala (1995) observed in her studies of bibliometrics of journal of tropical agriculture, that the greater number of the scientists had cited in large number of periodical articles.

Ramakrishan & Pangannaya (1999) in their study on growth of biotechnology research literature found that the trend of relative growth rate was exponential or linear in different subjects.

Biradar & Sujatha (2000) observed in their bibliometric study of ecological literature that bibliographical form, authorship pattern and country wise distribution were analysed. The journal evolution occupies the first rank.

Maheswarappa & Mathias (1987) analysed the growth of applied science literature and found the relative growth rate had constantly decreased over the period. The double time in the applied science literature was reported to have increased.

Arunachalam (2001) analysed the mathematics research literature output in India from 1988-1998 by indexing all the 1730 records and classified them by journal impact factor, institution, geographic distribution etc. Results revealed that the future of mathematics depended to a great deal on the few DAE institutes, ISI and Board of higher mathematics.

Chiu & Ho (2003) studied the homeopathy research performance based on 977 papers published in SCI indexed periodicals between 1991-2003. The use of the bibliometric analysis technique for examining this topic does not exist in the literature. They conducted homeopathy-related publications in SCI and foundout that the most frequently cited article was published in JAMA-Journal of American Medical Association which was the second highest impact factor journal in the category of General & Internal Medicine. Twenty highest cited papers written by 70 authors from 5 different countries were all published in English.

Patra & Mishra (2006) analysed the growth of the bioinformatics literature available in NCBI PubMed using standard bibliometric techniques. The study explored publication type,

language, and the country of publication to find that authors with single publication were more predominant (73.58%) contrary to what predicted by Lotka's law.

Arunachalam & Gunasekaran (2002) observed in their studies on diabetes research in India and China stated that it promoted cross-disciplinary research. India and China should come forward to do international collaboration for research programmes. Their study showed much higher rate in world share of research fields than medicine.

Macias-Chapula (2002) observed in his studies on Bibliometric and Webometric analysis of health system reforms in Latin America and Caribbean that the diversity in form and content of the documents produced on health care reform in Latin American and Caribbean regions indicated the absence of comprehensive database in terms of time, document types and content coverage. The analysis also showed some of the output indications that contrast to the structure where health care reforms in Latin America and the Caribbean stood by that time. New information and communication technologies can support the development of an integral regional initiative so as to manage and exploit existing information resources in a coordinated and efficient manner.

Gli-Montoya *et. al.*, (2006) analysed the publications to obtain a geographic world map of scientific production on dentistry. He also analysed the literature quantitatively and qualitatively by using impact factor. The study found out that the qualitative results of this study were not consistent with the quantitative findings, and the countries that produced most publications, were not of the highest quality.

Ugolini Donatella et.al., (2001) showed in their paper European Union that the US held the leading position on ophthalmology and the distribution of papers. In biomedical field, European Union scientists published many papers on researchers from the US. The top four produces the major part of the articles (78%). International Collaboration in research appears to be an important factor in article production in international journals. There exists a high concentration of scientific promotion on few factors and this is true in all levels of desegregation studies. Quick cross analysis of successful research fields of UNESCO and similar codes show that the successful research was granted by Colciencias activity.

Shokeen & Kaushik (2004) studied the authorship pattern and citation pattern of articles that appeared in *Indian Journal of Plant Physiology*. The study indicated 39 articles published in 1 to 4 of volume 7 are three-authored. However, it is found that two

authored citations are more common which is followed by single authored

Mapping of Science and Technology literature

About 40 years ago, **Price (1965)** initiated studying science by using the scientific methods. Since then, research in scientometric has developed techniques to analyse publication data sets for information retrieval, policy analysis, research evaluation, introduction to co-citation analysis, clustering and research front identification.

Most of the early works by **Garfield (1955)** and **Garfield et. al., (1964)** focused on identifying networks on clusters of authors, papers, or references. Alternative methods based on co-word analysis were developed to identify semantic themes using advances in computing capabilities which facilitated the analysis of large scale document data set.

Garfield mapped the world of science literature (**1998**) and also narrow specialty fields like biomedical engineering (**1986**), Cholera research (**1986**), etc. He derived the list by combination of online and manual literature searches using keywords, concepts, prominent authors, and growth of literature by authors, institutions and its country on the given fields. This included core and citing papers from current trends of S & T research fronts.

The mapping in more than a single dimension, however, requires a two-dimensional visualization technique (**Small & Sweeney, 1985; Small *et al.*, 1985; cf. Leydesdorff, 1987; Small, 1999; and Chen, 2003**).

Tijssen, R. J. W. *et al.* (1987) used quasi-correspondence analysis to map the journals as groups on the basis of their deviation from normalized expectations. Clusters of journals could then be made visible. However, the delineations had to be penciled into the pictures and remained based on intuitive or expert-based classification. One advantage of this method was that it allowed the visualization of both the cited and the citing patterns in a single mapping.

Leydesdorff (1986; 1987) used factor analysis on selective parts of the aggregated journal-journal citation matrix. The factor analysis provides us the clear delineations, but this technique remains limited in terms of the number of variables that can be rotated in each run.

Ortega-Priego & Aguillo (**2005)** made a co link study of the web sites of the different centres of the Spanish main public research body. The objectives were to find the relationship existing among research areas of these centres as well as to study the similitude's and differences according to two measures: cosine and Pearson's correlation coefficient. A co link matrix is built from

Yahoo! Search results. The main research areas identified in the CSIC are the Physics and Materials Sciences. The Agrobiology, Biomedicine and Food Technologies areas, proved to the greater importance in the applied research than in the fundamental research. With regard to the results in the cosine and the correlation coefficient model, there are slight differences between two measures as much in the MDS map as in the clustering dendrogram.

Ortega-Priego (2003) studied the Biology and Biomedicine Centres of two European National Research Councils, Spanish Council for Scientific Research (CSIC) comprising 131 research centres of different disciplines, some of them collaborated with universities and these centres' web environment was studied. For this study he applied Vector Space Model approach to the Triple Helix dimensionality.

Haiyan Hou & Zeyuan Liu (2006) attempted to reveal the potential intellectual structure and dynamics in the field of scientific studies during the past thirty years, presenting a domain analysis of the discipline based on co-citation analysis. 2,24,058 citations of 10,893 papers published in the six international journals in the field of science studies were retrieved from the Science Citation Index (SCI) and Social Sciences Citation Index (SSCI) during 1975 to 2004. Author co-citation analysis (ACA) is

applied to identify the dynamics of the intellectual structure of science studies over three 10-year sub-periods, 1975-1984, 1985-1994, and 1995-2004.

Dastidar & Ramachandran (2005) and Dastidar (2004) studied the engineering research scenario in ocean sector and ocean science & technology at global level using SCI database. The SCI journal set for Ocean Engineering for the year 2000 was used. The most productive units were chosen to form co-occurrence matrices to which a multidimensional scaling algorithm (a SyStat sub-routine) was applied to produce the network maps. The study reveals that the joint authorship provides a reliable picture of links between the scientists who have worked together. The causal linkages between the knowledge productivity function and the socio-economic imperative of knowledge production units were studied. It gives a clue as to how science is practiced in a spatial and temporal dimension, besides being used as a measure of political and social affinities between the countries in terms of intellectual association.

McCain (1994) studied two types of citation relationships among journals in fisheries and aquatic sciences research to identify a core journal network and to explore within-field journal prominence, overall subject structure, and communication links in this multidisciplinary area. A core list of 43 journals was extracted

from the 1991 *JCR for Science Citation Index*. Using cluster analysis and multidimensional scaling (MDS), eight major journal clusters were identified as fisheries (2 clusters), geophysics, oceanography, phycology, freshwater biology, the marine environment, and marine biology. In a two-dimensional MDS map, the journal clusters are arranged along a subject continuum from the physical sciences (geophysics) through basic natural sciences research (marine biology) to application (fisheries). Fisheries research is distinct from marine and freshwater biology and oceanography but not isolated. The *Canadian Journal of Fisheries and Aquatic Sciences* appears to be the major link between fisheries research and marine biology.

Fish and aquaculture research in India has been mapped **Jayashree & Arunachalam (2000)** using data from six databases. Out of 460 papers, 82% are journal article. Less than a third of the journal articles are published in journals indexed in SCI. 61% of publications are contributed by government laboratories and over 25% by academic institutions. Most of their articles are published in low impact factor with low visibility journals. Academic institutions in journals of medium impact did not reach wider readership.

Arunachalam & Jayashree (2001) mapped fish and aquaculture research by People's Republic of China over the six years 1994-1999 using data from six databases viz. three abstracting services and three citation indexes. The results are compared with fish research in India. It is observed in the study on fish research in China and India that China contains a very large share of the world. It covered the budget outlay of fisheries research, export-import of fish products and foreign exchange outlet benefit in fish research in China and India.

Gunasekaran *et. al.* (2006) examined chemical sciences research in India. The results revealed that 4.5% of the global research and development output in chemical sciences was contributed by Indian. The Indian researchers have contributed 26% of the papers in US journals. Indian Institute of Science, Bangalore secured first rank with 345 papers. Major collaborative countries in chemical sciences were the US, Germany, Japan and Great Britain.

Leydesdorff & Jin (2005) developed methods for mapping the journal structure contained in aggregated journal-journal citations in the *Science Citation Index* that is applied to the *Chinese Science Citation Database* of the Chinese Academy of Sciences. This database covered 991 journals in 2001, of which only 37 had originally English titles and only 31 were covered by

the *SCI*. Using factor-analytical and graph-analytical techniques the journal relations are dually structured. The main structure is the intellectual organization of the journals in journal groups (as in the international *SCI*), but the university-based journals provide an institutional layer that orients this structure towards practical ends (e.g., agriculture). The *Chinese Science Citation Database* exhibits the characteristics of "Mode 2" in the production of scientific knowledge more than its western counterparts. The contexts of application lead to correlation among the components.

Leydesdorff (2004), aggregated journal-journal citation matrix derived from the *Journal Citation Reports* 2001 which can be decomposed into a unique subject classification by using the graph-analytical algorithm of bi-connected components. This technique was recently incorporated in software tools for social network analysis. The matrix can be assessed in terms of its decomposability using articulation points, which indicate overlap between the components. The articulation points of this set did not exhibit a next-order network of 'general science' journals. However, the clusters differ in size and in terms of the internal density of their relations. The clusters can also be extracted and mapped for the visualization.

Author productivity

Bird (1997) studied authorship patterns in marine mammal science during 1985-1993. In this study, a search was run on the Aquatic Sciences and Fisheries Abstracts database to identify marine mammal science papers published over the study period. A total of 1308 papers published in scientific journals were examined. There was weak but statistically significant trends of increase in the number of authors per paper as well as in the number of multi-authored papers written by authors from different institutions, in due course of time. Possible reasons for these results include the increasing specialization of researchers necessitating collaboration, more access to electronic means of communication, and more competition for research funds. Confounding factors in this analysis include the possibility that different journals have different publication patterns and regional Vs national or international journal differences.

Suresh Kumar & Gupta (2003) analysed the distribution of productivity of authors in Indian physics research as reflected in their publication output from 1800 to 1950. It focuses on the study of regularity in the distribution of productivity of various cohorts, having same length of activity, but different periods of participation. The study also analyses the frequency distribution

of the speed of the publications by authors, reflecting on the output and time spent by individual authors in Indian physics.

Dizon & Sadorra (1995) measured number of publication credits per year, of 105 BS, MS, and Ph.D degree holders at the authors institution – a non profit international fisheries research organization based in Manila. All authored and edited items produced by these staff, from 1978 to 1993, both published or in press were considered, and weights assigned depending on document type, number of pages, and rank of the name in case of multiple authorship or editorship. The staff's output of conference papers and technical reports out weighted contributions to the primary literature. Predictors of productivity were position, salary, education, and age. However, a large unexplained variance remained, suggesting that individual factor largely determine productivity.

Ravi (2001) analysed single versus multiauthored papers to find that the single authored papers constitute 19.07 % of the total publication and the remaining 80.43% of the multiauthored papers in nuclear science research. The analysis of author productivity showed that 35.75% of the authors had contributed only one paper in the field of nuclear science. It had been noted that 2-paper contribution was reported by 12.59% of the authors. The three-paper contribution was reported by 7.64% of the authors. One

paper-contributed authors to 10 papers contributed authors constitute 80.01% of the total authors. The striking finding was that only one author has contributed 1083 papers during l980 to 1994.

Farber (2005) examined the extent of publications written by a single author in different disciplines in Israeli universities. In the natural sciences the share of single-authored articles among the total amount of publications varies slightly between the different fields of science. A significant difference was found while comparing natural sciences as a whole with mathematics and a major one when compared with the social sciences and humanities.

Karisiddappa *et. al.*, (1990) studied the authorship pattern and collaborative research in psychology. The result showed that the proportion of single authored papers had fallen to 39.43 percent indicating the trend towards multiple-authorship. The pattern of authorship varies from one subject to another. The proportion of multiauthored papers was very high as 87% in one sub-field, and it ranged between 20-69% in other subfield. The degree of collaboration in research is 0.60 in Psychology as a whole.

Maheswarappa & Savadatti (1990) studied the authorship pattern and collaborative research in the field of plant breeding. The result showed the maximum incidence of single authored

papers during 1924-1974 and two authored papers during 1979-1989. Single authored papers were three-fourth of all papers with 19.34% that became one-fourth in 1989, resulting in increasing in multi-authored papers from 21.25% to 75.60%.

Kademani, *et. al.*, (2006) attempts to provide detailed quantitative analysis of Indian contributions on thorium in terms of publications output as per International Nuclear Information System database during 1970-2004. The results showed the authorship pattern most prolific authors and collaboration trend. 86.70% of the papers were collaborative. There were 79 international collaborative papers. Bilateral collaboration accounted for 90.14% of total collaborative papers. Bhabha Atomic Research Centre, Mumbai topped the list with 1251 authorship followed by Indira Gandhi Centre for Atomic Research, Kalpakkam with 168 papers.

Patra *et. al.*, (2006) analysed authors distribution in the field of bibliometrics using data from Library and Information Science Abstracts (LISA). The study has found that 4000 authors publish 3,781 articles, with 0.94 % articles per author. It means single authorship is very common in this field. Lotka's law was used to identify authors' productivity patterns. It observed that authors' distributions do not follow original Lotka's law. Study also

identified 12 most productive authors with more than 20 publications in this field.

Farahat (2002) examined the patterns of authorship in nineteen Egyptian journals of agricultural science. Multiple-authorship was found to be the predominant in the field and co-authored papers accounted for some 79 percent of the sample. The most common feature is the multiple authorship pattern involving three people. Considerable variation was found among sub-fields and co-authorship was found to be most common in social science related agricultural disciplines. The author found no significant differences in pattern of collaborations in the agricultural sciences in Egypt and two the other developing countries for which comparative data was available were India and Pakistan.

Geographical and chronological growth rate

Moin, *et. al.*, (2005) evaluated the scientific output of Iran over the past two decades. The information has been extracted by searching ISI in December 2003. Science production in Iran has been reviewed (1967-2003) and compared with 15 countries in the year 2000. During these years Iran's relative share in the scientific output in the world increased from 0.0003% in 1970 to 0.29% in 2003. Comparing the ratio of science output to GNP, Iran stands or thirteenth place among 16 countries in the year 2000. The study also showed that Iran had an increasing growth in

presenting articles after Iraq-Iran war, which marks the period of stability and development.

He, *et. al.,* (2005) analysed biochemistry and molecular biology database constructed for China from the Science Citation Index Expanded (SCI-Expanded) during 1999 – 2002 using the method of bibliometrics,. The results show that almost half the publications were published in Chinese journals. The percentage of articles published by Chinese authors of the total articles from the world is increasing. The research outputs are mainly located in Beijing, Shanghai and Hong Kong. The collaboration rate of Chinese output is low as compared to results from other countries. USA and Japan are the main international collaborating countries.

Cronin & Arenas (1989) analysed the distribution of Mexican health science publications according to the states of origin, institutions, and main cities derived from four main health science bibliographic databases. The results showed that Mexican health sciences research activities were highly skewed.

Perspectives of Channels of communications

Journal productivity and its impact factor

Dhawan & Gupta (2005) evaluated the citation performance of 1101 Indian Physics research papers published in 29 high Impact Physics journals in 1997. The study foundout that journal

impact factor was not a surrogate to citations. Nearly 12% of papers in high impact journals did won even a single citation with in six years of their publication. Secondly papers won high range of citations were published in a wide range of impact factor journals. The conclusion was that although impact factor was not guaranteed for citations, publication in high impact journals improved the probability of wining citations.

Liu & Wang (2005) mapped interdisciplinarity in demography through journal network analysis. This study visualized demographic intellectual structure through a citation analysis of 65 demography-related journals between 2000 and 2003. The journal citation data were collected from JCR. The subject relationship of the journals was evaluated through a cluster analysis, network diagram, and analysis of citation percentages between demography of all selected journals. The results revealed closer connection between the demography journals and neighboring social sciences journals, than with public health and medical science journals.

Tapaswi & Maheswarappa (1999) analysed serials preferred and cited in various communications by the Indian oceanographers during 1963 to 1992. The contributions to Indian serials showed a decrease. The implications of this trend were discussed. Rank list of serials cited by Indian oceanographers was correlated with the

rank list of serials cited at international level. A negative correlation with a marginal difference of –0.214 was observed between the two rank lists. Bradford graph for all datasets, but one, showed typical Bradford-Leimkuhler curves with or without clear Groos droops.

Senthilkumaran & Vadivel (2004) analysed various characteristics of literature on Spices and Aromatic crops using data collected from the *Journal of Spices and Aromatic Crops* for the period 1992-2000. The results showed that the number of articles appearing in this journal varied from volume to volume. Maximum number of articles were published in 1999 and minimum in 1993. Collaborative authors wrote maximum number of articles.

Arkhipov (1999) examined the scientometric study on subfields of the journal *Nature*. The methodology used was based on the analysis of the average age of employed instruments. The agreement between scientometric data from various sources of information depended on the development stage of the field of science. Calculated and measured scientometric curves were compared. One of the key trends in the development of basic sciences, was the increase of articles on instrumental analytical chemistry.

Moed (2005) described citation analysis of scientific journals and journal impact measures. Eugene Garfield's creative work on

journal impact measures served more than one function. These measures were originally designed and applied to monitor the journal coverage in Science Citation Index (SCI). On a permanent basis, they constituted a tool to identify the core journals in the scientific communication system, and to highlight candidates to be included or dropped to establish a cost-effective Citation Index.

Arunachalam (1999) mapped life sciences research in India with data obtained from BIOSIS 1992-1994 using standard techniques of scientometrics. It was found that about 46% of Indian papers had appeared in non-SCI journals, and a further 37.5% in journals with impact factor less than 1.0. The analysis also revealed the existence of two clusters: a large number of institutions devoted to agriculture and classical biology, publishing mostly in low impact journals, and a smaller group publishing some papers in new biology and some areas of medicine in international journals of medium impact.

Subject and multidisciplinary studies

Schwechheimer & Winterhager (2001) mapped the neuroscience research on Retrograde Amnesia to demonstrate the capabilities of co-citation mapping in combination with peer review. In an interview with a well-known expert in the field the co-citation map was confirmed as a good representation of the specialty. The expert was able to identify and comment on different regions of the

map and he could validate important documents in the cluster core and research front as well as the main actors on institutional and national level. The bibliometric data inspired the expert to outline the cognitive and social 'history' of specialty.

Moya-Anegon *et. al.*, (2006) presented a domain analysis of the library and information science discipline based on author co-citation analysis and journal co-citation analysis. The techniques used for map construction were self-organizing map (SOM) neural algorithm, wards' clustering method and multidimensional scaling (MDS). The results of this study on subject domains identified revealed the relationship of this realm with information science; especially the presence of the management on the journal maps.

Sombatsompop, et. al., (2005) evaluated the research performance of Thai researchers in various subject categories using a new mathematical index entitled "Impact Factor Point Average" (IFPA), by considering the number of published papers in journals listed in the Science Citation Index (SCI) database held by ISI for the years 1998-2002. The results showed that the direct publication number (PN) and PC indicators could not be used for comparison among fields or countries because of the strong field dependence. The results also showed that the Clinical Medicine ranked first in terms of the research performance by Thai scholars

listed in the SCI database, but exhibited the lowest improvement of performance. Chemistry was shown to be the most improved in subject category.

Gupta, B.M. *et. al.* (1990) analysed 2339 research papers appearing in 330 journals covered in Medicinal and Aromatic Plants Abstracts, India (1983) on the basis of their broad subject fields such as agronomy, phytochemistry, pharmacology and clinical research; their country of origin, plant genera and their species; and type of investigation. Under each of the broad subject fields and major genera, an attempt has been made to identify the nature and focus of research in different countries through minimal level content analysis. Special focus of the paper has been the analysis of Indian publication output.

Collaboration and Visibility

Authors, National and International collaborative research

Mohan et. al., (2003) analysed the materials science research in India for the period of five years (1995-1999), based on the papers published by Indian scientists in collaboration with foreign researchers, covered in Material Science Citation Index (MSCI). The results indicated that materials science in India was broad based and covered most of the important sub-areas, and was based on inherent strength. Most of the work involved bilateral rather than multilateral collaboration. The collaborative linkages with developing countries accounted for 10% of the total papers. Ten top Indian Institutions contributed nearly 50% of the

collaborated papers. The major areas of collaboration were theoretical studies, metals & alloys, electronic materials and super conducting materials.

Arunachalam & Jinandradoss (2000) mapped international collaboration in science by 11 Asian countries using data from SCI 1998. The results showed the collaboration of these countries and with G7, European Union, OECD and selected Latin American. African countries were classified under subject categories to characterize each country's total and collaborated scientific literature output. Japan (16.4% of internationally collaborated papers), India (17.6%) and Taiwan (16.3%) recorded an internationalization index less than 30 whereas China (28.5%), South Korea (24.6%) and Hong Kong (36.2%) recorded an internationalization indexed greater than 40. India, China and South Korea have collaborated more in physics, whereas the other eight countries have collaborated more in life sciences. In almost all fields, USA is the most preferred collaborating partner for almost all-Asian countries. All G7 countries collaborate more with China, which is emerging as a leader in regional collaboration, than India.

Gupta & Dhawan (2003) described the importance and need of collaboration in scientific research. They discussed and analysed the present status of India's collaboration with China on S&T as reflected in the co-authored papers. It was evident from the

rise for number of coauthored papers from 21 in 1994 to 74 in 1999. Field wise Physics and Clinical Medicine have been the priority areas for collaborative research accounting for 62% and 14% respectively. The average impact of all coauthored papers has been found to be 2.77. It is a good performance as compared to the overall impact of Indian research papers.

CHAPTER 3

METHODOLOGY

1. DESCRIPTION OF DATABASE

1.1. Bibliographic databases on coral reefs

The literature on various aspects of coral reefs are presently available in a numerous publications on life science, marine science and fisheries bibliographical databases such as Web Of Science (WOS), Biological Abstracts (BIOSIS), Chemical Abstracts (CAB), Biophysics and Biochemistry Citation Index (BBCI), Biotechnology Citation Index (BTCI), National Information Service Corporation (NISC) database on Fish and Fisheries Worldwide; Marine, Oceanography and Freshwater resources, Fish Base, Global Coral Reef Monitoring Network (GCRMN) database on South Asia Regional Coral Reef database, Reef base (***http://www.reefbase.org***) (A global information system on coral reefs) and Aquatic Science Fisheries Abstracts (ASFA).

1.2. Criteria for selecting the ASFA database

Although a number of databases were evaluated and sampling of data sources had been conducted focusing on the application of bibliometrics and scientometrics in the growth of literature in different fields, none of them studied the field of 'coral

reefs'. **Jayashree & Arunachalam (2000)** mapped fish research in India and very few bibliometric studies **(Arunachalam & Jayashree (2001)** and **Sylvain (1993)** also been done using ASFA database is one of the data source. Based on the literature overview felt that to select this database as data source for this study. Among the different databases, a CD ROM version of Aquatic Science and Fisheries Abstracts (ASFA) database published by Silver Platter Information Inc. was chosen for data collection.

The reason for the choice was its wide coverage, monthly updates and international standard in the field of Marine Biology, Marine Ecology, Hydrobiology, Marine geology, Oceanography, Marine biotechnology, Conservation and Management of living and non living organisms, Marine Technology, Aquaculture and Fish & Fisheries. The Aquatic Science and Fisheries Information System (ASFIS) is maintained jointly by Food and Agricultural Organization (FAO), the Intergovernmental Oceanographic Commission (IOC) and the United Nations Office for Ocean Affairs and Law of the Sea (UNOALOS) in collaboration with the United Nations Environment Program (UNEP) and the ASFIS Partners.

The ASFA database covers the period from 1975 to date, with monthly updates. The portion of the database published since 1982 is also available on CD ROM, with quarterly updates, from 1982 onwards. The printed products date from 1971. The ASFA

database comprehensively covers all those journal articles, books, papers on conference proceedings, theses, chapters in books, reports and other non-conventional literatures that scan more than 5,000 periodicals annually. Apart from the above, in terms of ease of searching the records are searchable with the use of keyword index as well as ASFA Thesaurus.

1.3. Search Strategy

Actual search capabilities and strategies depend on the host information retrieval system but database distribution format (ISO 2709) allows searches by author name, author address, corporate source, conference date, date of publication, document type, journal title, taxonomic terms, subject category codes, subject descriptors etc. Apart from the index, the subject descriptions are listed in the ASFIS Aquatic Sciences and Fisheries Thesaurus. Thesaurus includes aquatic and marine related terms, which occur in the abstracts. The following three concepts are adopted in the search strategy:

- Facilitated search of the broader or narrower retrieval of documents
- A combination of descriptors, title, abstract and category codes will result in Broadest document retrieval

- Facilitated search using Boolean and positional operators (OR, AND, NOT)

1.4 Marine Scientists Vs Information Manager in Searching Techniques

The product itself is easy to use and quite simple to learn in both the menu assisted version for non-experienced users, limited to only two word combination, and the dot command version for experienced users, which make all variations of nested Boolean commands possible. The instructions are clearly written and well presented for important busy librarians. For preoccupied scientists, they are concise. Downloading ASFA files for direct printing or on to a diskette or the hard disk is easily done with WinSPIRS - retrieval software.

2. METHODOLOGY

For this research Aquatic Science and Fisheries Abstracts CDROM version, the leading international marine and freshwater aquaculture database produced by the Silver Platter Inc. has been used. The ASFA database comprehensively covers all journal articles, authored books, papers in conference proceedings, theses, chapters in books, reports and other non-conventional literatures that are scanning more than 5,000s periodicals annually. To limit the chance of duplication, the researcher has recommended selecting one database. Therefore, ASFA database has been

selected as sample in order to evaluate the validity and reliability of published work on coral reef research.

2.1 Silver Platter Software

Silver Platter Software (Version 4.1) in Window version of WinSPIRS has been used for operating ASFA database.

2.2 Hardware Requirements

Compact disk (CD-ROM) is a high-density storage medium, which allows the database to be used through a microcomputer. The database can be searched and displayed using an IBM PC, XT or AT for true compatible equipped with a compact disk drive and the Compact Cambridge Software or WinSPIRS. CD ROM players manufactured by Philips, Hitachi, Sony, Toshiba and Digital Equipment Corporation are also suitable.

2.3 Installation Procedures

This section includes software installation procedure for Silver Platter's-WinSPIRS. Be certain that it is first reviewed for necessary system requirements and especially disk storage requirements before trying to load Winspirs. The installation procedure is also well documented and easy to follow. The installation diskette comes along with a manual, which includes step-by-step instructions for installing of the software on computers with hard disk.

2.4 Fields of ASFA Database

The ASFA records contain the following fields. Fields listed in bold are limit fields. For this study 10 fields were selected restricting the searches with limits.

Table 4 Fields of ASFA Database

Code	All Fields of ASFA Database	Code	Restricting Searches With Limits
AB	Abstract		
AF	Author Affiliation	**AF**	**Author Affiliation**
AN	**Accession Number**		
AU	Author(s)	**AU**	**Author(s)**
CA	Corporate Author(s)	**CA**	**Corporate Author(s)**
CL	Classifications	**CL**	**Classifications**
CO	Conference Information		
DE	Descriptors		
ER	**Environmental Regime**		
IC	Input Center Number		
ID	Identifiers		
IS	**International Standard Numbers**		
JA	**Journal Announcement**		
LA	**Language of Text**	**LA**	**Language of Text**
LS	**Language of Summaries**		
NT	Notes		
OT	Original Non-English Title		
OZ	**Ocean Zones**	**OZ**	**Ocean Zones**
PT	**Publication Type**	**PT**	**Publication Type**
PY	**Publication Year**	**PY**	**Publication Year**
RN	Report/Patent Numbers		
SO	Source (Bibliographic Citation)	**SO**	**Source (Bibliographic Citation)**

ST	Series Title/Information		
SU	Subjects		
TI	Title (English)	**TI**	**Title (English)**
UD	**Update Code**		

There is also a special subset of fields like Citation (CITN), which contains TI, OT, AU, CA, CO, SO, NT, RN, LA, and AN fields. Citation is used to display, print, or save the fields for a set of records.(Annexure I & II)

2.5 Methods and keyword used for data collection

The CD ROM version of ASFA Database is used in this study. **Lancaster (1986)** has stated that the subject heading term takes care of the synonyms, homonyms and it is expected to retrieve maximum records. Each record having ten fields of the bibliographic information was selected from the database i.e. author, authors' affiliation, corporate authors, title, source, publication type, publication year, language, ocean zone and classification for downloading the data. Coral reef information was searched using keywords from ASFIS Thesaurus, to collect the data on global level coral reef literature:

"CORAL REEFS OR **CORAL** OR **REEFS** OR **CORAL ISLANDS** OR **ATOLL** OR **ATOLL LAGOONS** OR **BIOGENIC DEPOSITS**"

The first author's address was taken for the affiliation purpose, as it was only available. Finally, data were downloaded in text file and converted into excel format. The duplication work and

all the pollutant records on "**coral reef**" were not taken into account. It resulted in a primary data with 13,982 records for the period 1988- 2005. The data were processed and tabulated using MSWord and Microsoft Excel 2003.

3. Statistical Tools

Mapping of coral reef research literature with respect to countries, subjects, sources of communication and languages was done using three techniques as:

- Deviation of observation from expectation
- Calculation of distance and similarity measures
- Decomposition of the matrix.

The derived measures were used as Scientometric indicator on the basis of multivariable analysis components of **Cluster Analysis** (CA) and **Multidimensional Scaling** (MDS) and related mathematical methods. These methods were used in a number of studies (**Hagedoorn & Schakenraad (1992) and Tijssen (1992)**. The cluster analysis was carried out using SyStat and the MDS and Statistical Package for Social Science (SPSS) was applied.

3.1 Spearman Correlation Coefficients

To identify to correlation coefficient for the periods of six year each i.e. 1988-1993; 1994-1999; and 2000-2005 selected top 50 countries and ranked using Spearman rank correlation through

the SAS system. There 64 countries were listed for selecting the top 50 countries in each set of period.

3.2. Bibliometrics Laws

The bibliometric approach to Science and Technology is primarily based on quantitative characteristics and attributed to research publications such as article titles, authors, books, journals conference proceeding, reports etc. Research and development on social sciences and other sciences like Genetic Engineering, Bioinformatics, Aquaculture, etc. are growing rapidly and it can be easily observed that extensive co-operation is required among different research groups and countries. In view of using bibliometric techniques to identify the trends in a subject to study scientific communications and its distribution, the following two laws are used in this study.

- Lotka's law (1926) implies the productivity of authors in terms of scientific papers
- Bradford's law (1934) empirically depicts the scattering articles over different journals.

The bibliometric laws are regarded as milestones in bibliometrics. **Bookstein (1976)** briefly discussed that these different bibliometric distributions allowed one to understand them as being different version of a single theoretical distribution. He

expressed the following function to describe the bibliometric processes.

$f(x) = k / x^{\infty}$

$X = 1, 2, 3 \ldots\ldots$

$K, \infty > 0$

This function can be used to describe the famous Lotka's law and Bradford's law as follows:

- f(x) = the number of authors who have published x papers is proportional to $1/x^{\infty}$ $(\infty > 1)$
- f(x) = the number of journals which contains x articles in a given subject is proportional

  to $1/x^{\infty}$ $(\infty > 1)$

3.3 Sengupta's Law of Bibliometrics

Sengupta law states that "during phases of rapid and vigorous growth of knowledge in a scientific discipline, articles of interest to that discipline appears in increasing number of periodicals distant from that field". The data pertaining to this discipline the extension of Bradford law i.e. Sengupta law used to this study.

Mathematically Sengupta's law stands in the following form:

$$F(x + y) = a + b \log (x + y)$$

Where f (x + y) is th cumulative number of references as contained in the first (x + y) most productive journals, x indicates

number of journals in the same discipline and y stands for number of journals of unrelated disciplines (y > x) and a and b are two constants.

4. Format of Reference List

The **APA (American Psychological Association) Citation Style Guide** rules were followed for writing the list of references at the end. The Publication Manual for instructions available in the web site, ***http://www.ldl.net/~bill/aparev.htm*** (Guidelines for Writing the APA Style) was also helpful. A mock reference list was formed in the APA style by taking grammar and punctuation rules into consideration. The reference list is an alphabetical order (by author, year) for all the sources of references at the end of the thesis to enable the reader to find the details easily.

References cited within the text of the thesis would appear in the list of references, and any source included in the list of references would also be cited in the text.

This guide provides examples of citations use of in research papers following the APA standard. Explanations and formats are based on the Publication Manual of the American Psychological Association, (fourth edition), (BF76.7 .P82 1994 Ref.) and the Columbia Guide to Online Style (PN171.F56 W35 Ref.) available at the Reference Desk.

CHAPTER – 4

DATA ANALYSIS

This investigation is based on a download of 13,982 records on coral reef literature on global level drawn from the CD ROM version of Aquatic Science and Fisheries Abstracts database. The database covers the period of 18 years from 1988 to 2005. In a formulated search strategy acceptable to the ASFA database, the publication pertaining to the study period on global levels were downloaded for analysis. The data have been tabulated and interpreted. Suitable statistical tools and techniques have been applied wherever necessary.

1. CORAL REEF RESEARCH PRODUCTIVITY TRENDS

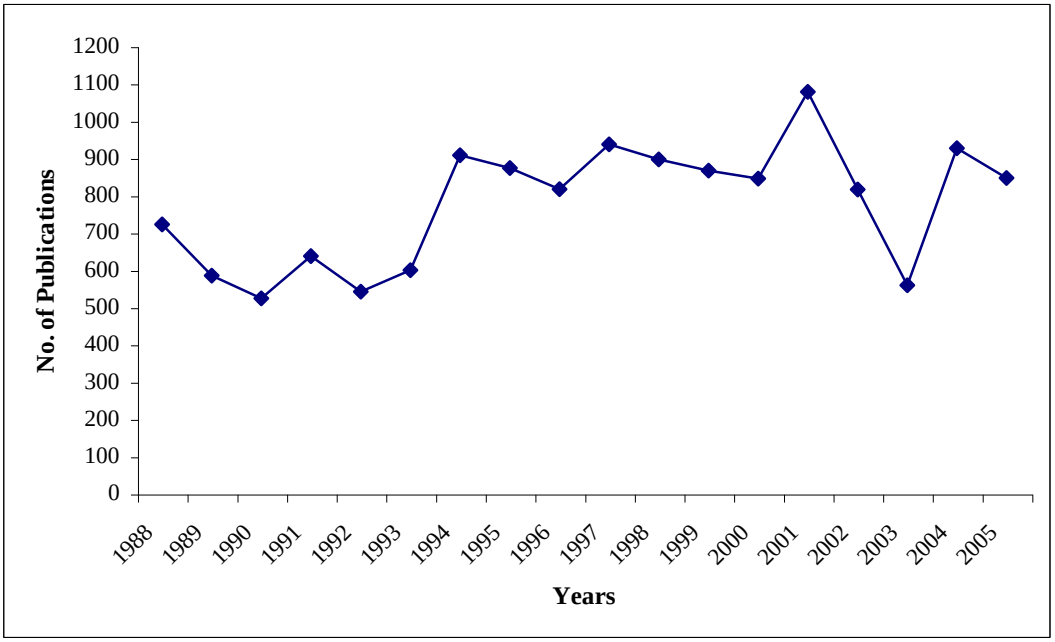


Figure 5. Coral Reef Literature Productivity Trend

The analysis of productivity growth rate of coral reef research literature has major focus on the study to appraisal of the performance of research and development in the field of marine science. **Figure 5** indicates that there was no stable growth of literature. In the year 2001, it crossed the level of thousand to have the top rank during the study period, followed by that of in years, 1997, 2004, 1994, and 1998 with second to fifth rank. In 1990 it had low percentage of 3.75% to secure last rank.

2. LANGUAGE WISE DISTRIBUTION OF CORAL REEF LITERATURE

The publications covered in ASFA database are published in approximately 40 languages. **Figure 6** shows number of publications in 25 languages. It includes 24 languages other than English on coral reef literature.

SyStat's hierarchical agglomerative clustering approach was used to analyse the language wise distribution of coral reef research literature. The cluster analysis based on the pattern similarity (correlations) of the 25 languages was performed for the annual frequencies. The output of a cluster analysis is a cluster tree, which is a graphical display of the clustering process. It begins by joining two languages with the most similar patterns according to the distance criterion. A total of three clusters can be identified, with first one being the English language. The overwhelming volume churned out by contribution in English

language might have had a camouflaging effect on the overall grouping scenario leaving the other distances masked. Two pairs of languages French and Chinese form the second cluster while the other languages form the third cluster with sub-clusters within them.

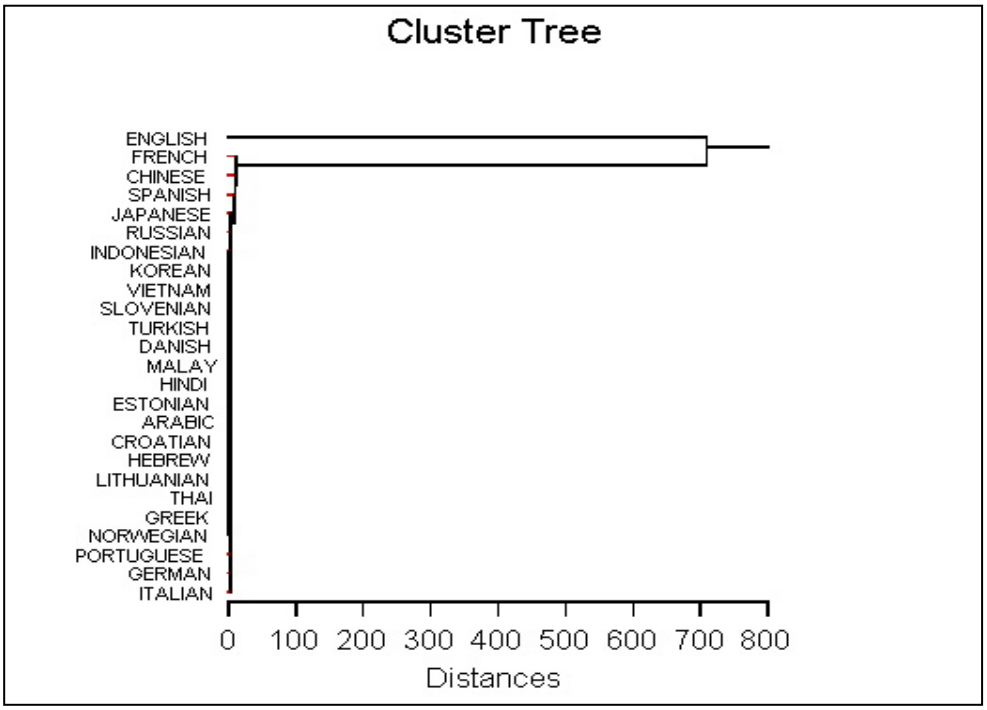


Figure 6. Language wise distribution of coral reef literature (SyStat-Cluster analysis)

Since, English is the official scientific language in many countries; it leads to its wide usage in dissemination of scientific data and proceedings. This observation matches with other scientific publications where information is available largely in English.

3. MAPPING OF WORLD CORAL REEF RESEARCH DEVELOPMENT 1988-2005

Science would not exist if the results of scientific work were not communicated. Communication is the driving force of science. Publication to exchange research findings is an important aspect of science and is a basis of methods to evaluate scientific productivity. Many methods have been suggested to evaluate the scientific productivity of countries (**Braun et al., 1995; Bonitz et al., 1997**).

A total of 13,982 records were retrieved from the ASFA CD ROM database based on the search words. The country from where scientists publish their work is provided as their affiliation. Since, there were only 1,071 records, with 7.66%, the author's affiliations were not displayed, and these entries were not included for this analysis.

3.1 Mapping of coral reef literature-Top 50 Countries

To study the pattern of the coral reef literature of various countries, multi dimensional scaling technique was applied to the annual frequencies classified based on the their publications over the study period (1988-2005). Contributions made by the top 50 countries out of 142 countries were taken for analysis and **Figure 7** clearly shows the performance made by the countries of with Australia and USA being aloof, and other countries clubbing closely.

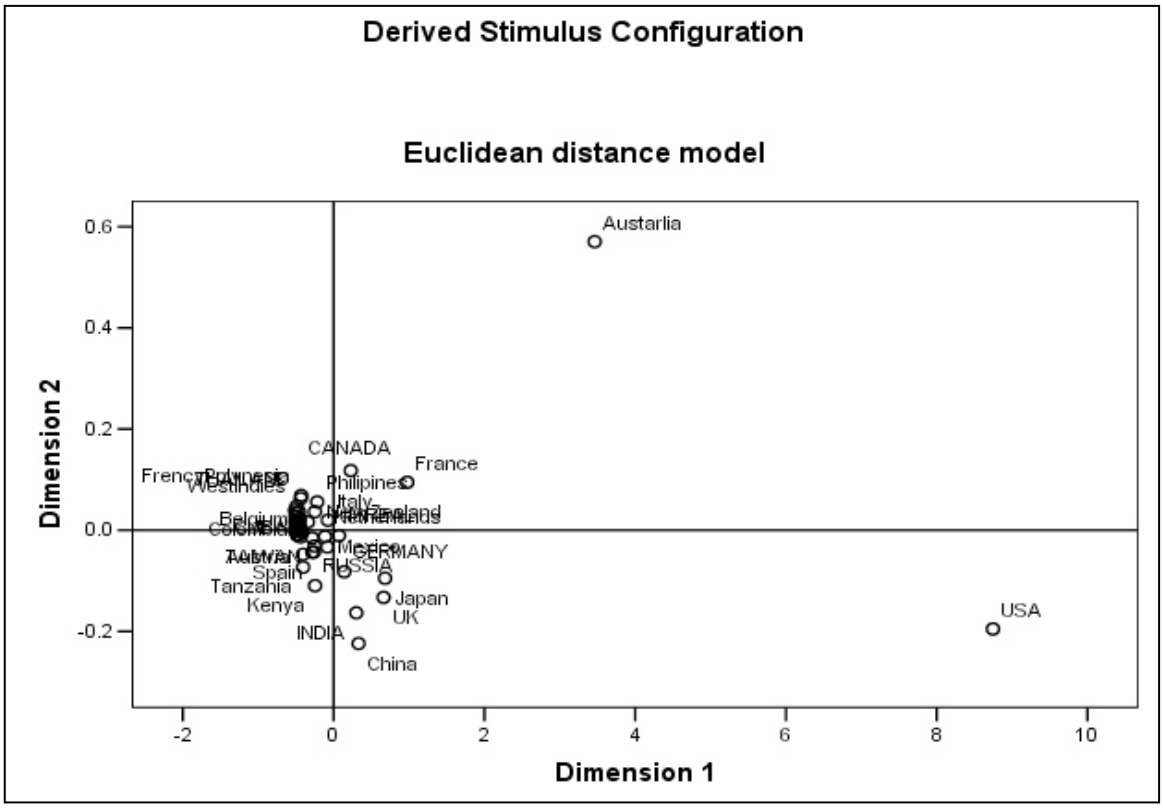


Figure 7. Mapping of coral reef literature-Top 50 Countries

3.2 Coral reef research development in top 10 countries

To identify relative homogeneous groups of countries based on the annual productivity of literature frequencies, the hierarchical agglomerative clustering approach was used. This approach uses the algorithm that starts by joining two countries whose patterns are most similar in accordance with the distance criterion chosen in this study with average linkage. The results are displayed in **Figure 8.** It is a visual representation of the steps in hierarchical clustering solution showing the clusters and the values of the distance coefficients in each step by rescaling the

actual distances to numbers between 0 and 25, preserving the ratio of the distances between steps. The figure indicates that there are three main clusters, out of which two main clusters are individuals with USA and Australia. The countries forming as sub clusters within the other main cluster are France, UK, Japan, India, China, Canada, Israel and Germany. The overwhelming volume churned out by US and Australia during the period of observation might have had a camouflaging effect on the overall grouping scenario.

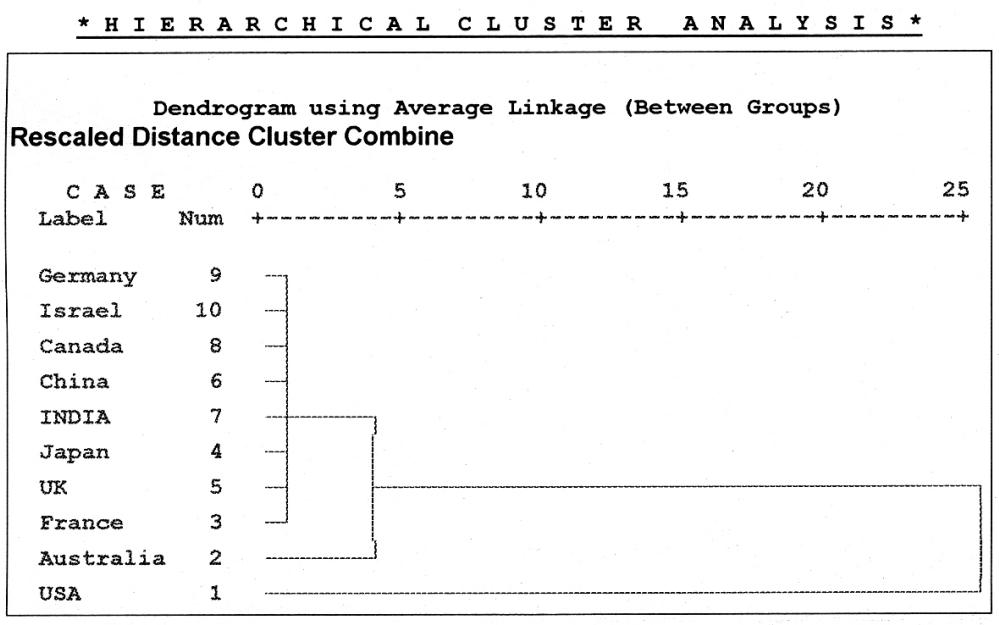


Figure 8 - Cluster Analysis on Top 10 Countries productivity

3.3 Contributions of G8 Countries on Coral Reef Research

In order to verify the observed G8 Countries productivity, the researcher has made an attempt to findout whether G8 Countries such as UK, USA, France, Canada, Italy, Japan, Germany and

Russia's productivity on coral reef research literature is similar to that of World's Science.

To understand the similarity (or dissimilarity) pattern of G8 countries over the study period, multi dimensional scaling technique was applied using SPSS ALSCAL algorithm. **Figure 9** shows the grouping of G8 countries based on dissimilarities. USA is the coherent group emerging with predominant distance as this country has the higher productivity over the study period. A perusal reveals similarity between the G8 countries with UK, Germany, Japan and Italy grouped in one quadrant while Russia, Canada and France grouped in another quadrant.

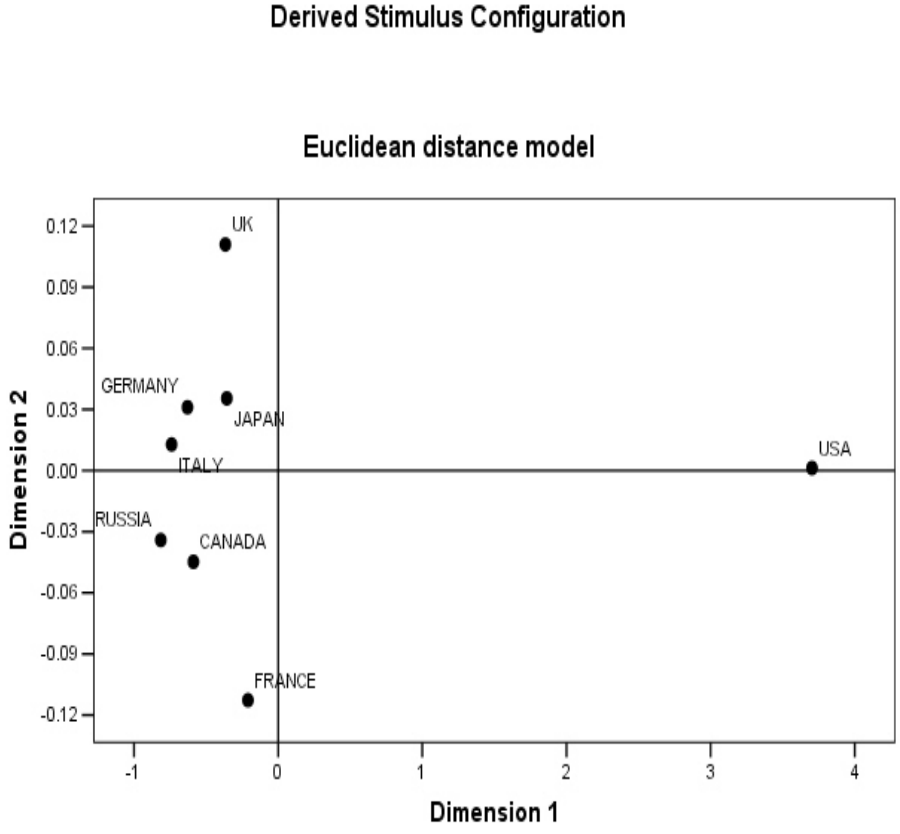


Figure 9. Contribution of G8 Countries according to Multidimensional Scaling (SPSS-MDS)

4. SUBJECT BASED PUBLICATION ACTIVITY

It has been found that coral reef research has exponential linkages with subjects like Medicine, Biotechnology, Marine Engineering and related technologies, Marine Biology, Marine Ecology, Marine Geology, Oceanography, Marine Pollution, Marine Chemistry, Law & Policy related to coastal regulation, Fish and Fisheries, Economics, Conservation and Management.

4.1 Subject wise distribution in publications – Global level

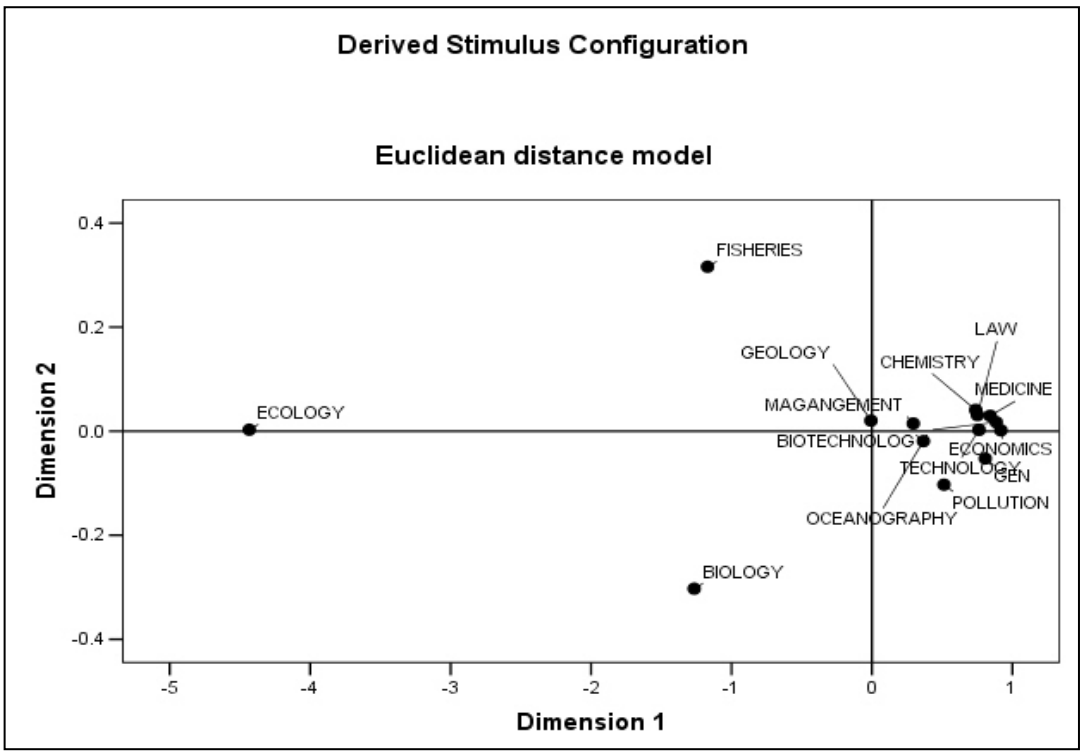


Figure 10. Subject wise distribution –global level MDS map

Apart from identifying the authorship pattern, attempt to find the underlying similarity pattern of the subjects over the same period was made. The frequencies were classified into 14 subjects and MDS technique was carried out. It was clearly seen from **Figure 10** that Ecology was dissimilar from other subjects. The result was the same as that in Figure 2.4 where clustering was done for the subject wise frequencies of G8 countries. It represents that in the study period publications and research was mostly concentrated on Ecological studies of coral reef. The perusal further shows that the Fisheries and Biology is similar in dimension 1, although they are dissimilar in the other dimension. The other subjects are grouped closely to each other.

4.2 Subject wise distribution - top 50 countries

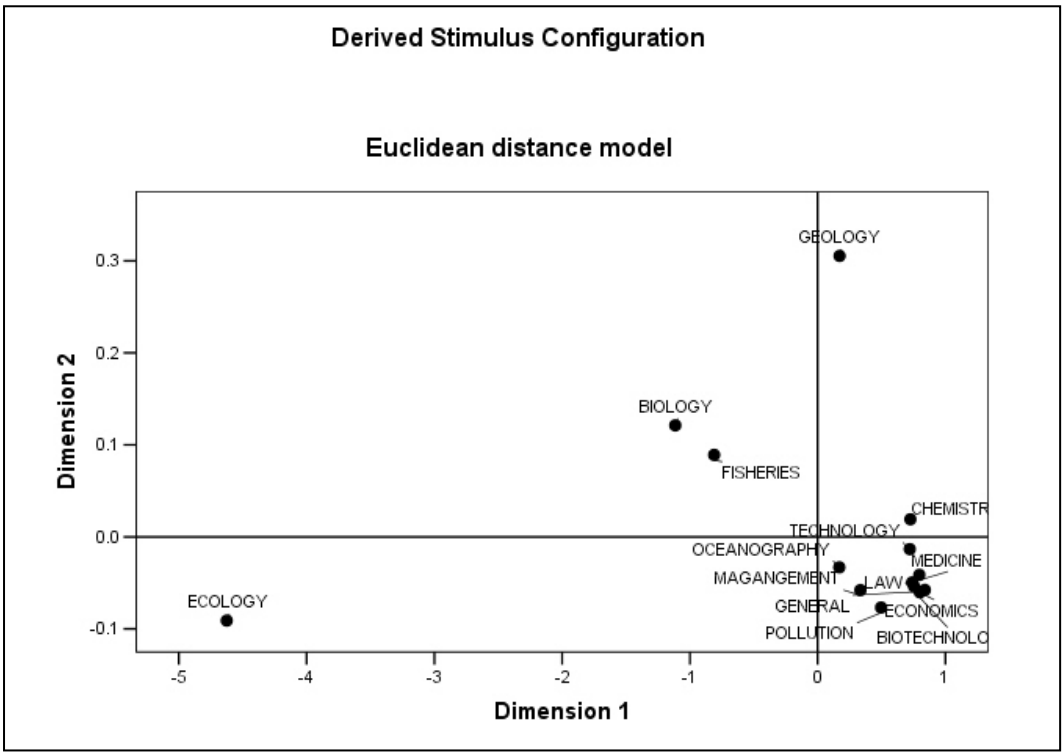


Figure 11. Subject wise distribution - top 50 countries (SPSS-MDS map)

Figure 11 shows a two dimensional MDS map of the intellectual structure for top 50 countries contributing to coral reef research. The disciplines covered in the study are General studies, Law & Policy towards coastal zone regulations, Biology, Ecology, Fisheries, Marine Chemistry, Marine Pollution, Marine Biotechnology, Marine Geology, Oceanography, Marine Technology, Medicine (pharmacological activities on marine organism), Management (coastal zone management), and Economics. Ecology is seen to be more predominant than the other subjects. Biology and Fisheries are seen to be more similar, while Geology is left aloof. All the other subjects are grouped closely leaving little chance to notice the frequency pattern.

4.3 G8 Countries contribution in subjects

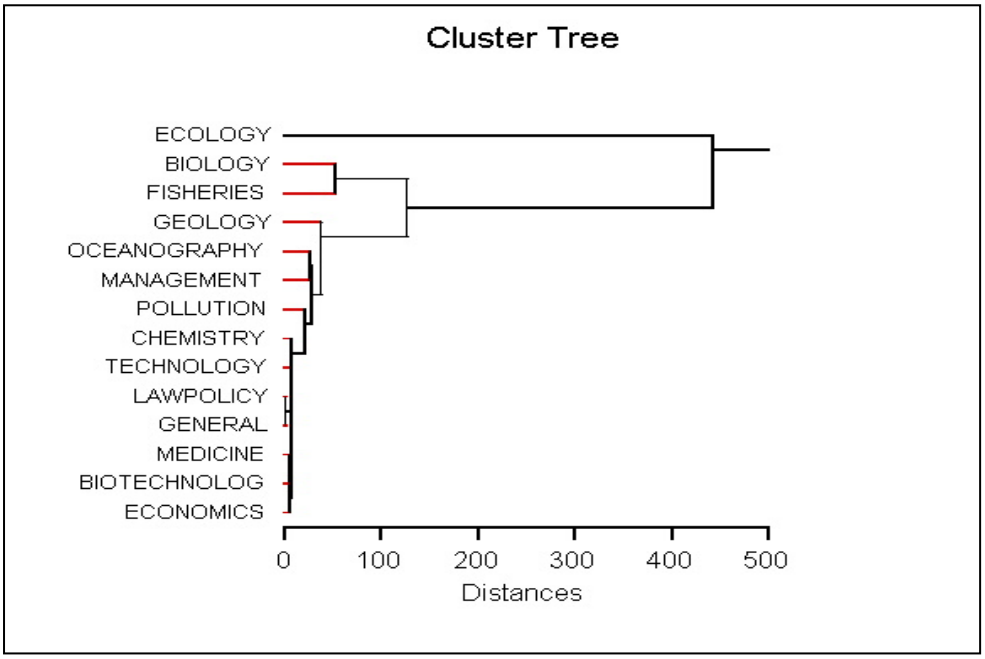


Figure 12. G8 Countries - subject wise cluster analysis

To identify the prevailing research trend of the G8 countries clustering technique was done using SyStat package. Frequencies were generated based on fourteen disciplines over the study period for the G8 countries. **Figure 12** presents the subject wise cluster map of G8 Countries. Three main clusters were formed with the independent cluster being Ecology in constituting coral reef research. The study of coral reef ecology is the most common key issue of marine science research. At present stage of development, this is clear from the results in the cluster tree that Ecology is the coherent group with predominant frequencies. The second cluster is that of biology and fisheries. Geology, oceanography, management, pollution, chemistry, technology, law policy, general, medicine, biotechnology and economics form the third cluster with sub clusters. The results coincide with **Figure 10 & 11** and showing that Ecology was not only predominant when analysed in G8 Countries but also with top 50 countries.

5. AUTHORSHIP PATTERN: TREND ANALYSIS

Figure 13 shows global level authorship patterns in the coral reef research. According to this, a single author wrote 29.21 % of 13764 papers while the other 70.79 percent were the work of more than one person. This clearly reflects a trend towards multi-authorship pattern in the field. Such a trend may be due to the proliferation of sub-fields in the coral reef research and

interdisciplinary nature of these, both with one another and with other science and technology discipline. The interdisciplinary nature of a field is one of the obvious reasons for collaborative research.

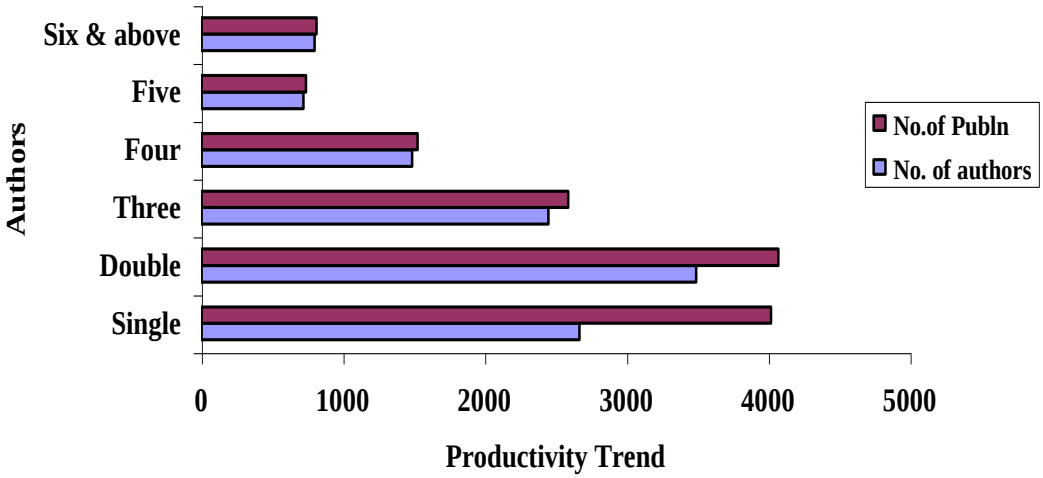


Figure 13. Authorship pattern versus Publication trend

5.1 Single Versus Multi-authored Publications

For the analysis of single versus multi-authored papers, the researcher has classified the study period in to three categories. It can be seen in **Table 5**, during the first phase of the study period 1988-1993, the single author contributed papers constituted 38.88 % and the remaining majority was multiauthored papers.

During the second phase of the study i.e. 1994-1999, the single authored papers showed the declining trend i.e. 31.34 %. At the third phase, single authored papers constitute 20.14% of the publications reported in the study, and the remaining i.e. 79.86% of publications are multiauthored papers.

Table 5 - Single versus Multi-authored Publications

Year	Single authored papers		Multi- authored papers			
	Number of Authors	Percentage	Number of Authors	Percentage	Total	%
1988-1993	1381	38.88	2171	61.12	3552	25.81
1994-1999	1630	31.34	3571	68.66	5201	37.79
2000-2005	1009	20.14	4002	79.86	5011	36.41
Total	**4020**	**29.21**	**9777**	**71.03**	**13764**	**100**

5.2 Degree of Collaboration in Coral Reef Research

Subramanian has deduced a formula for calculating the degree of collaboration as

C=Nm/(Nm+Ns)

Where c=extent of collaboration

Ns=number of single authored papers

Thus applying the formula as given below one can arrive at the percentage of collaboration:

C=Nm/Nm+Ns

The analysis of the extent of collaboration on Coral reef research during the study period from 1988 to 2005 throws light on the trend of the authors in publishing their research output. The degree of collaboration, C is shown in the **Table 6.** It is evident that these statistics support the findings above with values

for Collaboration increasing from 0.61 during 1988-1993 to 0.69% during the second phase of the study period 1994-2000.

Table 6. Degree of collaboration

Year	Degree of Collaboration (C)
1988-1993	0.61
1994-1999	0.69
2000-2005	0.80

The third phase of study period during 2000 – 2005 stands first in the order (0.80) of collaborative research endeavour. The first phase of the study period during 1988-1993 recorded last in the order (0.61) of collaboration. The over all study periods reveal coral reef research intended for collaborative rather than 'lone rangers'

5.3 Lotka's Law of Authors' productivity

Lotka's law states that the number of authors who contribute one paper will constitute the largest group, around 60 % of the total authors. In this study, this group of authors constitutes 89.53% of the total authors, and the remaining authors are at ranks 2 to 12, consisting of 10.47% of 11,670. It perceived that 1222 authors have contributed 3316 out of the total papers 13764.

Table 7. Application of Lotka's law of Author Productivity

No. of Publication	Observed No. of Authors	Observed % of authors	Expected No.of Authors	Expected % of Authors	(f-p)2/p
1	10448	100	10448	100	0
2	802	7.68	2612	25	1254.25
3	228	2.18	1160	11.11	748.81
4	93	0.89	653	6.25	480.25
5	40	0.38	417	4	340.84
6	23	0.22	290	2.77	245.83
7	17	0.16	213	2.04	180.35
8	7	0.07	163	1.56	149.3
9	2	0.02	128	1.23	124.03
10	3	0.03	104	1	98.08
11	2	0.02	86	0.82	82.04
14	2	0.02	53	0.51	49.07
15	3	0.03	46	0.44	40.19

5.4 Authors Productivity

The study of author productivity is essential in identifying the research performance in any area of science. Author productivity is determined on the basis of number of papers contributed by the scientist in a field. A small number of authors in a field are highly productive (**Lotka, 1926**) and their research publication works as "Models' for later research. The **Table 8** reveals the striking highly productive authors on coral reef research during the study period 1988-2005. The authors Humes,-A.G.(USA), Latypav,-Yu.Ya. (Russia), and Mueller,-H.G. (Germany) have contributed 15 articles each and most of them are from

journals. Mostly they contributed in the field of Carcinology (taxonomy and morphology), Ecology and Biology.

The inference is, the frequency of names of authors and numbers of contributions were in reverse proportion.

Table 8 – Highly contributed authors

Name of the Author	No. of Papers	Name of the author	No. of Papers
Humes,-A.G.	15	Bombace,-G.	6
Latynov,-Y.Y.	15	Bruce,-A.J.	6
Mueller,-H.G.	15	Clarke,-R.D.	6
Grigg,-R.W.	14	Craik,-W.	6
Lewis,-J.B.	14	Done,-T.J.	6
Cairns,-S.D.	11	Fishelson,-L.	6
Otto,-J.C.	11	Glasby,-T.M.	6
Gordon,-H.R.	10	Goldberg,-W.M.	6
Moshchenko,-A.V.	10	Harding,-J.M.; Mann,-R.	6
Robertson,-D.R.	10	Jordan,-D,E.	6
Edmunds,-P.J	9	Keller,-N.B.; Pasternak,-F.A.	6
Glynn,-P.W.	9	Leis,-J.M.; Carson-Ewart,-B.M.	6
Alongi,-D.M.	8	Lesser,-M.P.	6
Bayer,-F.M.	8	Lough,-J.M.	6
Connell,-S.D.	8	Lough,-J.M.; Barnes,-D.J.	6
Holden,-H.; LeDrew,-E.	8	Obura,-D.O.	6
McClanahan,-T.R.	8	Polovina,-J.J.	6
Munro,-J.L.	8	Russ,-G.R.; Alcala,-A.C.	6
Rinkevich,-B.	8	Sano,-M.	6
Barnes,-D.J.; Lough,-J.M.	7	Veron,-J.E.N.	6
Bellwood,-D.R.	7	Wilson,-E.C.	6
Birkeland,-C.	7	Wulff,-J.L.	6
Conand, C	7	Xue,-C.	6
Falace,-A.; Bressan,-G.	7	Ayukai,-T.	5
Faust,-M.A	7	Brazeau,-D.A.; Lasker,-H.R.	5
Harriott,-V.J.	7	Buddemeier,-R.W.; Fautin,-D.G.	5

Kulbicki,-M.	7	Cortes,-J.	5
Letourneur,-Y.	7	Gladstone,-W.	5
Lirman,-D.	7	Gourlay,-M.R.	5
McManus,-J.W.	7	Grutter,-A.S.	5
Pandolfi,-J.M.	7	Grygier,-M.J.	5
Perry,-C.T.	7	Guzman,-H.M.; Cortes,-J.	5
Riegl,-B.	7	Guzman,-H.M.; Guevara,-C.A,	5
Sorokin,-Yu.I.	7	Hallock,-P.	5
Stanley,-D.R.; Wilson,-C.A.	7	Hawkins,-J.P.; Roberts,-C.M.	5
Wood,-R.	7	Hodgson,-G.	5

6. SOURCE WISE DISTRIBUTION OF PUBLICATION

Type of publications on Coral reef research includes various categories of primary, secondary and tertiary sources. The literature is available in a variety of publications in the form of Bibliography, Book, Conference Proceedings, Journal Articles, Dictionary, Manual, Numerical data, Patent, Report, Review Article, Standard, Summary, Thesis, Map and Computerized information (digital forms). The material excluded from the ASFA Database includes popular, non-technical article, pamphlets and most newsletters. The **Table 9** shows that the distribution of the type of documents used by the coral reef researchers over the period of study.

table-9

6.1 Types of Publication: Trend Analysis

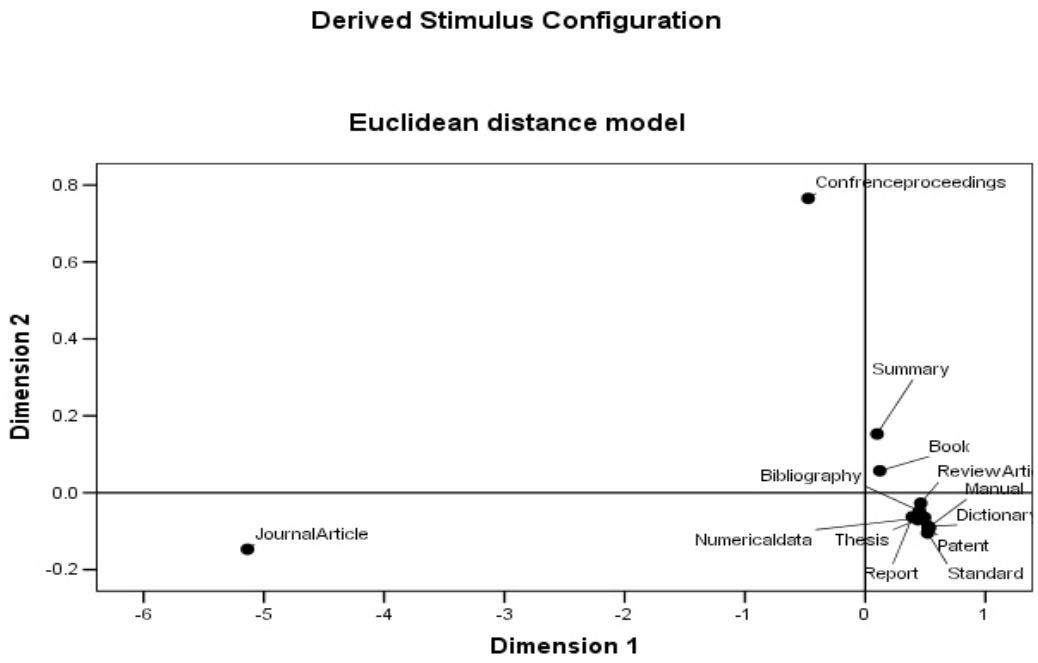


Figure 14. MDS map on Source wise distribution

To understand the similarity/dissimilarity pattern of the source of publication, multi-dimensional scaling technique was performed to the annual frequencies of the data pertaining to the entire study period.

In **Figure 14** Journal article clearly pursued a distinct pattern over the years. Consistent performance was seen in the case of Conference proceedings. A closer look reveals that Book and Summary articles exhibiting under current are placed in a separate quadrant while the review of articles, Manual, Dictionary, Patents, Thesis, Numerical data, Reports and Standards were grouped in another quadrant.

6.2 Journal Article: Year wise

The **Figure 15** shows the publication of journal articles in 1988 to the tune of 3.27%. In 1989, it decreased to 0.21%. Then there was an increased trend in the number of journal articles for the period from 1990 to 1995; it was found that a little difference existed for the period between 1999 and 2001 in the growth of journal productivity with 0.08%. From 2001 onward there was a gradual decreasing trend in the journal productivity. By comparing the study periods it was noticed that in 2004 the coral reef researcher had used 861 journals to publish their research output.

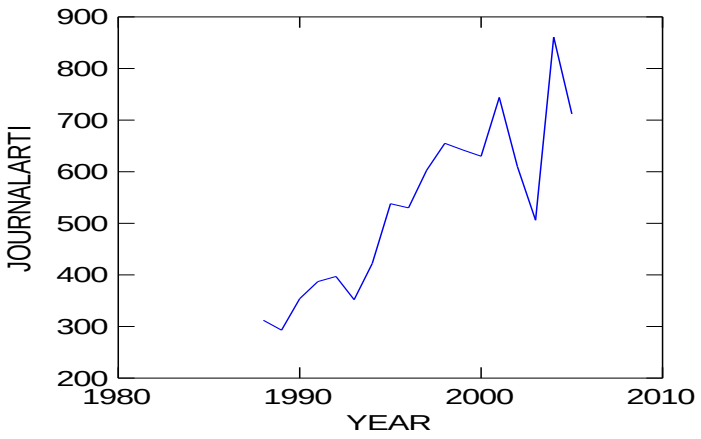


Figure 15. Journal Article: Trend Analysis

6.3 Conference Proceedings

Figure 16 shows that the scientists use to contribute their research results in conference proceedings with their grade of the 2nd rank. When over all productivity of the types of communications is compared, it is found that the conference

proceedings cover 14.34% of the articles. In the year 1988 it showed the highest contribution followed by the year 1994 and 1995 with 220 and 185 papers respectively, contributed by the scientists. Lowest rate of contribution was in 2003.

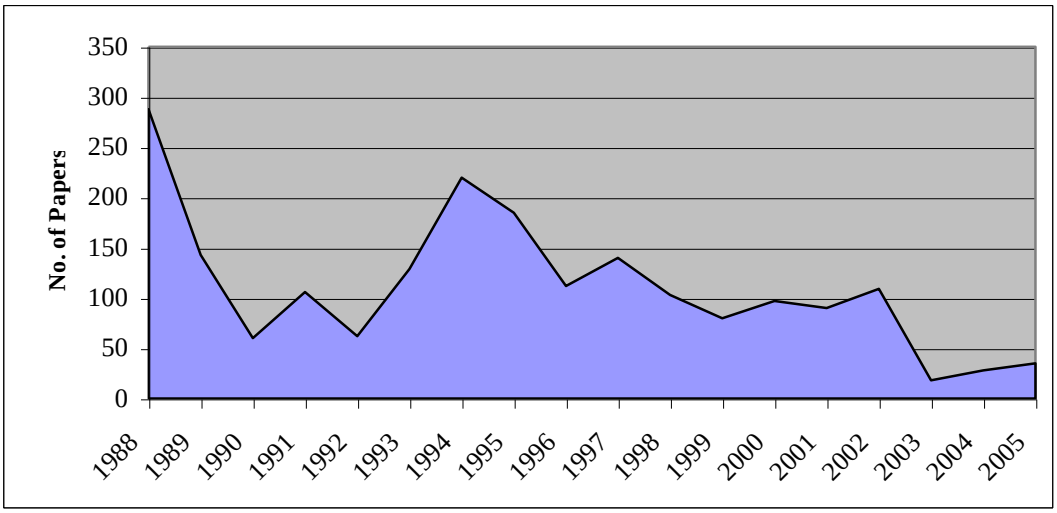


Figure 16. Conference Proceedings: Yearwise

6.4 Summary

It is also interesting to note that only about 5.72% of literature was covered under summary. An analysis of the summary of the articles indicated that the highest number (151) was published in the year 1994 (**Figure 17**). In 2004 there has been any publication and in the year 1990, only 5 has been encountered.

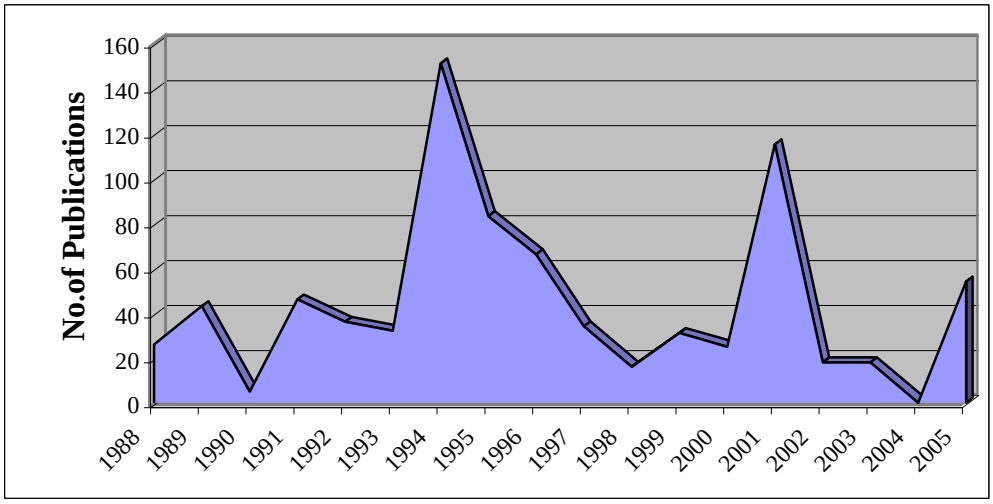


Figure 17 - Summary: yearwise

6.5 Book

A total of 745 (5.33%) articles of books and book chapters were published by the scientist. In 1997, the highest contribution of 12.22% was found and very few publication in books appeared in 2003 and 2004 with 0.8% each. Another interesting feature was noted from the study that a book was found in almost all the years of the study **(Figure 18)**.

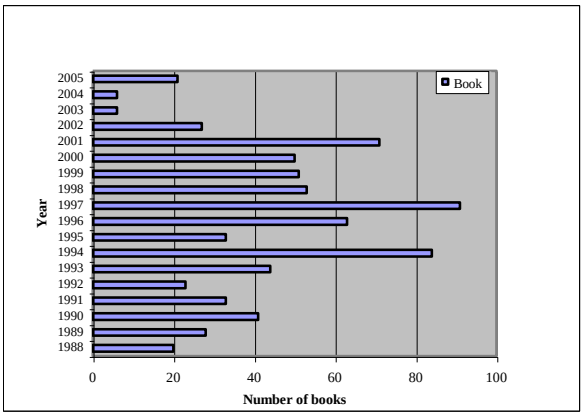


Figure 18 - Year wise distribution of Book

6.6 Technical Reports

Technical reports and non-conventional literature comprised about 262 (1.82%) (**Figure 19**). The performance of scientific communities was seen in this study on technical reports distributed all over the years with 1.88%. In 1997, the researcher published the highest number 30, 1998 with 28 articles followed by 21 each for 1999 and 2000. In the year 2003, only 2 reports were indexed.

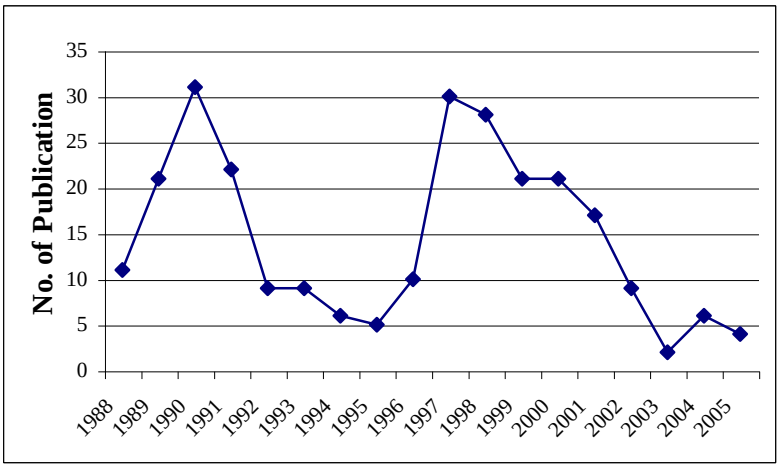


Figure 19. Report: Yearwise

6.7 Review Articles

Figure 20 shows that the scientists contributed 1.07% of the review articles on books and journal articles on coral reef research. The annual contribution for review articles has been taken for analysis. It reflected in the high frequencies in the year 1988 with 26. In 2004, there was no review article. This indicates the poor response of the scientists towards reviewing of reports.

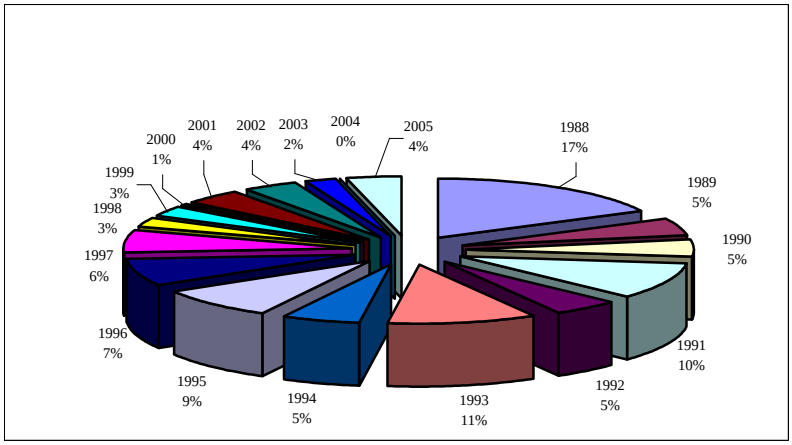


Figure 20. Review Article: Yearwise

6.8 Theses

It was observed that the year wise distribution of thesis used to be 1.26% of all the published reports. **Figure 21** shows the trend of contribution by thesis in the year 2002 with 17.61% by the scientists, followed by the year 1989 with 15.84%, in 1998 with 11.93% and 2005 with 7.39%. In the years 1993 and 2004 there was no thesis publication.

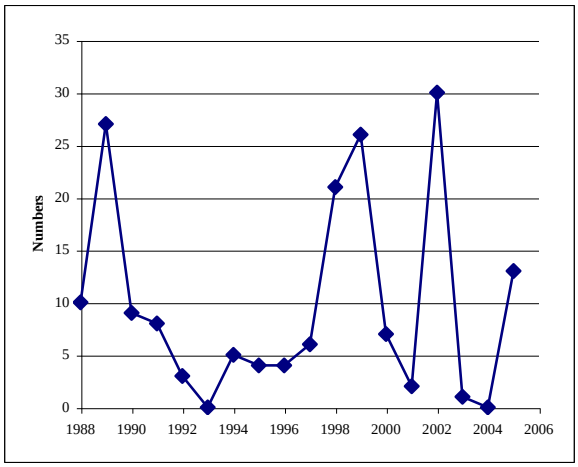


Figure 21. Theses: Yearwise

6.9 Other forms of communication

Bibliography

It is found that scientists have published the bibliography on coral reefs during all the years of the study with 1.12% of overall research output. **Figure 22** shows that the publication in the year 2001 with 19.75%. In the subsequent years sudden change has occurred in the trend with only 3.18% each in the years 2002 and 2003 and further decline response. In the year 2005 only one bibliographic report was published by a scientist.

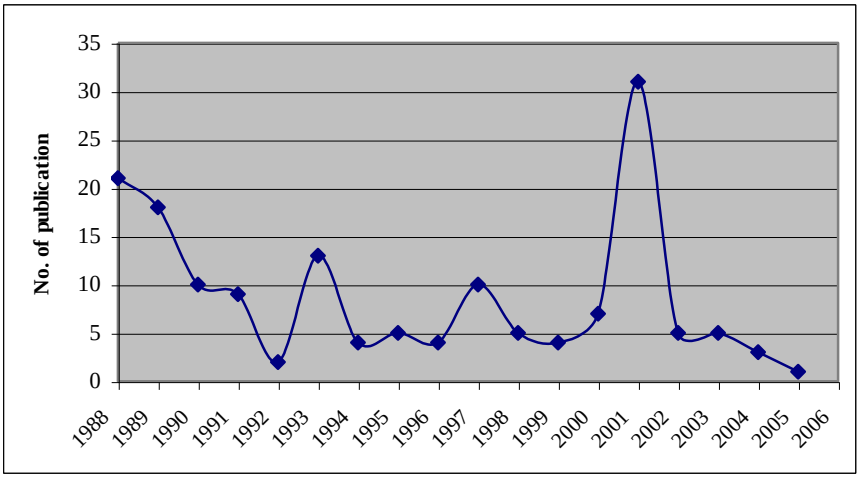


Figure 22. Bibliography: Yearwise

Numerical data

From the study it was observed during the study period the scientists have published numerical data with 0.54%. **Figure 23** depicts that in the year 1996 the scientists have contributed 12 numbers of the statistical data where as during the years between 2003 and 2005, there was no publication. The result indicated the

above observation and matched the types of publication trend analysis on MDS map (**Figure 14**).

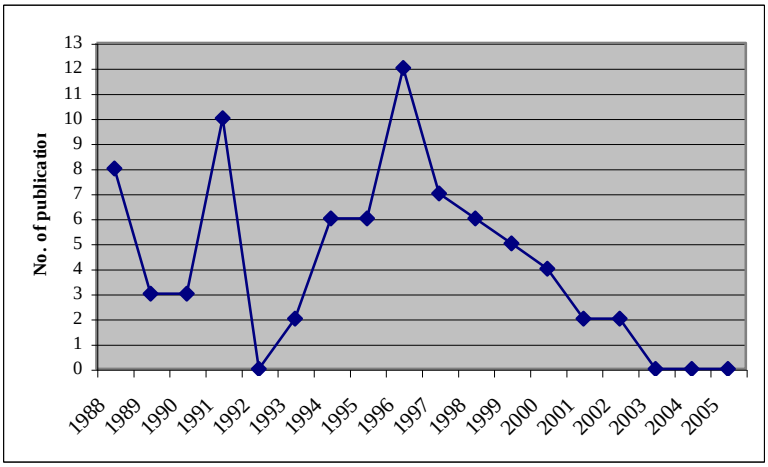


Figure 23. Numerical data: Yearwise

Dictionary

Figure 24 shows the dictionary article, that pursues a distinct pattern over the years with 0.14%. A closer look reveals that in the years 1988, 1991, 2001 to 2004 there were no articles. In 1989, 1992, 1994, 1998-2000 and 2005 a single article each was published. In the years 1990 and 1995 it was 2 articles and three articles each for the years 1993, 1996 and 1997. It also matches with the results of **Figure 14**.

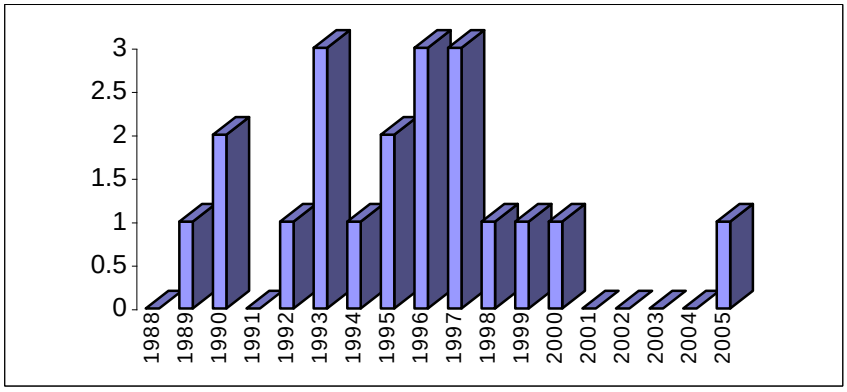


Figure 24. Dictionary: Yearwise

Standard

Figure 25 presents the scientists' contribution for over all study period, with a total of 16 (0.11%) articles published. It is seen that only in the years 1992 and 2004 the articles on standards have been published with 1 and 15 articles respectively. The result also matches with **figure 14**.

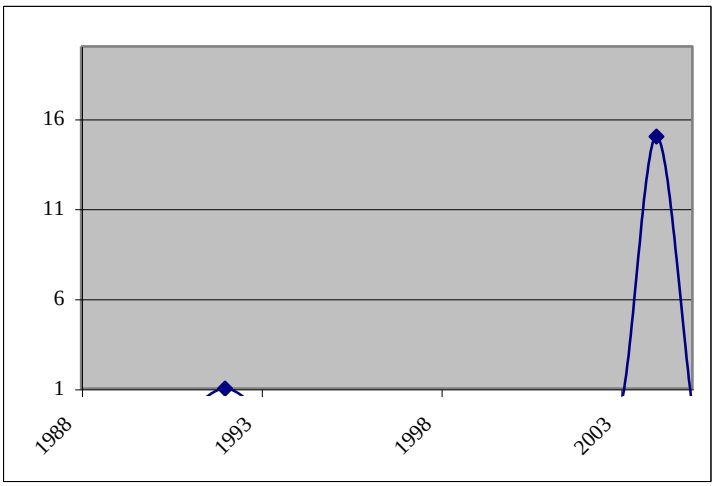


Figure 25. Standard: Yearwise

Patent

It has been observed that the patent publication was poor with 0.07% was published during the study period. It is observed from the year wise distribution of the patent publications that the scientists have published only during six years (**Figure 26**). It also noted that in 1998, 4 patents have been published, in the year 2004, 2 patents, in the years 1990, 1991, 1997 and 2000, one each of the patent published.

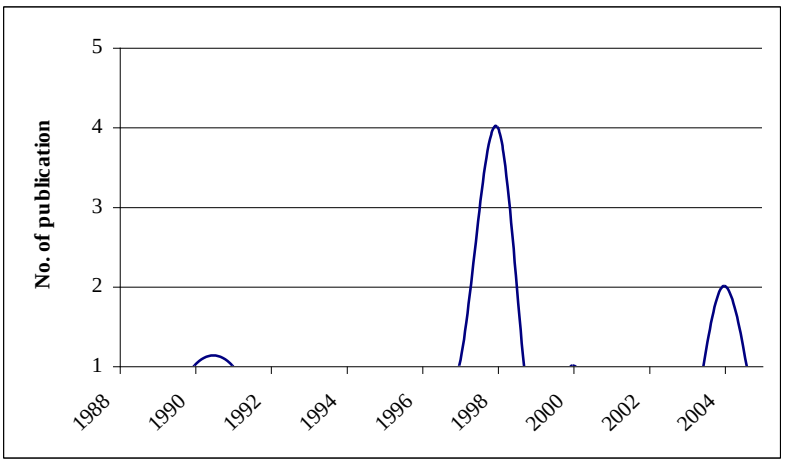


Figure 26 - Patent:Yearwise

Manual

'Training Manual' for technical and non-technical people on coral reef ecosystem (**Fig. 27**), Maps on coral reef distribution and their management and finally Digitized information (Computer) on coral reef are found in literature.

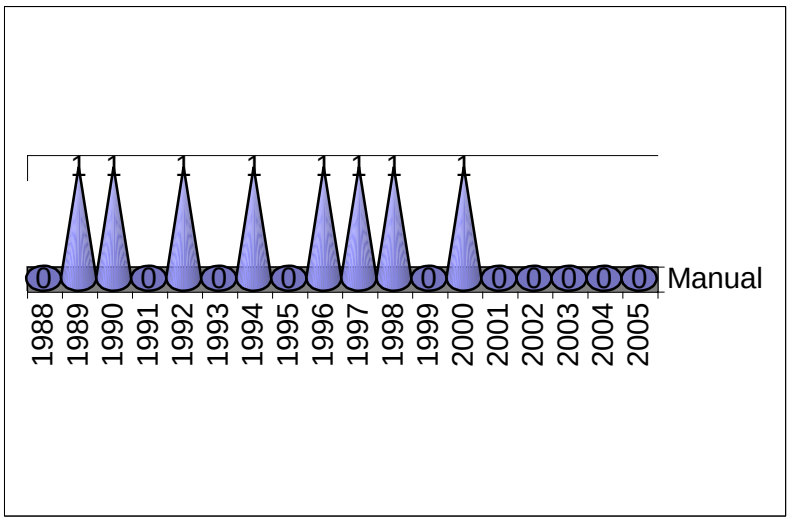


Figure 27. Manual: Year wise

7. SERIALS TREND IN CORAL REEF RESEARCH

An attempt has been made in this analysis to determine the serials preferred by the coral reef researchers during 1988 to 2005. As it has often been demonstrated, bibliometric distributions are generally skewed, presenting a set of a small number of highly used journals and a large number of lesser-used ones (Bradford's Law).

7.1 Journals Vs Number of Papers

The observation on the Bradford's bibliographs (Figure 28) plotted curve-using number of journals versus the cumulative number of papers. It depicts that the 9548 journal articles were found scattered in 812 different periodicals. In 1997, there were 294 journals used by the scientists to publish 603 papers. In 1988

they used 130 journals to publish 312 papers. In 2004, published 861 papers with 181 journals. Only 293 papers published in 1989 with 144 journals.

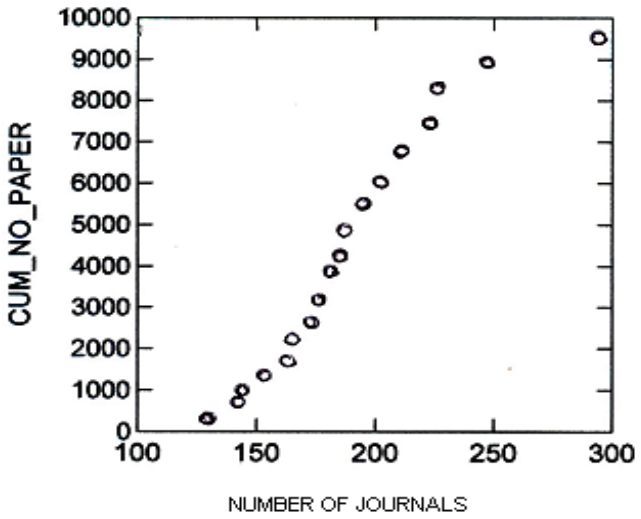


Figure 28. Number of Journals Vs Cumulative No. of Papers during 1988-2005

7.2 Application of Bradford's Law of Scattering

Table 10 revealed that scattering of the periodicals by applying the Bradford's Law. It gives the results as 1.23% of the journals take the first one third i.e. 34.43 % of total articles published, 8.37 % of the journals take the next one third i.e. 33.47% and 90.40% of the journals retain the last one third with 32.10%. It is greater than the value reported by Bradford.

Table 10. Application of Bradford's Law of Scattering

ZONES	NO. OF JOURNALS	PERCENTAGE	NO.OF PAPERS	PERCENTAGE
I	10	**1.23**	3287	**34.43**
II	68	**8.37**	3196	**33.47**
III	734	**90.40**	3065	**32.10**
	812	**100**	**9548**	**100**

7.3 Core journals in the field of coral reefs

Table 11 reveals that Science Citation Index (SCI) has covered a set of 10 core journals accounting for over 34.43% of the total articles in which authors with a global level affiliations have published their results. It was found that 84.24% of the articles of the complete data set (Annexure-3) had been published by 498 journals covered by SCI as seen from JCR 2005 and 15.26% of the articles published by 314 journals (Annexure –4) which were either not indexed in SCI or had been assigned an impact factor of zero where grouped under Non-SCI journals (**Figure 29**).

Table 11. List of core journals in the field of coral reefs

No.of Articles Published	CORE JOURNALS	Impact Factor JCR 2005
682	Coral Reefs	1.25
637	Mar.-Ecol.-Prog.-Ser	1.81
430	Bull.-Mar.-Sci.	0.62
391	Mar.-Biol.	1.45
316	J. Exp.-Mar.-Biol.-Ecol.	1.29
210	J. Shellfish-Res.	0.74
186	Mar.-Pollut.-Bull.	1.26
154	Environ.-Biol.-Fish.	0.79
142	Palaeogeogr.,-Palaeoclimatol.,-Palaeoecol.	0.99
139	J. Natural-Products	1.18

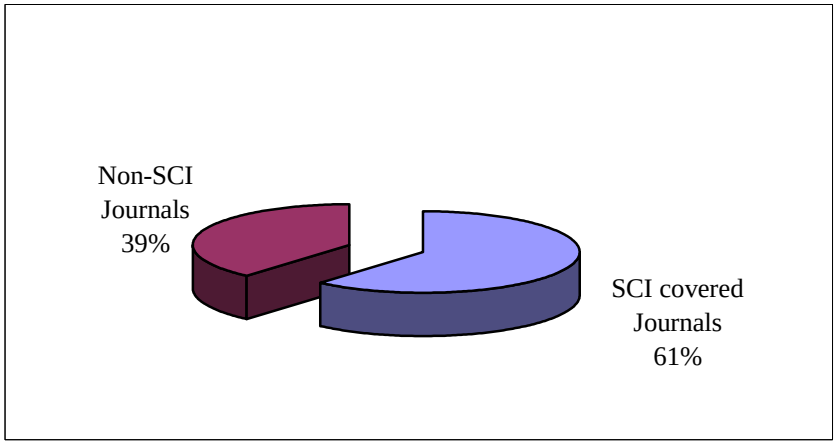


Figure 29. Article Published in SCI Covered and Non-SCI Journals

7.4 Impact Factor Range of Journals

The 812 journals in which coral reef researchers have published their work have been classified under the different impact factor ranges of journals, as seen from JCR 2005 (**Table 12**). Over 84.24% of papers have appeared in 498 journals

indexed in SCI with impact factor. The most often used journal '*Coral reef*' has been assigned impact factor value 1.25. About 73.33% of the papers published by coral reef researchers have appeared in journal impact factor less than 2.0. Only 899 papers (9.41%) have appeared in journal impact factor grater than 2.0. Only 2 journals namely, *Chemical review* and *Lancet* have appeared the impact value 12.17 and 12.32 respectively. The journals 'science' and 'nature' have published 95 and 79 papers each and these two journals have appeared impact value greater than 14.0.

Table 12. Distribution of coral reef literature by Impact Factor range of Journals (Based on impact factor data from JCR 2005)

Impact Factor Range	No. of Journals	Percentage	No. of Papers	Percentage
0.00	314	38.67	1457	15.26
> 0.0 - ≤ 0.5	134	16.5	1148	12.02
>0.5 - ≤ 1.0	150	18.47	2496	26.14
>1.0 - ≤ 1.5	95	11.70	2445	25.62
>1.5 - ≤ 2.0	47	5.79	1103	11.55
>2.0 - ≤ 2.5	17	2.09	250	2.62
>2.5 - ≤ 3.0	16	1.97	252	2.64
>3.0 - ≤ 3.5	11	1.36	135	1.41
>3.5 - ≤ 4.0	6	0.74	9	0.09
>4.0 - ≤ 4.5	7	0.86	35	0.37
>4.5 - ≤ 5.0	4	0.50	25	0.26
>5.0 - ≤ 5.5	4	0.50	4	0.04
>5.5 - ≤ 6.0	1	0.12	1	0.01
>6.5 - ≤ 7.0	1	0.12	8	0.08
>7.0 - ≤ 7.5	1	0.12	4	0.04
>12.0 - ≤ 12.5	2	0.25	2	0.02
>14.5 - ≤ 15.0	1	0.12	95	1.00
>16.0 - ≤ 16.5	1	0.12	79	0.83
Total	**812**	**100**	**9548**	**100**

7.5 Journal Ranking

Table 13 shows the overall ranking of journals based on their productivity count and their corresponding percentage. Among 812 journals involved in the present study, the journal ' *Coral reef*' ranked first with an output of 682 papers, which contributed 7.14% of the total periodical literature output. Second came '*Marine Ecology Progressive Series*' with 6.67 % of the total journal articles. The third, fourth, and fifth in the ranked list were '*Bulletin of Marine Science'*, '*Marine Biology*', and '*Journal of Marine Biology and Ecology*' with the percentage contributions of 4.5, 4.1, and 3.31 respectively. It was interesting to note that the multidisciplinary journals such as '*Science*' (IF value 14.68) and '*Nature*' (IF value 16.07) had 16th and 19th rank based on their output of 95 and 79 papers respectively. The impact value of the above journals indicated here was no way related to the present ranking. Distribution pattern of total number of journals covered under the study period is more and the journals having the same rank beyond 30 are also more as shown in **Table 14.** .

Table 13. Overall Journal Ranking list

Name of the Journals	No. of Papers
Coral Reefs	682
Mar.-Ecol.-Prog.-Ser	637
Bull.-Mar.-Sci.	430
Mar.-Biol.	391
J. Exp.-Mar.-Biol.-Ecol.	316
J. Shellfish-Res.	210
Mar.-Pollut.-Bull.	186
Environ.-Biol.-Fish.	154
Palaeogeogr.,-Palaeoclimatol.,-Palaeoecol.	142
J. Natural-Products [Journal Ofnat-Prod]	139
Pac.-Sci.	134
Limnol.-Oceanogr.	128
Sediment.-Geol.	125
Mar.-Geol.	116
Hydrobiologia	105
Science (Wash.)	95
Atoll Research Bulletin [Atoll Res. Bull.].	82
Rev.-Biol.-Trop.	82
Nature	79
J. Coastal-Research [Journal Ofcoast-Res]	71
Ecology	69
J. Fish-Biol.	69
Biol. Bull. Mar. Biol. Lab. Woods Hole	66
Estuar.-Coast.-Shelf-Sci.	64
Geology	63
ICES-Journal-Of-Marine-Science [ICES-J-Mar-Sci]	61
J. Paleontology [Journal Ofpaleontol]	61
J. Phycology [Journal Ofphycol]	58
Mar.-Freshwat.-Res	57
Oecologia	53

Fish.-Bull.	48
Paleoceanography	47
Ambio.	44
Copeia	44
Indian J. Chem. (B Org. Med.)	44
J. Mar.-Biol.-Assoc.-U.K.	43
Aust.-J.-Mar.-Freshwat.-Res.	41
Biol.-Mar.-Mediterr.	40
J. Natural-History [Journal Ofnat-Hist]	40
Cont-Shelf-Res	38
Aquat. Conserv.: Mar. Freshwat. Ecosyst.	37
Ocean Coast. Manage.	37
Aust.-J.-Ecol.	35
Indian J. Mar. Sci.	35

Table 14. Distribution pattern of Journal Articles

No. of Journals	Freq	Total No. of Papers	Percentage	Cumulative Percentage
1	682	682	7.14	7.14
1	637	637	6.67	13.81
1	430	430	4.5	18.31
1	391	391	4.1	22.41
1	316	316	3.31	25.72
1	210	210	2.2	27.92
1	186	186	1.95	29.87
1	154	154	1.61	31.48
1	142	142	1.49	32.97
1	139	139	1.46	34.43
1	134	134	1.4	35.83
1	128	128	1.34	37.17
1	125	125	1.31	38.48
1	116	116	1.21	39.69
1	105	105	1.09	40.78
1	95	95	0.99	41.77
2	82	164	1.72	43.49
1	79	79	0.83	44.32
1	71	71	0.74	45.06
2	69	138	1.45	46.51
1	66	66	0.69	47.2
1	64	64	0.67	47.87
1	63	63	0.66	48.53
2	61	122	1.28	49.81
1	58	58	0.6	50.41
1	57	57	0.6	51.01
1	53	53	0.56	51.57
1	48	48	0.5	52.07
1	47	47	0.49	52.56
3	44	132	1.38	53.94
1	43	43	0.45	54.39
1	41	41	0.43	54.82
2	40	80	0.84	55.66
1	39	39	0.41	56.07
1	38	38	0.4	56.47
2	37	74	0.78	57.25
5	35	175	1.83	59.08

3	34	102	1.07	60.15
2	32	64	0.67	60.82
5	31	155	1.62	62.44
1	30	30	0.31	62.75
3	29	87	0.91	63.66
2	28	56	0.59	64.25
2	27	54	0.57	64.82
5	25	125	1.31	66.13
7	24	168	1.76	67.89
3	23	69	0.72	68.61
5	22	110	1.15	69.76
1	21	21	0.22	69.98
7	20	140	1.47	71.45
4	19	76	0.79	72.24
3	18	54	0.57	72.81
9	17	153	1.6	74.41
7	16	112	1.18	75.59
5	15	75	0.8	76.39
6	14	84	0.88	77.27
13	13	169	1.77	79.04
7	12	84	0.88	79.92
5	11	55	0.58	80.5
11	10	110	1.15	81.65
17	9	153	1.6	83.25
22	8	176	1.84	85.09
19	7	133	1.39	86.48
34	6	204	2.14	88.62
39	5	195	2.04	90.66
47	4	188	1.97	92.63
52	3	156	1.63	94.26
130	2	260	2.72	96.98
288	1	288	3.02	.....
812		**9548**	**100**	**100**

8. INSTITUTION WISE DISPERSION OF PUBLICATIONS

In all, 13982 research papers were published during 1988 – 2005 by the different institutions at global level. Of these 1071 records i.e. 7.66% the author's affiliation were not displayed and these were not included for this analysis. **Figure 30** shows that during the 18 years study period 12,792 coral reef related articles were published from 5714 institutions consisting of academic, government, government funded research laboratories and 119 papers published by 80 home addresses i.e. others. The contributions from 3391 academic institutions consisting of general colleges, universities, engineering and fisheries colleges have published 7406 papers, 2186 research institutions under different countries have contributed 5191 papers. It resulted that academic institutions contributed more number of papers then research institutions.

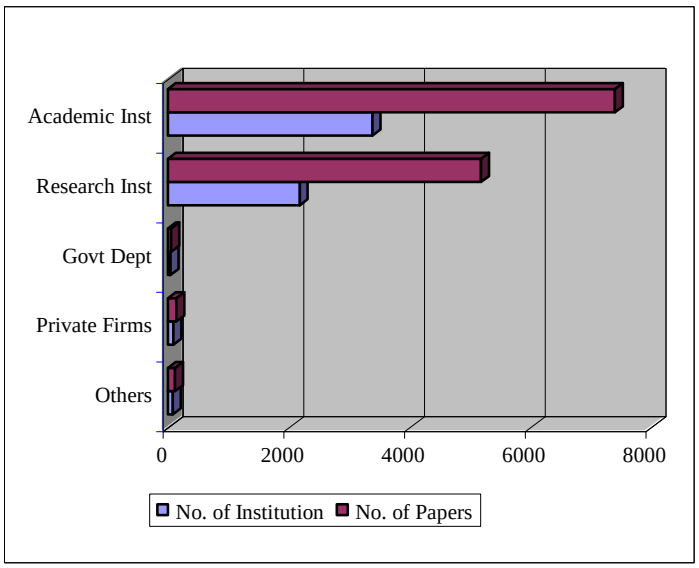


Figure 30. Institution wise distribution of coral reef litearture 1988-2005

The **Table 15** indicated that top 20 institutions include 9 academic institutions. The most prolific contributors are the Australia-based Australian Institute of Marine Science (AIMS) and James Cook University, followed by the ORSTOM (Institute of French Research and Scientific Development Cooperation, France).

Table 15. Global level TOP 20 Institutions publishing papers

RANK	No. of Papers	INSTITUTIONS
1	334	Australian Institute of Marine, Science, Townsville, Queensland, Australia
2	132	Dept. Marine Biology, James Cook University, Townsville, Australia
3	90	ORSTOM (Inst. Fr. Rech. Sci. Dev. Coop.) 213, Paris, France
4	86	South Chinese Sea Institute of Oceanology, Chinese Acad. Sciences, China
5	74	NOAA-Natl. Mar. Fish. Serv., Beaufort Lab., 101 Pivers Island Rd., USA
5	74	Rosenstiel Sch. Mar. & Atmos. Sci., Div. Mar. Biol. and Fish.,Univ. Miami,USA
6	68	Smithsonian Tropical Research Institute, Unit 0948 USA,
7	65	School of Marine Biology and Aquaculture, James Cook University, Australia
8	62	National Institute of Oceanography (NIO), Goa , India
9	58	Central Marine Fisheries Research Institute, Cochin 682 014 India
10	57	Great Barrier Reef Marine Park Authority, Townsville, Qld. Australia
11	54	CSIRO, Australia
12	47	ICLARM-The World Fish Center, PO Box 500, GPO, 10670 Penang, Malaysia
13	41	Dept. Biol. Sci., State University of New York, Buffalo, New York 14260, USA
14	38	Obs. Oceanol. Eur., Cent. Sci. Monaco, Ave. Saint Martin, Monaco
15	37	Kenya Mar. and Fish. Res. Inst., Mombasa Lab., , Mombasa, Kenya
16	35	Virginia Institute of Marine Science, The College of William and Mary, USA
17	32	Ecole Pratique des Hautes Etudes - URA CNRS 1453, Univ. de Perpignan,France
17	32	Neth. Inst. Sea Res. (NIOZ), PO Box 59, 1790 AB Den Burg, Texel, Netherlands
17	32	Scripps Institution of Oceanography, Univ. California-San Diego,

		California , USA
18	31	Mar. Sci. Inst., Univ. Philippines, 1101 Diliman, Quezon City, Philippines
19	30	Institute of Marine Sciences, University of Dar es Salaam, Zanzibar, Tanzania
20	30	School of Biol. Sci. A 12, Univ. Sydney, Sydney, N.S.W. 2006, Australia
21	29	Dept. Zoology, Faculty of Life Sciences ,Tel Aviv University, Israel

9. SENGUPTA'S LAW OF BIBLIOMETRICS

Table 14 shows that 812 journals have produced 9548 papers on Coral reef literature out of them, 31 journals have published 52% of the total output. 288 journals constituting from the distant of the field produced single article each amounting to 3.02% of the total. These results are in conformity with **Sengupta**'s (**1974**) law, which states, "During phases of rapid growth of a scientific discipline, the small group of journals accounting for the larger part of the significant literature of the subject lie as a relatively high proportion of unrelated journals".

10. STATISTICAL ANALYSIS

10.1 Spearman Correlation Coefficients

Correlation coefficient is to determine the relation among the publications out put from selected countries by pairing the consecutive years. To identify the correlation coefficient for the period of six years each i.e. 1988-1993; 1994-1999; and 2000-2005 top 50 countries were selected and ranked using Spearman rank correlation through the SAS system. 64 countries were enlisted for selecting the top 50 countries in each set of period.

The **Table 16** represents that the highest correlation in during the period 1994-1999. It means that during these time periods there is a consistency in the amount of literature produced. On the other hand, the lowest correlation coefficient is found during 1988 and 1993, which shows a greater discrepancy in the amount of literature produced in that period.

Table 16 – Spearman Correlation coefficients

PERIODS	**1988-1993**	**1994-1999**	**2000- 2005**
1988-1993	1.00000	0.73185 <.0001	0.64639 <.0001
1994-1999	0.73185 <.0001	1.00000	0.83426 <.0001
2000-2005	0.64639 <.0001	0.83426 <.0001	1.00000

N=64; Prob > [r] under HO: Rho=0

Hypothesis tested

Table 17 and **18** reports the illustration of hypothesis by ANOVA. It shows that the calculated value of F is greater than that of F crit value. As per the first hypothesis, the growth rate of coral reef literature significantly varies geographically and chronologically is valid as revealed from the above results.

Table 17 Significant test on First Hypothesis

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Rows	1122491	48	23385.24	303.3697	0	1.373593
Columns	7551.791	17	444.223	5.762772	1.49E-12	1.6353
Error	62901.32	816	77.08495			
Total	1192944	881				

Table 18 Significant test on First Hypothesis

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Rows	721104.6	7	103014.9	333.0697	5.34E-75	2.087429
Columns	12423.56	17	730.7974	2.362827	0.003682	1.709271
Error	36805.44	119	309.2894			
Total	770333.6	143				

The second hypothesis is that there is a significant variation in languages in which maximum numbers of articles are published. This is valid for the result of ANOVA with $p<0.05$. But there was no such difference between the years (ANOVA; $p>0.05$) (**Table 19**)

Table 19 Statistical Test on Second Hypothesis

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Rows	8631510	24	359646.2	353.237	5.8E-256	1.544088
Columns	18037.7	17	1061.041	1.042132	0.410662	1.647855
Error	415402.9	408	1018.144			
Total	9064950	449				

The third hypothesis is that there has been an increasing trend in collaborative research and it is valid for the results of Subramanian's degree of collaboration test (Chap. 4.5.3) and with the ANOVA; $p<0.05$ (**Table 20**).

Table 20 Statistical Test on third Hypothesis

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Rows	634652.8	5	126930.6	97.00981	1.29E-33	2.321812
Columns	72609.33	17	4271.137	3.264322	0.000158	1.744297
Error	111216.6	85	1308.43			
Total	818478.7	107				

The fourth hypothesis is that there is an implication of Lotka's Law related to author productivity in coral reef research. In this study (**Table 7**) the number of authors who contribute one paper will constitute the largest group with 89.53% (around 90%) of the total authors and the remaining authors with 10.47%. The Lotka's law states that "one paper will constitute around 60% of the total author". The hypothesis is rejected. The results have been shown to be statistically significant.

The fifth hypothesis is that there is a significant difference between sources of publications. It is valid for the result of significant test ANOVA: $p<0.05$ (Hypothesis is rejected). But there is no such difference between the years (Hypothesis is accepted) ANOVA: $P>0.05$

Table 21 Statistical Test on fifth Hypothesis

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Rows	4639282	14	331377.3	144.872	8.3E-108	1.733522
Columns	30434.17	17	1790.245	0.782662	0.712449	1.665843
Error	544396.4	238	2287.38			
Total	5214112	269				

Statistical analysis indicates the significant difference between institutions when ANOVA; $p<0.05$. But there is no such significant differences between years when ANOVA $p>0.05$.

Comparison of publications reveals the relative emphasis has been placed on different aspects of marine science information for coral reef literature. The statistical analysis indicates that there is

a significant level of variations in literature output in various branches of Science and Technology ANOVA: $p<0.05$ (**Table 22**).

Table 22 Statistical Test on seventh Hypothesis

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Rows	1693905	13	130300.4	266.2567	5E-127	1.764654
Columns	32713.65	17	1924.332	3.932195	9.28E-07	1.669171
Error	108152.7	221	489.3787			
Total	1834771	251				

The eighth hypothesis is that there is significantly difference between the means of the literature output among the countries and subject wise research is valid for the ANOVA test $p<0.05$ (**Table 23**).

Table 23 Statistical Test on eighth Hypothesis

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Rows	1447013	49	29530.87	4.854098	1.05E-21	1.374262
Columns	509656.1	13	39204.31	6.444157	1.45E-11	1.735529
Error	3875317	637	6083.7			
Total	5831985	699				

Comparing the impact factor of the journals, (**Table 11 & 12**) there was a considerable variation in impact factor (JCR 2005) among the journals which publish coral reef research work. The present study reveals that the 'core journals' of coral reef research have impact factor (IF) less than 2.0. The most often used journal, 'Coral Reef" has the IF of 1.25. About 73.33% of the papers published by coral reef researchers have appeared in journals with impact factor less than 2.0. Only 9.41% have appeared in journal with impact factor grater than 2.0. However the multidisciplinary

journals of "*Science*' and '*Nature*' has impact value grater than 14.0.

Sl. No.	Sources	YEAR																	
		1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	Total
1	**Bibliography**	21	18	10	9	2	13	4	5	4	10	5	4	7	31	5	5	3	1	**157**
2	**Book**	20	28	41	33	23	44	84	33	63	91	53	51	50	71	27	6	6	21	**745**
3	**Conf. Proceedings**	288	143	60	106	62	129	220	185	112	140	103	80	97	90	109	18	28	35	**2005**
4	**Dictionary**	0	1	2	0	1	3	1	2	3	3	1	1	1	0	0	0	0	1	**20**
5	**Journal Article**	312	293	354	387	397	352	422	538	530	603	655	642	630	744	610	506	861	712	**9548**
6	**Manual**	0	1	1	0	1	0	1	0	1	1	1	0	1	0	0	0	0	0	**8**
7	**Numerical data**	8	3	3	10	0	2	6	6	12	7	6	5	4	2	2	0	0	0	**76**
8	**Patent**	0	0	1	1	0	0	0	0	0	1	4	0	1	0	0	0	2	0	**10**
9	**Report**	11	21	31	22	9	9	6	5	10	30	28	21	21	17	9	2	6	4	**262**
10	**Review Article**	26	7	7	15	7	16	8	13	11	9	4	4	1	6	6	3	0	6	**149**
11	**Standard**	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	15	0	**16**
12	**Summary**	26	43	5	46	36	32	151	83	66	34	16	31	25	115	18	18	0	54	**799**
13	**Thesis**	10	27	9	8	3	0	5	4	4	6	21	26	7	2	30	1	0	13	**176**
14	**Computer**	0	0	0	0	0	0	0	0	1	2	0	0	0	0	0	0	0	0	**3**
15	**Map**	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	1	0	**3**
	Total	**722**	**585**	**524**	**637**	**542**	**600**	**908**	**874**	**817**	**937**	**897**	**867**	**845**	**1078**	**816**	**559**	**922**	**847**	**13977**

CHAPTER 5

Discussion

The conclusion from Chapter 3 is that ASFA database source is technically feasible, provided that metadata include conference proceedings also. Based on the nature and quality of the relevant articles from the sources, duplicate data has been eliminated and relevant data have been extracted from the source in the hectic process of data collection.

This chapter discussed the accuracy of search strategy for downloading the relevant data. It is concluded that more work needs to be done in order to tackle this problem and thus further need to increase the accuracy of fields of search, fields and subfields was felt in the selected discipline.

As a Classical approach, the methodology applied in this study is the scientometric programme. The derived measures were used as scientometric indicator on the basics of Multivariable analysis components of Cluster Analysis and Multi Dimensional Scaling (MDS). Adequacy of coverage of the source of publication database is a crucial issue. The literature on coral reefs published globally and covered by ASFA database during the time period 1988-2005, has been used for analysis.

Discussion of Preliminary results

In this study, the methodology is mostly same as that used in many other studies of scientific research performance. The principal difference is that the current study has expanded with ASFA database with main focus on exploratory studies. The application of scientometric indicators is experimental with the assumption that the publication database and methodology provide a valid reflection of the research performance in marine science, especially in coral reefs; tentative conclusion can be drawn from the following analyses:

Focusing on the trends of coral reef research productivity during 1988-2005, the out come shows that in 2001, the impact of the coral reef research productivity has significantly crossed the world average. The growth rate of coral reef literature during this period was not stable and recorded an all time high in the year 2001. The impact of literature published in later years was higher than that of articles published in 2003.

Section 4.2 shows that number of languages has also increased substantially with about 40 languages for research reporting as have been reflected from the ASFA database. Figure 6 shows the cluster analysis based on the pattern similarity (correlation) for 25 languages, performed for the annual frequencies. From the output of a Cluster Analysis a total of three

clusters (3 languages) can be identified, with first being English. It has been foundout that as the English is the official scientific language in many countries, it leads to its wide usage in dissemination of scientific output.

From the country wise publications, for the period (1988-2005) it was found out that the 142 countries, out of which 31 countries had contributed single publication accounting 0.24%, had made contribution. 46 countries have published 192 (1.49%) reports. 15 countries with 218 articles (1.69%), 92 countries with 441 publications (3.42%). First 50 countries have contributed 12470 publications (96.58%), which have been taken for Multi Dimensional Scaling technique analysis. **Figure 7** indicated the performance made by the countries with close similarity but Australia and USA being aloof.

The hierarchical agglomerative clustering approach was used for the top 10 countries. The Figure 8 indicates the overwhelming volume churned out by USA and Australia during the period of observation. In order to verify the observed results attempt has been made to find out the G8 countries productivity using MDS techniques. The Figure 9 shows that USA is the coherent one emerging with predominant distance with the highest productivity over the study period.

Subject wise distribution of coral reef literature

Analysis of the distribution of coral reef literature in subject wise manner they have both advantages and disadvantages depending on the aims of the study. Advantage is its capacity to offer a useful overview of a scientific field, at an appropriate level of granularity.

In this study, the MDS map clearly denotes that ecology is dissimilar from 14 subjects. It shows that publications and research are mostly concentrated on ecological studies. The perusal further shows that the fisheries and biology are similar in dimension 1, although they are dissimilar in other dimensions. The other subjects Chemistry, Pollution, Biotechnology, Medicine, Management and Economics are grouped closely to each other.

MDS map of top 50 countries shows that ecology is more predominant than other subjects. Biology and Fisheries are seen to be more coherent, while Geology is left aloof. Rest of the subjects is grouped closely leaving little chance to notice the frequency pattern.

With the subject wise cluster analysis on for G8 countries, it has been found that Ecology is the coherent group with predominant frequencies. The second cluster is that of Biology and Fisheries. Other subjects form the third cluster with sub clusters. The results coincide with Figures 10 & 11, showing that Ecology is

not only the predominant when analysed for top 10 countries, but also with top 50 countries.

Hinze (1994) suggests that it is especially problematic to map highly multidisciplinary fields because of the disciplinary orientation of classification systems to cluster, both of which may result from the fact that controlled terms are largely defined with regard to the specialist terminologists of the disciplines towards which databases are oriented.

In the case of ASFA database, the ASFIS Thesaurus has assigned subject classification headings assumed to represent the main elements of a publication's content. Moreover, each heading is considered as an intellectual item in a systematic codification of knowledge. Usually, the headings are assigned to publications by professional indexers.

Author wise distribution

In the visibility analyses of present study, authors were ranked by the number of publications. Various methods of counting author's publications and citation have been developed and different counting methods are distinguished from each other by the way they treat multiple authorship how they allocate credit to scholars who co-author the publication. Theoretically, credit should be given for authors, according to their contribution to the paper. However, it is nearly impossible to assess the relative

contributions in co-authored papers based on the publicly available data like sequence of authors alone on the paper (Lindsey, 1982. Further evidence for adjusting for multiple authorship. *Scientometrics, 4,* 389-395.)

According to **Figure 13**, a single author contributed 29.21% out of 13764 publications while the rest of publications were contributed by multiple authors. This clearly reflects a trend towards multiauthorship pattern in the field. Such a trend may be attributed to the proliferation of subfields in the coral reef research and interdisciplinary nature.

The present study however took a simplified approach to fractional and complete count by taking six authored papers. It hoped that this approach would supplement sufficiently strict fractional and complete counts as publications with more than 6 authors were not expected to occur too frequently based on the analysis of present study.

Subramanian's formula has been applied and tested for the degree of collaboration in authors' productivity to know for the study period that coral reef research intends for collaborative research rather than 'Lone rangers'.

Lotka's law has been applied and verified to know scientific productivity of the authors in this study. 89.53% of authors contribute one paper constituting the largest group of the total

authors and the remaining authors are at ranks 2 to 12, consisting of 10.47% of 11,670 publications. It is also perceived that 1222 authors have contributed 3316 publications out of the total papers 13,764.

Source wise distribution

ASFA database covers more than 20 categories of source documents. For convenience, 15 categories have been taken as shown in Table 9 during 1988 to 2005. They depend upon what researchers include in their publication. For instance, evidence was obtained that the scientists in the journals publish 68.31% of the articles. The aforesaid MDS map on types of publication is taken into account to know that the researchers in the field of coral reef use different types of literature in which journal article clearly pursue a distinct pattern over the years. This observation also explains the researchers do publish 14.35% of articles in Conference Proceedings. A closer look reveals that book (5.33%) and summary articles (5.72%) exhibiting under current are placed in a separate quadrant while the reports (1.88%), thesis (1.26%), bibliography (1.12%), review article (1.04%), numerical data (0.54%), dictionary (0.14%), standard (0.11%) patents (0.07%), manuals (0.06%), computerized information (0.02%), and map (0.02%) were grouped in another quadrant as they are seen to be less important.

Though data on journal articles showed an increasing trend from 1988-2005, they fluctuate between the years 2001 and 2005, with their prolific nature.

Another interesting feature has been noted from the study that conference proceedings and summary of the journal articles are the two channels of communications, which appear during all the years of study. An analysis of the conference proceedings indicated the year 1988 to have the highest number of publications, leaving 2005 with only 35.

It is concluded that the researchers are more and more stimulated – if not forced – to create and apply quality standards. One way to come to such standards could be to identify particular publication source that can normally only enter if the work presented is of high quality and the ways peers evaluated the past performance of research groups.

Journals vs. Papers

The identified articles (9548) were published in 812 journals. Bradford's law of Scattering had employed to study the journal literature distribution and to identify the 'core' journals. By graphically describing the Scattering of articles of a specific field in different journals, it can be decided, what journals should be included in a collection to cover a specific percentage of the relevant article in coral reefs. **Figure 28** shows the Bradford's

bibliographs plot where the cumulative total publications have been plotted against the logarithm of the journals rank. On the plot the core journals are those points that lie on the initial curved part of the 'S' until the tangent becomes a strait line. For the field of coral reefs it was observed that the slope of the curve decreased slightly after the 16th journal indicating that these were well on their way to form the core group.

The core journals were identified as '*Coral reefs*', '*Marine Ecology and Progressive Series*', '*Bulletin of Marine Science*', '*Marine Biology*', *Journal of Experimental marine biology and ecology*', *Journal of shellfish research*', *Marine pollution bulletin'*, *Environmental biology of fishes*', *Palaeogeography*' and *Journal of Natural products'*. It is also important to note that the curve took a 'J' shape rather than a typical 'S' shape. There was no "cross droop" at the end. Brooks Theory explains this phenomenon where it was observed that first few papers on a subject were published in a few suitable journals. Gradually, journals shifted towards the subjects and with the development of the subject, a core set of journals developed. At the same time other journals also started to publish papers in that subject. It was interesting to note that the multidisciplinary journals such as 'Science' and 'Nature' had 16th and 19th rank based on their output of 95 and 79 papers respectively.

However, incase of coral reef literature, due to exponential growth of literature and shifting of more journals towards the subject, the Bradford curve has taken almost a linear shape after an initial rise.

FINDINGS AND CONCLUSION

The present study is " Mapping of coral reef research literature: a global perspective", includes mapping the literatures on coral reef drawn from ASFA database during the period from 1988-2005. This study identifies the quantitatively and qualitatively the contributions made by the scientists in the field on coral reef to fulfill the objectives of this study.

Coral reef research publication trends

The years 1994, 1997 and 2001 showed an increased number of publications compared to the output of the rest of the period. The Year 2002 is expected to have more productivity, but there was a sudden decline in productivity trend and the same trend followed in the year 2003 also. The productivity on coral reef has declined, equaling to the years 1990 and 1992. It seems that the Gulf war has caused this decline. In 2004, there was an improvement on publication productivity on coral reefs.

Country wise distribution of coral reef literature

Coral reefs composed of dead polyps cover about 2, 84, 300 Sq.Km. of the earth's surface and about 100 countries have coral reefs. Collaboration between the countries widens the scope to address the R & D. The mapping study finds 141 countries participating and contributing 13,982 papers.

The results showed the performance made by the countries with the USA and Australia being aloof and other countries clubbing closely in the MDS map. Based on the dissimilarities, it is found that the grouping of top 50, top 10 and G8 countries, USA is the coherent group emerging with predominant distance as this county has the higher productivity followed by Australia, France, Japan, UK, China, India, Canada, Germany and Israel. It is interesting with the group of top 10 countries except Australia, India and Israel, which belong to G8 countries and Italy being excluded from the group of top 10 countries. 31 countries have a single publication. 30 countries have the below 0.03% of the publication count with 80 publications.

Coral reef research productivity trend in India

India has contributed 397 papers with 2.88% of total output. India is one of the major top 10 countries on coral reef literature production, while globally the empirical relationship between the distributions of the coral reefs it is found to be 2.04% of the world total area and 10th largest reef nation in the world. The publication productivity is highly unevenly distributed. For some countries like USA, the literature productivity goes in excess of what could be the size of the reef areas.

Language wise distribution of publication

The distribution of coral reef literature includes 24 languages other than English. It is perceived that based on the cluster analysis, the English language has the camouflaging effect on the overall grouping scenario leaving the other languages masked. French and Chinese form a group and other languages formed the third cluster with sub clusters within them.

AUTHORSHIP PATTERN

Single authors Vs Multi-authorship Pattern

According to this study, a single author contribution is 29.21% of 13,764 while the other70.79 percent are the works of more than one person. More than 5% of the articles are published by six or more authors. One to three authors have produced more than 77.61% of the papers of the total and this proves that the theory of **Price (1976)**, who has connected the authors who produce at least half of the total papers. The authors' inflation is a more insidious problem because it is difficult to check the contributions of authors, but more stringent norms of authorship are needed.

It has significantly increased a trend towards multi-authorship pattern on coral reef research. Such a trend may be due to the proliferation of subfields in the multi-disciplinary

nature. The interdisciplinary nature of a field is one of the obvious reasons for collaborative research. In recent decades, there has been a gaining trend towards collaboration in research in almost all pure and applied sciences.

Among the multi-authorship pattern double authors find to be predominant while single authors' contribution show a declining trend from 1999 to 2005.

Degree of collaboration

Subramanian has deduced a formula for calculating the degree of collaboration. The analysis of the extent of collaboration of coral reef research depicts the following facts:

- Degree of collaboration had an initial value of 0.61% during the period 1988-1993. It increased to 0.69% in 1994-2000 and to 80% during the period 2001-2005.
- It revealed the declining of single author papers and on other hand increased multiple authorship patterns.
- It is evidenced that the scientist on coral reef research intended to take collaborative participations.

It is proved that the application of Subramanian's formula corroborated with the results obtained in this study.

Application of Lotka's law

It is revealed that author productivity is very essential in identifying the research performance of any area in Science. In this study, the number of authors who contribute one paper is highly predominant (89.53). Of the total authors, the remaining authors are at ranks at 2 to 12 consisting of 10.47% of 11,670. It is perceived that 1223 authors have contributed 3316 papers out of 13,764.

The results of this study so far as authors productivity is concerned, it is corroborated that of Lotka's finding and this group (one paper contributors) of authors constitutes excess amount of papers that the Lotka's findings.

Authors' Frequency

The study reveals that striking highly productive authors on coral reef research during the study period. The authors Humes,-A.G. (USA), Latypav,-Yu.Ya. (Russia) and Mueller,-H.G. (Germany) have contributed 15 articles each and most of them are from journals. Mostly, they contribute articles on Carcinology (Taxonomy and Morphology), Ecology and Biological studies of coral reefs.

The inference is the frequency of names of authors and the number of contributions is in reverse position.

Mapping sources of information

The channels used to communicate research on coral reef, resulted in 15 types of forms like bibliography, book, conference proceedings, journal article, dictionary, manual, numerical data, patent, report, review article, standard, summary, thesis, maps and digitized information. The aforesaid MDS map on the types of publications takes into account the fact that the researchers in the field of coral reef use different type of literature in which the journal article clearly pursued a distinct pattern over the years. Consistent performance has been seen in the case of conference proceedings. A closer look reveals that book and summary article exhibiting under current are placed in a separate quadrant while the review articles, manual, dictionary, patents, theses, numerical data, reports and standards are grouped in another quadrant.

An interesting trend has emerged from the analysis of serials used by the authors in their communication. In over all trend analysis of periodical literature, there is an increasing trend in output. In 2004, out of 9548, 9.02% of journal articles published by the scientist with 1st rank. Though data on journal articles showed an increasing trend from 1988-2005, with irregular ups and downs in between the trend for future periods commencing with 2005 it may be of prolific nature.

Another interesting feature noted from the study is that conference proceedings and summary of the journal articles (abstracts) can find these two channels of communication in almost all the years of the study.

It is resulted that communication is the exchange of information between individuals by means of a common signal system.

Subject wise distribution of coral reef literature

To analyse the distribution of coral reef literature subject wise, they have advantages and disadvantages depending on the aims of the study. Its great advantage is its capacity to offer a useful overview of a scientific field, at an appropriate level of granularity.

In this study, the MDS map is clearly denotes that Ecology is dissimilar from 14 subjects. It represents that publications and research are mostly concentrated on ecological studies of coral reef. The perusal further shows that the Fisheries and Biology are similar in dimension 1, although they are dissimilar in other dimensions. The other subjects Chemistry, Pollution, Biotechnology, Medicine, Management and Economics are grouped closely to each other.

The result is the same as that where in MDS map of top 50 countries, Ecology is seen to be more predominant than other subjects. Biology and Fisheries are seen to be more similar, while Geology is left aloof. All the other subjects are grouped closely leaving little chance to notice the frequency pattern.

With the cluster analysis on subject wise with in G8 countries, the cluster tree shows that Ecology is the coherent group with predominant frequencies. The second cluster is that of Biology and Fisheries. Other subjects' forms the third cluster has sub clusters. The results coincide with Figures 10 & 11, showing that Ecology is not only predominant when analysed in top 10 countries but also with top 50 countries.

Hinze, (1994) suggests that it is especially problematic to map highly multidisciplinary fields because of the disciplinary orientation of classification systems to cluster, both of which may result from the fact that controlled terms are largely defined with regard to the specialist terminologists of the disciplines towards which databases are oriented.

In the case of ASFA database, the ASFIS Thesaurus has assigned subject classification headings assumed to represent the main elements of a publication's content. Moreover, each heading is considered an intellectual item in a systematic codification of

knowledge. Usually, the headings are assigned to publications by professional indexers.

JOURNAL PRODUCTIVITY

Application of Bradford's law of scattering

The results as 10 journals with 1.23% take the first one third i.e. 34.43% of the total articles published, these journals have produced 3287 articles forming the first zone. The third zone contains large number (90.40%) of the journals published with 32.10%. It is grater than the value reported by Bradford.

It is seen that the third zone data set does not have characteristic Bradford plotted curve shape. Therefore, it needs further research to explain this exceptional data set.

Core journals

Science Citation Index has covered a set of 10 core journals accounting for over 34.43% of the total articles in which authors with a global level affiliation have published their results. Out of 812 periodicals, the journal '*Coral reef*', '*Marine Ecology Progressive Series*', '*Bulleting of Marine Science'* etc.

(**Table 11**) form a set of core journals.

Journal Ranking

It is noted that the journals '*Coral reef*', is ranked first with an output of 682 papers. Second comes '*Marine Ecology Progress*

Series' with 6.67% of the total journals articles. The third, fourth and fifth in the rank list are '*Bulletin of Marine Science*', '*Marine Biology and Ecology'*, with the percentage contribution of 4.5, 4.1, and 3.31 respectively. It was interesting to note that the multidisciplinary journals such as '*Science*' and '*Nature*' have 6th and 19th rank based on their output of 95 and 79 papers respectively.

The rank list of journals helps in identifying the literature of the scientists. The periodical acquisition could very well be planned using such rank list. They are the mirrors of the scientists' requirements. The acquisition policy should be based on the recent rank list as far as possible as the research areas keep changing. The need of the acquisition of core literature, of course does not change.

The rank list of serials preferred for communication gives an idea of the spread of literature. The large scatter, the more difficult it is to have a control on chalking out the current status or reviewing the progress.

Institution wise dispersion of coral reef literature

During the 18 years study period, 12,792 coral reef related articles have been published from 5714 institutions consisting of academic, government, government funded research laboratories and 119 papers published by 80 home addresses i.e. others. The

contributions from 3391 academic institutions consisting of general colleges, universities, engineering and fisheries colleges have published 7406 papers, 2186 research institutions under different countries have contributed 5191 papers. It resulted that academic institutions contribute more number of papers than research institutions.

The result perceived is that the top 20 institutions include 9 academic institutions. The most prolific contributors are the Australia-based Australian Institute of Marine Science (AIMS) and James Cook University, Australia and followed by the ORSTOM (Institute of French Research and Scientific Development Cooperation, France).

TRADITIONAL LAW OF BIBLIOMETRICS

Sengupta's Law of Bibliometrics

The study has analysed that 812 journals have produced 9548 papers on Coral reef literature; out of them, 31 journals have published 52% of the total output. 288 journals constituting from the distant of the field produced single article each amounting to 3.02% of the total. These results are in conformity with **Sengupta**'s (**1974**) law, which states, "During phases of rapid growth of a scientific discipline, the small group of journals accounting for the larger part of the significant literature of the subject lie as a relatively high proportion of unrelated journals".

STATISTICAL ANALYSIS

Spearman's Correlation Coefficients

Correlation coefficient is to determine the relation among the publication output from top 50 countries being selected and ranked using Spearman rank correlation through the SAS system. 64 countries have been enlisted for selecting the top 50 countries in each set of period.

The result depicts that the highest correlation is found during the period 1994-1999. It means that during this time period, there is a consistency in the amount of literature produced. On the other hand, the lowest correlation coefficient is found during 1988 and 1993, which shows a greater discrepancy in the amount of literature produced during that period.

Table 9 – Source wise distribution of publication

Sl. No.	Sources	YEAR																		
		1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	Total
1	**Bibliography**	21	18	10	9	2	13	4	5	4	10	5	4	7	31	5	5	3	1	**157**
2	**Book**	20	28	41	33	23	44	84	33	63	91	53	51	50	71	27	6	6	21	**745**
3	**Conf. Proceedings**	288	143	60	106	62	129	220	185	112	140	103	80	97	90	109	18	28	35	**2005**
4	**Dictionary**	0	1	2	0	1	3	1	2	3	3	1	1	1	0	0	0	0	1	**20**
5	**Journal Article**	312	293	354	387	397	352	422	538	530	603	655	642	630	744	610	506	861	712	**9548**
6	**Manual**	0	1	1	0	1	0	1	0	1	1	1	0	1	0	0	0	0	0	**8**
7	**Numerical data**	8	3	3	10	0	2	6	6	12	7	6	5	4	2	2	0	0	0	**76**
8	**Patent**	0	0	1	1	0	0	0	0	0	1	4	0	1	0	0	0	2	0	**10**
9	**Report**	11	21	31	22	9	9	6	5	10	30	28	21	21	17	9	2	6	4	**262**
10	**Review Article**	26	7	7	15	7	16	8	13	11	9	4	4	1	6	6	3	0	6	**149**
11	**Standard**	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	15	0	**16**
12	**Summary**	26	43	5	46	36	32	151	83	66	34	16	31	25	115	18	18	0	54	**799**
13	**Thesis**	10	27	9	8	3	0	5	4	4	6	21	26	7	2	30	1	0	13	**176**
14	**Computer**	0	0	0	0	0	0	0	0	1	2	0	0	0	0	0	0	0	0	**3**
15	**Map**	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	1	0	**3**
	Total	**722**	**585**	**524**	**637**	**542**	**600**	**908**	**874**	**817**	**937**	**897**	**867**	**845**	**1078**	**816**	**559**	**922**	**847**	**13977**

ANNEXURE - I

Full format of ASFA record

TI:	Copepods (Poecilostomatoida: Lichomolgidae) associated with the scleractinian coral Gardineroseris planulata in the Molluscs.
AU:	Humes,-A.G.
AF:	Boston Univ. Mar. Program, Mar. Biol. Lab., Woods Hole, MA 02543, USA
SO:	INVERTEBR.-TAXON. 1992. vol. 6, no. 2, pp. 303-335
PY:	1992
LA:	English
LS:	English
PT:	J (Journal-Article)
ER:	M (Marine)
AB:	Six new poecilostomatoid copepods associated with the scleractinian coral Gardineroseris planulata (Dana) at Poelau Gomumu in the Moluccas are described. These include include two new genera and species, Euxynus capulus and Moluccomolgus lordus , and four new species of the genus Paramolgus, P. angustus, P. eparmatoides, P. gibberulus , and P. setellus .
DE:	ISEW,-Indonesia,-Moluccas; coral-reefs; associated-species; Copepoda-; new-species; new-genera; Anthozoa-; Gardineroseris-planulata; Euxynus-capulus; Moluccomolgus-lordus; Paramolgus-; taxonomy-; animal-morphology
CL:	Carcinology:-Taxonomy-and-morphology-1283; Productivity,-Ecosystems,-Species-Interactions:-Species-interactions:-General-1483
JA:	ASFA --1:-Biological-Sciences-and-Living-Resources (Q1)
OZ:	Pacific-Southwest (ISEW)
IC:	CS9207412
AN:	2712224

ANNEXURE – II

Record of Conference Proceedings

TI: Reef fish monitoring and assessment at the Marine Resources Research Institute (MRRI)
AU: Sedberry,-G.R.; McGovern,-J.C.
AF: Mar. Resour. Res. Inst., Charleston, SC, USA
CO: A Coral Reef Symposium on Practical, Reliable, Low Cost Monitoring Methods for Assessing the Biota and Habitat Conditions of Coral Reefs, Annapolis, MD (USA), 26-27 Jan 1995
SO: A-CORAL-REEF-SYMPOSIUM-ON-PRACTICAL,-RELIABLE,-LOW-COST-MONITORING-METHODS-FOR-ASSESSING-THE-BIOTA-AND-HABITAT-CONDITIONS-OF-CORAL-REEFS. Crosby,-M.P.;Gibson,-G.R.;Potts,-K.W.-eds. 1995 vp
NT: Available at: http://www.epa.gov/OW/coral/sedberry.html (6 Nov 1996).
PY: 1995
LA: English
PT: B (Book); K (Conference)
ER: M (Marine)
AB: Methods used at the MRRI to assess and monitor stocks of reef fishes include a variety of removal and non-removal sampling techniques. A non-removal diver census of fishes inhabiting three habitats (backreef, reef crest/cut, and forereef) on the barrier reef and two offshore atolls of Belize indicated differences in relative abundance of dominant and economically valuable fishes among habitats and between marine reserve and unprotected areas. The forereef had the greatest number of species, but diversity (H') was highest in the cuts. Fish abundance was also greatest on the forereef. In atoll forereef and barrier reef cut habitats, individuals and species per observation were greater in protected areas, which also had greater abundances of commercially important fishes. Many herbivorous species were more abundant in unprotected areas, perhaps due to predator removal by fishing.

DE: coral-reefs; marine-ecology; reef-fish; population-number; species-diversity; commercial-species; habitat-; visual-inspection; tagging-; fishery-resources

CL: Population-studies:-Population-structure-1441
JA: ASFA-1:-Biological-Sciences-and-Living-Resources (Q1)
IC: NO9603393
AN: 3965020

ANNEXURE - III

No.of Articles Published	Science Citation Index covered Journals	Impact Factor JCR 2005
682	Coral Reefs	1.25
637	Mar.-Ecol.-Prog.-Ser	1.81
430	Bull.-Mar.-Sci.	0.62
391	Mar.-Biol.	1.45
316	J. Exp.-Mar.-Biol.-Ecol.	1.29
210	J. Shellfish-Res.	0.74
186	Mar.-Pollut.-Bull.	1.26
154	Environ.-Biol.-Fish.	0.79
142	Palaeogeogr.,-Palaeoclimatol.,-Palaeoecol.	0.99
139	J. Natural-Products	1.18
134	Pac.-Sci.	0.3
128	Limnol.-Oceanogr.	2.58
125	Sediment.-Geol.	0.74
116	Mar.-Geol.	1.19
105	Hydrobiologia	0.61
95	Science (Wash.)	14.68
82	Rev.-Biol.-Trop.	0.06
79	Nature	16.07
71	J. Coastal-Research	0.57
69	Ecology	2.48
69	J. Fish-Biol.	0.9
66	Biol. Bull. Mar. Biol. Lab. Woods Hole	1.6
64	Estuar.-Coast.-Shelf-Sci.	1.07
63	Geology	2.19
61	Ices-Journal-Of-Marine-Science	0.87
61	J. Paleontology	0.44
58	J. Phycology [Journal Ofphycol]	1.62
57	Mar.-Freshwat.-Res	0.62
53	Oecologia	1.54
48	Fish.-Bull.	0.62
47	Paleoceanography	3.49
44	Ambio.	0.96
44	Copeia	0.62
44	Indian J. Chem. (B Org. Med.)	0.32
43	J. Mar.-Biol.-Assoc.-U.K.	1.07

41	Aust.-J.-Mar.-Freshwat.-Res.	0.69
40	J. Natural-History [Journal Ofnat-Hist]	0.41
39	Earth And Planetary Science Letters [Earth Planet. Sci. Lett.].	2.8
37	Ocean Coast. Manage.	0.28
35	Aust.-J.-Ecol.	0.87
35	Geochim.-Cosmochim.-Acta	3.02
35	Indian Journal Of Marine Sciences [Indian J. Mar. Sci.].	0.1
35	Sedimentology	1.31
34	Botanica-Marina [Bot-Mar]	0.71
34	Cybium	0.3
34	J. Geophys.-Res.-C-Oceans	0.75
32	J. Sediment.-Petrol.	1.18
32	Toxicon	1.2
31	Am.-Zool.	2.4
31	Conserv-Biol	1.88
31	Geophys. Res. Lett.	2.42
31	J. Sediment.-Res.-A-Sediment.-Petrol.-Process.	1.12
31	Lethaia	0.77
30	Biol. Conserv.	0.77
29	Aquaculture	0.86
29	Zool.-Sci.	0.77
28	C.-R.-Acad.-Sci.-Ser.-2a-Sci.-Terre-Planet.-Earth-Planet.-Sci.	0.32
28	Oceanol.-Acta	0.88
25	Chem. Pharm. Bull. (Tokyo)	1.04
25	Deep Sea Res. (Pt I, Oceano. Res. Pap.)	1.7
25	Symbiosis	0.71
24	Coast. Manage.	0.25
24	Crustaceana	0.27
24	Curr-Sci	0.26
24	Evolution	2.54
24	Fish. Res.	0.31
24	Quatern.-Res.	1.79
23	Ichthyol.-Res.	0.37
23	J. Crust.-Biol.	0.71
22	Biol.-Morya-Mar.-Biol.	0.14
22	Cah.-Biol.-Mar.	0.31
21	Mar.-Ecol.	0.51
20	Appl. Environ. Microbiol.	2.56
20	Ecol.-Model.	0.6

20	Mar.-Technol.-Soc.-J.	0.17
20	Mol.-Ecol.	3.02
20	Palaeontology	0.75
20	Palaios	1.38
19	Mar.-Micropaleontol.	1.53
19	Mon.-Weather-Rev.	1.64
19	Sci. Marina	0.48
18	Can.-J.-Fish.-Aquat.-Sci.	1.49
17	Can.-J.-Zool.-J.-Can.-Zool.	0.82
17	Ecol.-Appl.	2.39
17	Int.-J.-Remote-Sens.	0.88
17	J. Biogeogr.	0.92
17	J. Exp.-Biol.	1.85
17	Mar.-Biotechnology [Mar-Biotechnol]	1.07
17	Paleobiology	1.79
16	Ciencias-Marinas [Cienc-Mar]	0.32
16	Comp.-Biochem.-Physiol.,-B	0.85
16	Japanese-Journal Of Ichthyol.	0.21
16	Mar.-Chem.	1.74
16	Nippon-Suisan-Gakkaishi	0.29
16	Remote Sens. Environ.	1.23
15	Estuaries	0.84
15	Geo-Mar.-Lett.	0.6
15	J. Chem.-Ecol.	1.32
15	N. Z. J. Mar. Freshwat. Res.	0.47
15	Zool.-Stud.	0.33
14	Am.-Nat.	2.92
14	Environ.-Conserv.	0.44
14	Fish. Sci..	0.52
14	J. Sediment.-Res.-B-Stratigr.-Global-Stud.	1.36
14	New-Sci.	0.42
14	Phycologia	0.88
13	Animal Behaviour [Anim. Behav.].	1.74
13	Biol.-J.-Linn.-Soc.	1.05
13	Comp.-Biochem.-Physiol.,-A	0.78
13	Deep Sea Research (Part Ii, Trop.Stud.Ocean.)	0.95
13	Ecol.-Monogr.	4.09
13	Sea-Technol.	0.08
13	Trans.-Am.-Fish.-Soc.	0.9

13	Trends Ecol. Evol.	4.58
12	Appl.-Optics	1.39
12	C.-R.-Acad.-Sci.-Ser.-3-Sci.-Vie-Life-Sci.	0.59
12	J. Plankton-Research	1.41
12	Mar.-Environ.-Res	1.19
12	Mar.-Geodesy [Mar-Geod]	0.49
12	Zool.-J.-Linn.-Soc.	0.79
11	Dis-Aquat-Org	1.13
11	Global Change Biol.	3.05
11	Mar.-Freshwat.-Behav.-Physiol.	0.41
10	Behavioral Ecology [Behav. Ecol.].	2.67
10	Bioscience -Washington-;	1.77
10	Coast-Eng	0.51
10	J. Geol.-Soc.-India	0.21
10	Mar.-Mamm.-Sci.	0.61
10	Ophelia	0.86
10	Sarsia	0.63
9	Antarct.-J.-U.S.	0.25
9	Aust-J-Earth-Sci	0.88
9	Ecology Letters [Ecol. Lett.].	1.52
9	Environ. Sci. Technol.	2.49
9	Fisheries	0.43
9	Global Biogeochem. Cycles	4.04
9	J. Am.-Chem.-Soc.	4.92
9	J. Molluscan-Studies	0.47
9	J. Physical-Oceanography	1.88
9	Sci.-China-Ser.-D-Earth-Sci.	0.39
9	Spill-Sci.-Technol.-Bull.	0.16
8	Behav. Ecol. Sociobiol.	1.97
8	Biodiversity-And-Conservation	0.95
8	Comp.-Biochem.-Physiol.,-C	0.88
8	Ieee Journal Of Oceanic Engineering [Ieee J. Ocean. Eng.].	0.54
8	Int-J-Earth-Sci	0.68
8	Invertebr-Biol	0.93
8	J. Applied Phycology	0.76
8	J. Biological-Chemistry	6.53
8	J. Clim.	3.07
8	J. Geophys.-Res.-B	0.88
8	Okeanologiya	0.23

8	Org.-Geochem.	1.31
8	Vie-Milieu	0.4
7	C.-R.-Acad.-Sci.-Ser.-2-Mec.-Phys.-Chim.-Sci.-Terre-Univers	0.44
7	Geochem-J	0.54
7	Global-Planet.-Change	1.37
7	Helgol.-Meeresunters.	0.7
7	Invertebr. Reprod. Dev..	0.68
7	J. Environ.-Radioact.	0.61
7	J. Mar.-Syst.	0.86
7	J. Sea-Research [Journal Ofsea-Res]	1.12
7	J. Theor.-Biol.	1.23
7	Oceanus	0.29
7	Oikos	1.53
7	Tissue & Cell [Tissue Cell].	1.17
6	Can.-J.-Earth-Sci.-J.-Can.-Sci.-Terre.	1.06
6	Chem. Geol.	1.23
6	Environ.-Toxicol.-Chem.	1.8
6	Ethology	1.05
6	Eur. J. Phycol.	1.26
6	Invertebr-Taxon	0.56
6	J. Environ.-Manage.	0.38
6	J. Geophys.-Res.-D-Atmos.	1.1
6	J. Great-Lakes-Res.	0.89
6	J. Mar.-Res.	2.02
6	Mar.-Min.	0.64
6	Mol.-Biol.-Evol.	4.41
6	Polar-Biol	1.13
6	Raffles-Bull-Zool	0.28
6	Rev.-Fish-Biol.-Fish.	3.05
6	S.-Afr.-J.-Sci.-S.-Afr.-Tydskr.-Wet.	0.57
6	Sea-Front.	0.03
6	Sov.-J.-Mar.-Biol.;Biol.-Morya	0.01
6	Tetrahedron	1.93
5	Auk.	0.85
5	Condor	0.76
5	Cryptogamie:-Algol	0.26
5	Earth-Sci.-Rev.	2.21
5	Earth-Surf.-Process.-Landforms	0.76
5	Emu	0.38

5	Environ.-Manage.	0.57
5	Environ.-Monit.-Assess.	0.4
5	Experientia	1.12
5	Int.-J.-Parasitol.	1.14
5	Interciencia	0.23
5	J. Afr.-Earth-Sci.	0.33
5	J. Molecular-Evolution	2.99
5	J. Paleolimnology	1.11
5	J. Parasitol.	0.92
5	J. Zoology	0.83
5	Mar.-Fish.-Rev.	0.13
5	Mol.-Mar.-Biol.-Biotechnol.	1.53
5	Naturwissenschaften	0.97
5	Nautilus	0.24
5	Ohio Journal Of Science	0.18
5	Prog.-Oceanogr.	1.88
5	S.-Afr.-J.-Mar.-Sci.	0.47
5	Syst.-Parasitol.	0.49
5	Tetrahedron Lett.	2.19
5	Veliger	0.36
5	Water-Res.	1.42
5	Zoological-Zhurnal [Zool-Zh]	0.14
4	Arch.-Hydrobiol.	0.99
4	Behaviour	1.12
4	Curr. Biol.	7.06
4	Ecological Engineering [Ecol. Eng.].	0.54
4	Ecoscience	1.1
4	Ecosystems	2.4
4	Environ.-Geol.	0.37
4	Functional-Ecology [Funct-Ecol]	1.7
4	Gene	3.57
4	Geol.-J.	0.62
4	Geologie-En-Mijnbouw [Geol-Mijnbouw]	0.39
4	Geomorphology	0.92
4	Holocene	1.84
4	J. Appl.-Ecol.	1.05
4	J. Aquat.-Anim.-Health	0.95
4	J. Comp.-Physiol.,-A	1.46
4	J. Exp.-Zool.	1.33

4	J. Fish-Diseases [Journal Offish-Dis]	0.85
4	J. Geol.	1.82
4	J. Mar.-Biotechnol.	0.62
4	J. Royal-Society- Ofnew-Zealand [Journal Ofr-Soc-N-Z]	0.46
4	Math.-Comp.-Model.	0.28
4	N.Z.-J.-Geol.-Geophys.	0.56
4	Phytochemistry	1.19
4	Restor.-Ecol.	0.9
4	Water,-Air,-And-Soil-Pollution [Water,-Air,-Soil-Pollut]	0.88
3	Acta-Ecol-Sin; Shengtai-Xuebao	0.58
3	Am.-Sci.	1.97
3	Annales-Zoologici-Fennici	0.71
3	Annu. Rev. Ecol., Evol. Syst.	4.29
3	Antarctic Science [Antarct. Sci.].	0.89
3	Aquacult.-Res.	0.57
3	Chemosphere	1.23
3	Development Genes And Evolution [Dev. Genes Evol.].	1.98
3	Ecological-Economics [Ecol-Econ]	1.05
3	Environ.-Pollut.	1.24
3	Geotimes	0.15
3	Int-J-Environ-Stud	0.25
3	J. Atmos.-Ocean.-Technol.	1.13
3	J. Biomed.-Mater.-Res.	1.35
3	J. Field-Ornithol.	0.37
3	J. Herpetology [Journal Ofherpetol]	0.42
3	J. Invertebrate-Pathology [Journal Ofinvertebr-Pathol]	0.88
3	J. Waterway-Port-Coast-Ocean-Eng	0.39
3	J. Wildlife-Diseases [Journal Ofwildl-Dis]	0.56
3	Mar.-Georesources-And-Geotechnology [Mar-Georesour-Geotechnol]	0.21
3	Mar.-Policy	0.33
3	Mol. Phylogen. Evol.	3.31
3	N.Z.-J.-Zool.	0.33
3	Ocean. Eng	0.27
3	Plant,-Cell-Environ	2.49
3	S.-Afr.-J.-Bot.-S.-Afr.-Tydskr.-Plantkd.	0.25
3	Search-Syd.	0.25
3	Tectonophysics	0.26
3	Trans.-R.-Soc.-S.-Aust	0.41
3	Wildl.-Res.	0.68

2	Aapg-Bulletin [Aapg-Bull]	1.43
2	Am.-J.-Sci.	2.52
2	Am.-Malacol.-Bull.	0.41
2	Ann.-Inst.-Oceanogr.,-Paris-Nouv.-Ser.	0.26
2	Appl.-Ocean-Res.	0.23
2	Aquacult.-Eng.	0.38
2	Arab-Gulf-J.-Sci.-Res.	0.1
2	Arch. Environ. Contam. Toxicol.	1.25
2	Arch.-Biochem.-Biophys.	2.55
2	Aust.-J.-Bot.	0.76
2	Aust.-J.-Chem.	0.9
2	Aust.-J.-Zool.	0.61
2	Biochem. Syst. Ecol.	0.72
2	Biochemistry-Wash..	4.56
2	Biomaterials	1.15
2	Brain-Behav-Evol	1.39
2	Calif. Fish Game	0.17
2	Can.-J.-Bot.-J.-Can.-Bot.	0.91
2	Clays-And-Clay-Minerals	1.01
2	Climate Dynamics [Clim. Dyn.].	3.08
2	Contrib.-Mar.-Sci.,-Univ.-Texas.	0.34
2	Dev.-Comp.-Immunol.	1.21
2	Ecol.-Res.	0.44
2	Environ.-Prog.	0.8
2	Environmetrics	0.41
2	Fems-Microbiol.-Ecol.	1.87
2	Fish Shellfish Immunol.	1.51
2	Global-Environ.-Change.	0.75
2	Gulf-Res.-Rep.	0.04
2	Health-Phys.	0.76
2	Helv.-Chim.-Acta	1.9
2	Hereditas	1.01
2	Hormones-And-Behavior [Horm-Behav]	1.69
2	Human-And-Ecological-Risk-Assessment [Hum-Ecol-Risk-Assess]	0.59
2	Ieee-Trans.-Geosci.-Remote-Sens.	1.04
2	Int.-J.-Climatol.	1.1
2	Int-Arch-Allergy-Immunol	1.42
2	Int-Rev-Hydrobiol	0.01
2	Isr-J-Aquacult; Bamidgeh	0.21

2	Isr-J-Zool	0.3
2	J. Acoust.-Soc.-Am.	1.25
2	J. Appl.-Meteorol.	1.14
2	J. Appl-Ichthyol; Z-Angew-Ichthyol	0.3
2	J. Asian Nat. Prod. Res..	0.29
2	J. Comp.-Neurol.	4.05
2	J. Comp.-Physiol.,-B	1.02
2	J. Cons.-Ciem.	0.6
2	J. Environ.-Syst.	0.3
2	J. Eukaryotic-Microbiology	1.46
2	J. Foraminiferal Research [J. Foraminifer. Res.].	0.79
2	J. Freshwater Ecology [J. Freshwat. Ecol.].	0.34
2	J. Hydraul.-Eng.	0.62
2	J. Hydrol.-Amst..	0.75
2	J. Marine-Science-And-Technology [Journal Ofmar-Sci-Technol]	0.8
2	J. Natural-Toxins [Journal Ofnat-Toxins]	0.77
2	J. Volcanology-And-Geothermal-Research	1.15
2	J. World Aquacult. Soc.	0.69
2	Mar.-Pet.-Geol.	0.78
2	Microb.-Ecol.	1.56
2	Nat.-Toxins	0.7
2	Nat-Resour-Forum	0.09
2	Neth.-J.-Sea-Res.	0.9
2	Oryx	1.05
2	Photochem-Photobiol	2.41
2	Precambrian-Res.	1.4
2	Prog-Phys-Geogr	0.68
2	S.-Afr.-J.-Zool.-S.-Afr.-Tydskr.-Dierkd.	0.46
2	Sci.-Am.	2.65
2	Sci.-China-Ser.-B	0.36
2	Toxicol.-Environ.-Chem.	0.55
2	Wetlands [Wetlands].	0.65
2	Zh.-Obshch.-Biol.-J.-Gen.-Biol.	0.25
2	Zoo-Biol.	0.45
2	Zoomorphology	0.82
1	Econ-Geol-Bull-Soc-Econ-Geol	1.1
1	Acta-Biotechnologica [Acta-Biotechnol]	0.34
1	Acta-Zool.-Stockh..	0.72
1	Advances-In-Marine-Biology [Adv-Mar-Biol]	2.27

1	Am.-J.-Physiol.	2.99
1	Am.-Mineral.	1.68
1	American Journal Of Botany [Am. J. Bot.].	1.49
1	Anal.-Chem.	3.74
1	Antiviral-Res.	2.15
1	Applied-Microbiology-And-Biotechnology [Appl-Microbiol-Biotechnol]	1.39
1	Arch.-Insect-Biochem.-Physiol.	1.51
1	Arch.-Protistenkd.	0.53
1	Archive-Of-Fishery-And-Marine-Research; Archiv-Fur-Fischerei-Und-Meeresforschung [Arch-Fish-Mar-Res; Arch-Fisch-Meeresforsch]	0.44
1	Atl.-Geol.	0.31
1	Aust.-J.-Plant-Physiol.	1.79
1	Aust-Meteorol-Mag	0.74
1	Aust-Syst-Bot	0.68
1	Avian-Dis.	0.89
1	Behav.-Neural-Biol.	0.58
1	Belgian-Journal-Of-Zoology [Belg-J-Zool]	0.35
1	Biochem.-J.	3.66
1	Bioessays	4.39
1	Biofutur	0.16
1	Biogeochemistry	1.67
1	Biologist	0.18
1	Biomolecular-Engineering [Biomol-Eng]	0.28
1	Bioorg.-Khim.	0.72
1	Biosci,-Biotechnol,-Biochem	0.91
1	Biotropica	0.66
1	Bird-Behavior [Bird-Behav]	0.34
1	Boreas.	1.03
1	Can.-Vet.-J.	0.45
1	Cancer-Res.	5.28
1	Can-Field-Nat	0.17
1	Catena	0.6
1	Chem.-Lett.	1.47
1	Chem.-Rev.	12.17
1	China Ocean Eng.	0.11
1	Chinese-Science-Bulletin [Chin-Sci-Bull]	0.2
1	Civil-Engineering,-Jsce [Civ-Eng,-Jsce]	0.1
1	Climatic Change [Clim. Change].	1.62
1	Cretaceous-Res.	0.55

1	Curr-Microbiol	1.12
1	Cytobios.	0.49
1	Discov-Innov	0.04
1	Dokl.-An-U.S.S.R.	0.32
1	Ecography [Ecography].	1.13
1	Ecology-Law-Quarterly [Ecol-Law-Q]	1.01
1	Ecology-Of-Freshwater-Fish [Ecol-Freshwat-Fish]	0.9
1	Ecotoxicol. Environ. Safty.	0.93
1	Ecotoxicology [Ecotoxicology].	1.25
1	Entomol.-Scand.	0.18
1	Environ.-Health-Perspect.	1.49
1	Environment.	0.86
1	Environmentalist.	0.12
1	Environment-International	0.47
1	Environ-Model-Software-Environ-Data-News	0.36
1	Environ-Res	1.26
1	Eos-Trans-Am-Geophys-Union	2.71
1	Epidemiol.-Infect.	1.47
1	Eur. J. Biochem.	3.44
1	Evolutionary-Ecology [Evol-Ecol]	1.77
1	Evolutionary-Ecology-Research [Evol-Ecol-Res]	1.13
1	Fems-Microbiology-Letters [Fems-Microbiol-Lett]	1.45
1	Fish.-Oceanogr.	1.37
1	Fish-Physiol-Biochem	1.3
1	Fluid.-Dyn.-Res.	0.52
1	Free-Radical-Biology-And-Medicine [Free-Radical-Biol-Med]	3.8
1	Fresenius-Environmental-Bulletin [Fresenius-Environ-Bull]	0.26
1	Genetics	3.41
1	Genome.	1.54
1	Geographical-Journal [Geogr-J]	0.3
1	Geol.-Soc.-Am.-Bull.	2.07
1	Hydrogeol-J	0.51
1	Ibis	0.82
1	Indian-J-Exp-Biol	0.25
1	Int.-Hydrogr.-Rev.	0.09
1	Int.-J.-Pharm.	0.95
1	Int-J-Dev-Biol	1.63
1	Island-Arc	0.97
1	Isr-J-Plant-Sci	0.55

1	J. Aerosol-Sci	0.99
1	J. Atmos.-Chem.	1.86
1	J. Bacteriology [Journal Ofbacteriol]	3.26
1	J. Biomaterials Applications [J. Biomater. Appl.].	0.6
1	J. Bioscience-Penang [Journal Ofbiosci-Penang]	0.39
1	J. Biotechnology [J. Biotechnol.].	1.4
1	J. Ecol.	1.68
1	J. Environ-Econ-Manage	0.52
1	J. Environ-Eng	1.05
1	J. Ethol	0.26
1	J. Food Protection [J. Food Prot.].	1.17
1	J. Gen.-Physiol.	5.15
1	J. Gen.-Virol.	2.76
1	J. Heredity [Journal Ofhered]	1.02
1	J. Infect.-Dis.	4.42
1	J. Liq.-Chromatogr.	1.35
1	J. Microbiological-Methods [Journal Ofmicrobiol-Methods]	1.07
1	J. Nematol.	0.73
1	J. Neurosurg.	2.24
1	J. Org.-Chem.	2.58
1	J. Sci.-Ind.-Res.	0.2
1	J. Therm.-Biol.	0.66
1	J. Toxicol.:-Clin.-Toxicol.	0.7
1	J. Water Resour. Plann. Manage.	0.51
1	Japanese-Journal Of Cancer-Res.	1.8
1	Kuwait-J.-Sci.-Eng.	0.09
1	Lancet.	12.32
1	Landscape	0.49
1	Letters-In-Applied-Microbiology [Lett-Appl-Microbiol]	0.89
1	Life-Sci.	2.61
1	Malacologia -Philadelphia-;	0.57
1	Mar.-Behav.-Physiol.	0.59
1	Mar.-Geophysical-Researches [Mar-Geophys-Res]	1.19
1	Mar.-Geotechnol.	0.32
1	Mater.-Performance.	0.12
1	Med.-Vet.-Entomol.	0.83
1	Medical-Science-Research [Med-Sci-Res]	0.34
1	Microbios	0.43
1	Micropaleontology	0.59

1	Miner.-Deposita	0.6
1	Mol.-Pharmacol.	5.02
1	Molecular-And-General-Genetics [Mol-Gen-Genet]	2.87
1	Mycol.-Res.	0.92
1	N.Z.-J.-Bot.	0.53
1	Nat.-Mus.	0.42
1	Neues-Jahrb.-Geol.-Palaeontol.-Abh.	0.43
1	Nucleic-Acids-Res.	4.57
1	Oil-And-Gas-Journal [Oil-Gas-J]	0.13
1	Parasitology	1.76
1	Pharmaceutical-Biology [Pharm-Biol]	0.15
1	Photogramm-Eng-Remote-Sensing	0.68
1	Photosynthetica	0.64
1	Physiol.-Zool.	1.46
1	Physis-A	1.2
1	Plant Cell Physiol.	1.55
1	Plant-Cell-Rep	1.55
1	Plant-J.	5.59
1	Plant-Mol.-Biol.	3.73
1	Polar-Research [Polar-Res]	0.41
1	Protist	2.28
1	Pure-Appl-Geophys	0.67
1	Res.-Commun.-Chem.-Pathol.-Pharmacol.	0.95
1	Res-Popul-Ecol	0.48
1	Rev.-Palaeobot.-Palynol.	0.57
1	Rev-Geophys	3.54
1	Sci.-Sin.-Ser.-B.	0.2
1	Syst. Appl. Microbiol.	1.93
1	Toxicology	1.24
1	Trans.-R.-Soc.-S.-Afr.	0.43
1	Trends In Microbiology [Trends Microbiol.].	5.35
1	Water-Environ.-Res.	1.04
1	Water-Sci.-Technol.	0.57
1	Z.-Naturforsch.,-Sect.-C.	1.07
1	Z.-Zool.-Syst.-Evolutionsforsch.	0.52
8091		

ANNEXURE - IV

No.of Articles Published	Non-Science Citation Index Journals
82	Atoll Research Bulletin
40	Biol.-Mar.-Mediterr.
38	Cont-Shelf-Res
37	Aquat. Conserv.: Mar. Freshwat. Ecosyst.
35	Proc.-Natl.-Acad.-Sci.-Usa
29	Gulf-Mex-Sci
27	Mar.-Geol.-Quatern.-Geol.
27	Mar.-Sci.-Bull.-Haiyang-Tongbao
25	Aquat. Living Resour.
25	Russ.-J.-Mar.-Biol.;Biol.-Morya
24	Proc.-R.-Soc.-Lond.-Ser.-B.
23	Galaxea-J-Jap-Coral-Reef-Soc
22	Chin.-J.-Mar.-Drugs
22	Isr.-J.-Zool.
22	Rev.-Invest.-Mar.
20	Trop.-Oceanol.-Redai-Haiyang
19	Bahamas Journal Of Science
18	Aquat.-Bot.
18	Fish.-Eng.-Japan-Suisan-Kogaku
17	J. Oceanogr.
17	J. Trop. Oceanogr.
16	Chemistry And Ecology [Chem. Ecol.].
13	Aquarium-Sci-Conserv
13	Aquat.-Microb.-Ecol.
13	J. Mar.-Biol.-Assoc.-India
13	N. Am. J. Fish. Manage.
13	Trop.-Geogr.-Redai-Dili
12	Acta-Oceanol-Sin-Chin-Ed;
11	Fish. Manage. Ecol.
11	J. Toxicol.-Environ.-Health
10	P.S.Z.N.-I:-Mar.-Ecol.
10	Rev-Bras-Biol
10	Trop.-Coast.-Area-Manage.
10	Zoosystema-Paris [Zoosystema]
9	Acta-Sci-Nat-Univ-Sunyatseni; Zhongshan-Daxue-Xuebao
9	Acta-Sedimentol.-Sin.-Chenji-Xuebao
9	Avicennia-Rev-Ecol-Oceanol-Biodivers-Trop
9	J. Oceanogr. Taiwan Strait
9	Mar.-Sci.-Haiyang-Kexue
9	Senckenb.-Biol.
8	Fish Fish.
8	Ital.-J.-Zool.
8	J. Ichthyol.
8	Oseana.
8	Philipp.-Sci.
8	Reef-Res
8	Trab-Oceanogr-Univ-Fed-Pernambuco
8	Venus-Jap.-J.-Malacol.
8	World Aquaculture [World Aquacult.].

7	Coast.-Manage.-Trop.-Asia
7	Hidrobiologica (Iztapalapa)
7	Intercoast-Network
7	Invertebr.-Taxon.
7	J. Bombay-Nat.-Hist.-Soc.
7	N.Z.-J.-Mar.-Freshwat.-Res.
7	Northeast-Gulf-Sci.
6	Aquat-Ecosyst-Health-Manage
6	Asian-Fish.-Sci.
6	Aust.-Fish.
6	Batalleria
6	Caribb.-Mar.-Stud.
6	Colonial-Waterbirds.
6	Geol.-Mediterr.
6	Indian Journal Of Fisheries
6	Int. J. Syst. Evol. Microbiol.
6	Mar-Fish; Haiyang-Yuye
6	Seaweed Research And Utilisation
6	Stud.-Mar.-Sin.-Haiyang-Kexue-Jikan
6	Underwat.-Nat.
6	West.-Fish.
6	West-Indian-Ocean-J-Mar-Sci
5	Appl.-Biol.-Sci.
5	Aquacult.-Mag.
5	Aqua-J-Ichthyol-Aquat-Biol
5	Aquat.-Mamm.
5	Florida Sci.,
5	Gulf Caribb. Res.
5	J. Andaman-Sci.-Assoc.
5	J.King-Abdulaziz-Univ-Mar-Sci
5	Mar.-Life
5	Seafood-Export-J.
5	Vopr.-Ikhtiol.-J.-Ichthyol.
4	Acta-Geogr.-Sin.-Dili-Xuebao
4	Acta-Zool.-Taiwan.
4	Afr.-Wildl.
4	Australas-Sci-Inc-Search
4	Calif. Coast Ocean
4	Fish.-Chimes
4	Geol-Pac-Ocean
4	Helgoland-Marine-Research
4	Hydro-Int
4	Int.-J.-Mar.-Coast.-Law
4	J. Indian Ocean Studies [J. Indian Ocean Stud.].
4	Jamstec-Journal Of Deep-Sea-Res
4	Ocean News & Technology
4	Ocean-Dev.-Int.-Law
4	Oebalia
4	Proc.-R.-Soc.-Queensl.
4	Russ. Acad. Sci. Oceanol.
4	Sea Technology [Sea Technol.].
4	Trans.-Oceanol.-Limnol.-Haiyang-Huzhao-Tongbao
4	Trop-Coasts
4	Wildl.-Aust.

3	Aquat.-Geochem.
3	Can-J-Remote-Sens
3	Caribb.-J.-Sci.
3	Cercet-Mar; Rech-Mar
3	Earth-System-Monitor [Earth-Syst-Monit]
3	Hist.-Biol.
3	J. Applied-Aquaculture
3	J. Fac.-Appl.-Biol.-Sci.
3	J. Taiwan-Mus.
3	J. Univ.-Kuwait-Sci.
3	Journal Of Mar.-Fish.-Res.
3	Journal Ofdalian-Fish-Univ
3	Journal Ofocean-Univ-Qingdao
3	Mar.-Ornithology [Mar-Ornithol]
3	Ocean-Res.
3	Rev.-Soc.-Mex.-Hist.-Nat.
3	Soc.-Nat.-Resour.
3	Stuttg.-Beitr.-Naturkd.-A-Biol.
3	Thai-Mar.-Fish.-Res.-Bull.
3	The-Ocean.-Eng.-Haiyang-Gongcheng
3	Today's-Aquar.
3	Women Fish. Inf. Bull..
2	Crust.-Res.
2	Acta Ecol. Sin./Shengtai Xuebao
2	Acta Oecologica [Acta Oecol.].
2	Acta-Biol.-Leopold.
2	Acta-Sci.-Circumstant.
2	Actual.-Biol.
2	African-Zoology [Afr-Zool]
2	Ann.-S.-Afr.-Mus.
2	Ann-An-Istrske-Mediter-Stud-Hist-Nat
2	Aquaculture-Asia-Bangkok [Aquac-Asia]
2	Aquat. Microb. Ecol.
2	Aquatic-Ecology [Aquat-Ecol]
2	Arq.-Biol.-Tecnol.
2	Australasian-Sci.
2	Biol.-Oceanogr.
2	Biol-Invasions
2	Chin-J-Oceanol-Limnol
2	Coast. Eng. J.
2	Ectropicos
2	Int.-J.-Estuar.-Coast.-Law.
2	Int.-J.-Naut.-Archaeol.-Underwat.-Explor.
2	Integr. Comp. Biol.
2	J. Aquat.-Ecosyst.-Stress-Recovery
2	J. Cetacean-Res-Manag
2	J. Fishery Sciences Of China
2	J. Mar.-Drugs-Haiyang-Yaowu.
2	J. S.-Asian-Nat.-Hist
2	J. Sch.-Mar.-Sci.-Technol.-Tokai-Univ.
2	J. Zhanjiang Ocean Univ.
2	J. Zhanjiang-Fish.-Coll.
2	Koedoe.
2	Mahasagar.

2	Mar. Environ. Sci.
2	Mar.-Biology Research [Mar. Biol. Res.].
2	Mar.-Drugs [Mar. Drugs].
2	Mar.-Fish.-Inf.-Serv.-Tech.-Ext.-Ser
2	Mar.-Models-Online
2	Mar-Fish-Res
2	Melanesian Geo [Melanes. Geo].
2	Ocean Dev. Int. Law
2	Ocean-Coast.-Law-J.
2	Ocean-Shoreline-Manage.
2	Pakistan-Journal-Of-Marine-Sciences
2	Proc-Indian-Acad-Sci-Earth-Planet-Sci
2	Rev.-Zool.-Iztacala.
2	Rev-Bras-Oceanogr; Braz-J-Oceanogr
2	Rev-Cub-Invest-Pesq
2	Rev-Hydrobiol-Trop
2	Rybn-Khoz-Mosc
2	South.-Fish.
2	Southeast. Nat.
2	Stuttg.-Beitr.-Naturkd.-B-Geol.-Palaeontol..
2	Thalassa
2	Vie-Mar.
2	Wetlands Ecol. Manage.
2	J. Shanghai Fish. Univ.
1	Acta-Biol-Venez
1	Acta-Cient-Venez
1	Acta-Geol.-Leopold.
1	Acta-Ichthyol.-Pisc.
1	Acta-Oceanogr.-Taiwan.
1	Acta-Soc.-Zool.-Bohemoslov.
1	Adv-Mar-Sci; Haiyang-Kexue-Jinzhan
1	Afr. J. Aquat. Sci.
1	Am-J-Int-Law
1	Animal-Conservation [Anim-Conserv]
1	Ann.-Naturhist.-Mus.-Wien-B-Bot.-Zool.
1	Ann.-Paleontol.
1	Ann-Mus-Civ-Stor-Nat-"Giacomo-Doria
1	Antarctic-Res.-Nanji-Yanjiu
1	Appl.-Phycol.-Forum.
1	Aquacult.-Eur.
1	Aquacult.-Fish.-Manage.
1	Aquacult-Econ-Manage
1	Aquaculture-International [Aquacult-Int]
1	Aquatic-Sciences [Aquat-Sci]
1	Archiv-Fuer-Molluskenkunde [Arch-Molluskenkd]
1	Asia-Pac-J-Environ-Law
1	Aust.-Nat.-Hist.
1	Austasia-Aquacult.-Mag.
1	Austral-Ecology [Austral-Ecol]
1	Aust-Sugarcane
1	Biociencias
1	Biogeosciences
1	Chem. Biodivers.
1	Chin.-Pharm.-J.

1	Columbia-J.-Environ.-Law
1	Concrete.
1	Conserv-Biol-Pract
1	Conserv-Pract
1	Datz
1	Divers-Distrib
1	Dokl.-Ran
1	Ecological Restoration [Ecol. Restor.].
1	Ecos
1	Fins.
1	Fish.-Fishbreed.-Isr.
1	Geowissenschaften.
1	Gidrobiol.-Zh.-Hydrobiol.-J.
1	Hum.-Ecol.
1	Hydrogeologie.
1	Hydrores.
1	Indian-J-Pet-Geol
1	Int.-Rev.-Gesamt.-Hydrobiol.
1	Int-J-Acarol
1	Int-Leg-Mater
1	Invertebr-Syst
1	Ir-Nat-J
1	J. Agric.-W.A.
1	J. Anim.-Morphol.-Physiol.
1	J. Aquaculture-In-The-Tropics
1	J. Aquaricult.-Aquat.-Sci.
1	J. Aquat.-Food-Prod.-Technol.
1	J. Chinese-Acad.-Fish.-Sci.
1	J. Clin.-Lab.-Anal.
1	J. Ecobiol.
1	J. Ecotoxicol-Environ-Monitoring
1	J. Environ-Dev
1	J. Environ-Pollut
1	J. Fac.-Mar.-Sci.-Technol.-Tokai-Univ.
1	J. Fish.-Soc.-Taiwan
1	J. Indian-Assoc.-Sedimentol.
1	J. Indian-Fish.-Assoc.
1	J. Korean-Fish.-Soc.
1	J. Marine-Environmental-Engineering
1	J. Med.-Entomol.
1	J. Natl-Fish-Univ-Japan
1	J. North American Benthological Society
1	J. Northw.-Atl.-Fish.-Sci.
1	J. Oceanological-Society- Ofkorea-Seoul
1	J. Rech.-Oceanogr.
1	J. R-Soc-West-Aust
1	J. Taiwan-Fish.-Res.
1	J. Tongji-Univ.-Tongji-Daxue-Xuebao.
1	J. Xiamen-Univ.-Nat.-Sci.-Xiamen-Daxue-Xuebao
1	Joides-Journal [Joides-J]
1	Kavaka.
1	Kenya-J.-Sci.-Technol.-B-Biol.-Sci.
1	Korean-J.-Polar-Res.
1	Mar.-Res.

1	Mar.-Res.-Indones.
1	Mar.-Resour.-Econ.
1	Maritime Studies [Marit. Stud.].
1	Maritime-Policy-And-Management
1	Maritimes
1	Medio-Ambiente.
1	Mediterr-Mar-Sci
1	Mycologia.
1	N.-Engl.-J.-Med.
1	Nat.-Areas-J.
1	Nat-Mus
1	Natura-Croatica [Nat-Croat]
1	Natural Product Research [Nat. Prod. Res.].
1	Nature-And-Resources [Nat-Resour]
1	Nature-Biotechnology [Nat-Biotechnol]
1	Northeast.-Nat.
1	Ocean Dynamics [Ocean Dyn.].
1	Ocean-Ind.
1	Ocean-Technol.-Haiyang-Jishu
1	Offshore-Eng.
1	Pac.-Discovery
1	Papua-New-Guinea-J.-Agric.-For.-Fish.
1	Res-Environ-Sci; Huanjing-Kexue-Yanjiu
1	Resonance [Resonance].
1	Rev. Palaeobot. Palynol.
1	Rev.-Biol.-Mar.
1	Rev.-Geofis.-Mex.
1	Rev.-Invest.-Cient.-Univ.-Auton.-Baja-Calif.-Sur-Ser.-Cienc.-Mar
1	Ribarstvo
1	Rivers-Future
1	Sci. Conserv.
1	Seaways
1	Smithson-Contrib-Zool
1	Sri-Lanka-J-Aquat-Sci
1	Su-Urun.-Derg.-J.-Aquat.-Prod.
1	Su-Urun-Derg; J-Fish-Aquat-Sci
1	Suva-Fiji Msp
1	Syst. Biodivers.
1	Trav-Sci-Parc-Natl-Port-Cros
1	Trianea
1	Umi; Mer
1	Verh.-Naturforsch.-Ges.-Basel
1	Vodn.-Resur.
1	Water-Environ.-Technol.
1	Water-Resources [Water-Resour];Vodnye-Resursy-
1	Water-Resources-Impact [Water-Resour-Impact]
1	World-Fish.
1	Xinan-Shiyou-Xueyuan-Xuebao; J-Southwest-Pet-Inst
1	Zoology-In-The-Middle-East [Zool-Middle-East]
1457	

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