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THE STATE OF THE ART OF LIMNOLOGY IN THE LAST DECADE

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Trabajo Fin de Título para la obtención del título de Grado en Ciencias del Mar

0. Title

The state of the art of Limnology in the last decade.

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4. Index

4.1. Text

4.2. Figures

4.3. Tables

5. Introduction

5.1. Objective and structure

The objective of this work is show the state of the art of Limnology. Then it was decided to divide the work in two parts: one theoretical and one practical.

The first part of this work is theoretical and it is focused on the lakes. This part describes only the lakes because they are the most important water bodies in Limnology, they contains more freshwater than others bodies like wetlands. Therefore, the work defines the most important aspects of these water bodies in such a way that the reader can get a comprehensive overview of current knowledge on this topic. This section finishes with some examples of recent changes of paradigm on Limnology at general level to provide the reader with recent ideas about this discipline as a whole.

The second part is more practical and aims to test the hypothesis that there was more publication on Oceanography than on Limnology in the last decade (2001-2010). To create this section the author has used numerical records of publications.

5.2. General context

The Limnology is the discipline that studies the inland waters (lakes, wetlands, rivers, ground water and streams), incorporating knowledge of geological, physical, biological and chemical processes at different scales. Then it is an interdisciplinary science and usually adopts an ecosystem approach to research problems (**Cao et al., 2012; Cole, 2009**).

The world's water is distributed as follows (Figure 1): approximately 96.3% of water is in the oceans as salt water and the remaining 3.7% percent is fresh water. However it is important to say that 1.93% of this 3.7% is fresh water trapped in glaciers and ice caps, so it is not useful to supply the population. The humanity can only drink fresh water from some aquifers and a portion of the fresh surface water that is free in the form of rivers, lakes and wetlands. The fresh surface water is very important as it shapes much of the landscape of the continents. The lakes (67.5%) and wetlands (8.5%) contain significantly more amount of fresh water than the rivers (1.6%). Thus these water bodies, studied by Limnology, are of vital importance to humanity by providing easy access to what is indisputably the most important recourse: the fresh water (**Marshall, 2013**).

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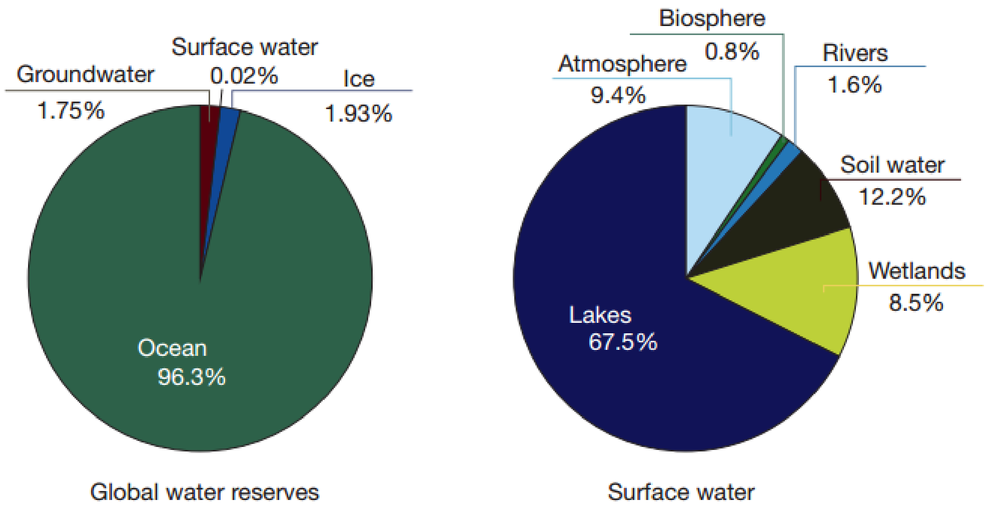

Figure 1. Distribution of Earth's water. Marshall (2013).

6. Material and methods

This work is based on a review of existing bibliographic information on Limnology and lakes and, to carry out this task, it used from scientific books to journal articles. These bibliographic sources were recompiled using computing resources used in the Universities as Scopus, ScienceDirect, Faro and others. Furthermore, the author used websites about Limnology to get some photographs that illustrate the examples of the lakes.

Finally, the program Excel was used to create tables and graphics related to the work.

7. Lakes

7.1. Definition

A lake is an enclosed body of freshwater totally surrounded by land and without direct access to the sea but they can be interconnected by rivers (**Thomas et al., 1992**).

The rock type in the area of catchment of water determines the chemical composition of lakes. The silicate rocks like basalt form freshwater rich in dissolved SiO_2 (20-30 mg/l), $(Ca+Mg)/HCO_3$ ratios <0.5 and SiO_2/HCO_3 ratios up to 0.45, but the sedimentary rocks like limestone form freshwater poor in dissolved SiO_2 (<20 mg/l), $(Ca+Mg)/HCO_3$) ratios >0.5 and SiO_2/HCO_3 from 0.02 to 0.34 (**Yan et al., 2002**).

7.2. Evolution

7.2.1. Description of its life

Lakes are geologically transitory. The lake basins are based on the nature of the processes responsible for building, excavation and damming. Excavation and damming that took place during the Pleistocene glaciations formed more basins than all the other processes together. Later, the lakes live through the stages of maturity and senescence, and their death occurs when its basin is finally filled with sediments (**Hutchinson, 1957**).

7.2.2. Water balance

It is possible calculate the water balance of the lakes with the next equation (**Sánchez-Moral et al., 2002**):

$$\frac{dV}{dt} = Q_p + Q_S + Q_I - Q_O - Q_E$$

Where $\frac{dV}{dt}$ is the water volume variation; Q_p is the precipitation rate; Q_S is the average surface runoff; Q_I is the ground-water inflow (influent seepage); Q_O is the ground-water outflow (effluent seepage) and Q_E is the evaporation rate.

The precipitation regulates the relation between lakes and their watersheds. If the precipitation exceeds the evaporation, the lake exports water to its watersheds and it sustains lake level over the long term. Conversely, if the evaporation is larger than the precipitation, the lake imports water from their watersheds in the form of stream flow, runoff, or groundwater inflow to persist in the landscape (**Lee et al., 2014**).

7.2.3. Seasonal variations

There are differences between boreal lakes and subtropical lakes:

- Boreal or temperate lakes experiment a turnover in the spring and the autumn and thermal stratification in summer, they are dimictic (**Oswald & Rouse, 2004**). However, the subtropical lakes suffers movements at the diurnal scale, approximately, there are stable stratification during the day and unstable convection during the night (**Wang et al., 2014**).

- There is a lag of 5 months between the time of maximum energy input into the lake and the time of maximum energy output, due the high heat specific of water, for deep lakes but negligible for shallow lakes (**Blanken et al., 2011**).

- The annual water loss by evaporation increase nonlinearly by the influence of ice cover created in the winter in northern lakes. Therefore, the ice-free subtropical lakes evaporate more water vapor and they are more rapidly affected by atmosphere than the northern lakes (**Blanken et al., 2003**).

7.3. Classification

7.3.1. Types of classification

There are several criteria of classification of lakes but the more known is the classification based on their origin and this is the criterion developed in this work. However, the work introduces the reader with a brief description of some examples of usual classifications (**Kar, 2014**).

Classification based on climatic zone (**Skowron, 2009**):

- Polar lakes: the water is always below 4ºC.
- Temperate lakes: the water reaches 4ºC twice a year, in spring and autumn.
- Tropical lakes: the water is always higher than 4ºC.

Classification based on the circulation and mixing (**Lewis Jr., 1983**):

- Monomictic lakes: the water completely circulates through the lake once a year.
- Dimictic lakes: these lakes have two periods of mixing: one spring and one autumn. They are thermally stratified in summer and they are ice-covered in winter.
- Polymictic lakes: the water is mixed several times throughout the year. They are usually shallow lakes.
- Amictic lakes: these lakes are completely covered by ice and there is no mixing.

Classification based on nutrition (**Dodds et al., 1998**)

- Oligotrophic lakes: they have a low concentration of nutrients, thus they have also a low algal biomass and the water is quite transparent.
- Eutrophic lakes: they have a high concentration of nutrients, thus they are rich in phytoplankton and the water is less transparent.
- Mesotrophic: these lakes have intermediate characteristics between oligotrophic and eutrophic lakes.

7.3.2. Classification based on their origin

The characteristics vary within each individual lake, and they are quite independent of the type of lake, instead they depend on factors such as climate, terrain geometry, age, human influences, etc. Accordingly, it was decided to talk more about these features within the concrete examples, rather than in the definitions of types, which are used to explain the formation mechanism of types that is the base of this classification. However, the work can introduce some concepts related to the characteristics in the definition of type when these aspects have a more general character.

7.3.2.1. Glacial lakes

7.3.2.1.1. Definition

The erosion by glaciers is not as uniform as by rivers, and local depressions develop in different places at different times depending on several factors like the local slope, the amount of ice and the terrain geometry. Later, water fills these depressions and creates the glacial lakes (**Herman et al., 2011**).

There are subtypes of glacial lakes (**Salerno et al. 2012**):

- Unconnected glacial lakes: lakes that are not directly connected with glaciers. However, it is possible that these lakes contain a glacier in their basins.

- Supraglacial lakes: lakes on the surface of the glacier downstream.

- Proglacial lakes: lakes that are limited by moraine deposits in the front of glacier. In occasions they can form Glacial Lake Outburst Floods (GLOFs), a sudden-onset outburst floods which arise from a failure of a moraine-dam (**Westoby et al., 2014**).

7.3.2.1.2. Example

The Great Lakes

These five enormous water bodies which comprise the Laurentian Great Lakes form the largest body of fresh water on the Earth. These lakes (Figure 2) are called Lake Superior, Lake Huron, Lake Michigan, Lake Ontario and Lake Erie (**Waples et al., 2008**). These lakes were formed during the last retreat of ice roughly 9,000 years ago in North America (**Larson & Schaetzl, 2001**).

There are large industrial cities in North America located on the shores of the Great Lakes, e.g. Chicago on Lake Michigan and Detroit on Lake Erie. Changes in level are caused by winds and changes in barometric pressure, leading to regular sloping of the lakes in its basin, a phenomenon called seiche. These lakes offer good conditions for the formation of waves (strong winds and large areas of deep water) (**Kar, 2014**).

It has been observed that the concentrations of calcium, sulfate and chloride are increasing in lakes Superior, Michigan and Huron and are declining in lakes Ontario and Erie. However, the upper lakes (Superior, Michigan and Huron) have very long residence times and when they are contaminated by anthropogenic causes, retain the contaminants and, later, they also affect the water quality of the lower lakes (Ontario and Erie), although the sources of contamination have been removed to conserve the environment (**Chapra et al., 2012**).

The zooplankton population mainly comprises of rotifers (e.g. *Keratella* and *Polyarthra*) at microzooplankton level and cladocerans (e.g. *Daphnidae*) and copepods (some genera are *Epischura*, *Eurytemora* and *Leptodiaptomus*) at macrozooplankton level (**Cangelosi et al., 2007; Fitzsimmons & Innes, 2005**; **Robertson, 1981**). The phytoplankton population is mainly formed by different species like diatoms (some genera are *Navicula*, *Nitzschia* and *Surirella*), dinoflagellates (*Ceratium* and *Peridinium*), colonial cyanobacteria (*Anacystis*), etc (**Cangelosi et al., 2007**). These lakes contain 179 species of fish. Some of these species are: ghost shiner (*Notoropis buchanani*), lake sturgeon (*Acipenser fluvescens*), common carp (*Cyprinus carpio*), American eel (*Anguilla rostrata*), goldfish (*Carassius auratus*), etc (**McCrimmon, 2002**).

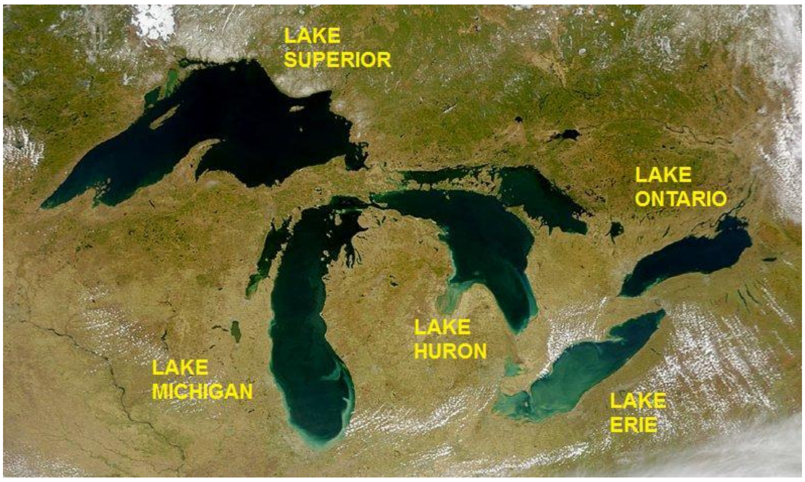

Figure 2. The Great Lakes. NASA, (2007).

7.3.2.2. Tectonic lakes

7.3.2.2.1. Definition

These lakes are formed by the movements of the Earth’s surface. The water fills the depressions created by the subsiding or lifting of a portion of the Earth’s surface in relation to other portion. Therefore, the fault movements can sink the valleys, raise the walls and tilt the floor layers, creating a basin. The synthetic and antithetic faults created in these displacements affect the morphology of the lake. Thus, they are usually found in rift valleys (**Laerdal & Talbot, 2002**). Some of these lakes are formed by the action of water in a karstic cavity that provoke the subsidence of this zone, creating a depression and forming, subsequently, a tectonic lake (**Ibouh et al., 2014**).

7.3.2.2.2. Example

Naini lake

Naini lake (Figure 3) is a natural kidney shaped tectonic lake located at 29º22’49’’N and 79º30’79’’E. The maximum and minimum depths are 26 m and 18 m. Fish mortality is a common phenomenon in this lake because this water body receives toxic metals, organic and inorganic pollutants from different sources like domestic discharge, recreational activities, etc (**Ali et al., 1999**). The fishery in this lake is dominated by mahseers (*Top putitora*, *Tor Tor*), common and indian major carps (*Cyprinus carpio communis* and *Labeo rohita*). Furthermore there are frequent algal blooms mainly due to the Chlorophyceae and Cyanophyceae species. The zooplankton population mainly comprises rotifers, cladocerans and copepods (the most important examples of these groups are *Asplanchna brightwelli*, *Daphnia longispina*, *Mesocyclops leuckarti*, *Eucyclops serrulatus*) (**Indian Council of Agricultural Research, 2000**).

Das et al. (1995) sampled sediments of the lake and found that there was evidence that this water body could have been contaminated with metals, although they could not confirm completely that it was really due to anthropogenic causes without perform further studies. However, there was an excess of trace elements such as V, Cr, Zn, Pb and Cu. Subsequently, **Joshi et al. (2006)** performed new studies of the same lake using energy dispersive X-ray fluorescence (EDXRF), measuring the concentration of certain elements in various areas of the lake. Finally, it was possible to conclude that the cleanup conducted in the lake decreased the levels of pollution below the safe limit.

Figure 3. Naini lake. Ghumakkar, (2013).

7.3.2.3. Volcanic lakes

7.3.2.3.1. Definition

These lakes are also called crater lakes. Sometimes, after a volcanic crater-formed eruption, the floor of such volcanoes is relatively flat and water accumulates in the deeper zones of this crater, forming a volcanic lake (**Kar, 2014**).

The composition of these lakes ranges from mostly meteoric waters to hyper-acid brines. Variations in water chemistry are related to variations in the composition and flux of volcanic fluids and gases into lake. Water evaporation may be an important process in these lakes, for their relatively small size, that results in a stable isotope fractionation (Figure 4). $\delta^{18}O$ is a tracer for the lake dynamics. An elevated lake water temperature gives enhanced isotopic fractionation. (**Varekamp & Kreulen, 2000**).

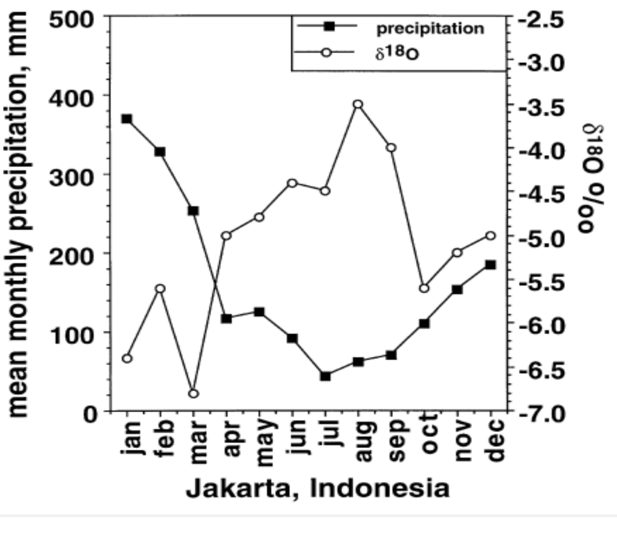

Figure 4. Variation in precipitation rate and isotopic composition in Jakarta, Indonesia in 1985. Varekamp & Kreulen (2000).

It is possible to classify the volcanic lakes in two groups (**Varekamp et al., 2000**):

- Volcanic gas-dominated systems: their rate of acidification is greater than the rate of neutralization by the higher amount of gas (mainly CO_2 and H_2S) and fluids circulate relatively rapidly through the sublimnic hydrothermal systems.

- Rock dominated-systems: their rate of neutralization is greater than the rate of acidification and fluids circulate relatively slowly through the sublimnic hydrothermal systems.

7.3.2.3.2. Example

Lake Taupo

Lake Taupo (Figure 5) is a large oligotrophic volcanic lake in New Zealand. In recent years, this lake has suffered a nitrogen contamination caused by human activities (**Matheson et al., 2011**).

Chimneys have been discovered at the bottom of the lake and their surfaces contain a number of elements such as S, Hg, As, Sb and Ti. These vents are increasing the concentration of SO_4, Cl, Na and SiO_2 in the water **(Ronde et al., 2002).**

There are sponges within the genus *Heterorotula* close to the vents that have bored into the chimneys. Furthermore, exist annelids of family *Enchytraeidae* living in the lake sediments and the crayfish (*Paranephrops planifrons*). Some species of fish are Koaro (*Galaxias brevipinis*) and Toitoi (*Gobiomorphus cotidianus*) (**Ronde et al., 2002; Rota & Manconi, 2004**).

Figure 5. Lake Taupo.Info.geonet.org (n.f).

7.3.2.4. Riverine lakes

7.3.2.4.1. Definition

Riverine lakes are also called oxbow lakes and they are formed by cutoff creation. As the water flows, it accumulates sediments on the convex bank and the sediments are eroded from the concave bank of the river, increasing the sinuosity of the meander and joining the two parts. Finally, a bar of sediments is created and this part of the river is excluded, forming an oxbow lake (**Delhomme et al., 2013; Hudson et al., 2012**).

There are four regimes of sedimentation in an oxbow lake (**Wren et al., 2008**):

1: While the lake is still connected with the river, the sand is deposited in this zone of less velocity.

2: Separation of the river with a high sedimentation rate from seasonal floods.

3: River migrates away from the lake and the sedimentation rate diminishes.

4: Increase of transparency of water because to the increase of sedimentation rate.

There are several factors that influence the advance of tie channels that connect these lakes to the main stem river: mainly sediment load, frequency of entrance of sediment-laden water and internal controls like the response to the channel lengthening and the influence of river hydrograph characteristics (**Rowland et al., 2005**).

7.3.2.4.2. Example

Mississippi's oxbow lakes

There are hundreds of oxbow lakes (Figure 6) that are periodically connected to the Mississippi River (North America) in the rainy season when increase the amount of water. The anthropogenic changes can modify the connectivity between the river and its floodplain (**Miranda, 2005**).

The trace elements like Cu, Fe, Mn, Pb, V, etc., suffers strong seasonal variations provoked mainly by processes redox by exists other minor mechanisms as changes of pH, hydrological factors like changes in discharge and mixing ratios of major tributaries that affect less the concentrations of these elements, except for Ba and U, where mixing of major tributaries with a very different concentrations is important (**Shiller, 1997**).

Some examples of fish are: pallid sturgeon (*Scaphirhynchus albus*), paddlefish (*Polyodon spathula*), round goby (*Neogobius melanstomus*), common carp (*Cyprinus carpio*), river carpsucker (*Carpiodes carpio*), logperch (*Percina caprodes*), etc. Moreover, there are introduced zebra mussels (*Dreissena polymorpha*) (**DuBowy, 2013;**

Miranda et al., 2013). There are many species of zooplankton like *Bosmina longirostris*, *Daphnia ambigua*, some genus of rotifers (*Filinia*, *Encentrum*, *Brachionus*, etc.) and others (**Burdis & Hoxmeier, 2011**). Furthermore, some examples of phytoplankton are: *Phaeodactylum tricornutum*, *Clacidiscus leptoporus*, *Odontella sinesis*, *Emiliania huxleyi*, etc (**Wawrik & Paul, 2004**).

Figure 6. Mississippi's oxbow lake. Eoearth (2008).

8. Paradigm shifts

A clear evidence of the advance in knowledge about Limnology is the amount of paradigm shifts that have resulted over the years. In this section it will explain some recent examples where scientists have showed that some old ideas are not true. It is very important to say though some ideas that arise in the field of Limnology can also affect the Oceanography for example the paradigm shifts described in 8.2 and 8.3 sections.

8.1. Nutrient limitation

Traditionally, it has been believed that phosphorus was the limiting nutrient in lakes (**Walz & Adrian, 2008**). However, there are now indications (Figure 7) that these water bodies are co-limited by the macronutrients phosphorus and nitrogen, with a contribution of micronutrients such as iron (**Lewis Jr. & Wurtsbaugh, 2008; Sterner, 2008**).

OLD PARADIGM → P is the limiting nutrient.

NEW PARADIGM → P, N and some micronutrients are the limiting nutrients.

Figure 7. The evolution of the concept of nutrient limitation.

8.2. Food webs

Currently it is known that the aquatic food webs are more diverse in their carbon sources and more versatile in their function (Figure 8). Except in the open oceans and big lakes, the benthic food influences the flow of carbon within the pelagic zone. At large scales, the biotic components do not function independently from the adjacent terrestrial system that is the source of important inputs of carbon, organic or inorganic, particulate and in solution. Therefore, the old paradigm based only in the importance of the open pelagic water has changed (**Reynolds, 2008**).

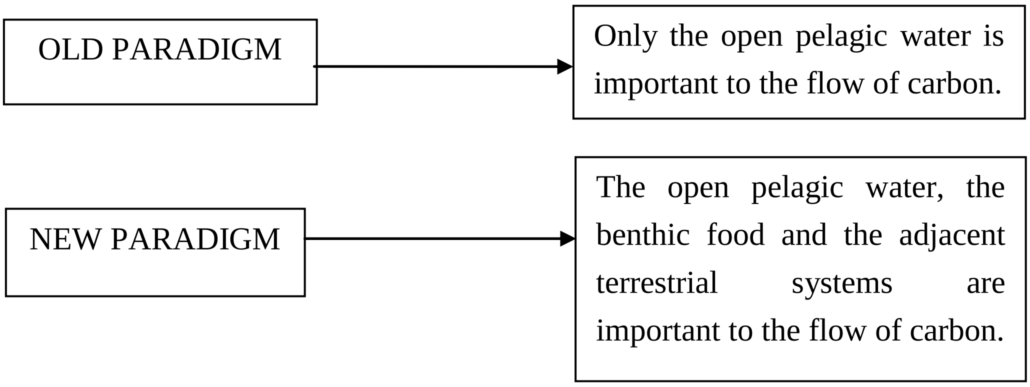

Figure 8. The evolution of the concept of food webs.

8.3. Biodiversity

Originally, it believes that diversity of genotypes, species and functional groups were consequences of ecosystems functions (like biomass production, elemental cycling, etc). Currently, the scientist known that the scenario (Figure 9) is more complicated and it is necessary to consider the biodiversity as active because its influences the ecosystems functions (**Gamfeldt & Hillebrand, 2008**). Some examples of ecosystem processes affected by the loss of biodiversity are: primary and secondary production, organic matter decomposition, carbon mineralization, oxygen production/consumption, denitrification, bioturbation, food web topology, provision of specific chemicals, etc. (**Giller et al., 2004**).

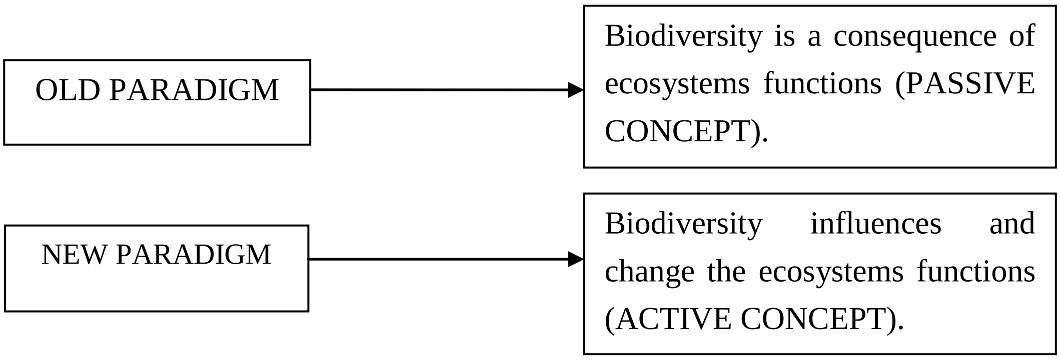

Figure 9. The evolution of the concept of biodiversity.

9. Results

This section performs a bibliometric analysis of Limnology and Oceanography to see which sector is the most researched.

9.1. Tendency in Limnology

The annual number of scientific articles on Limnology has been steadily increasing in recent years (Figure 10). These articles are found in the database of Science Citation Index (SCI) that is maintained by the Institute for Scientific Information (ISI) Web of Science (**Cao et al., 2012**).

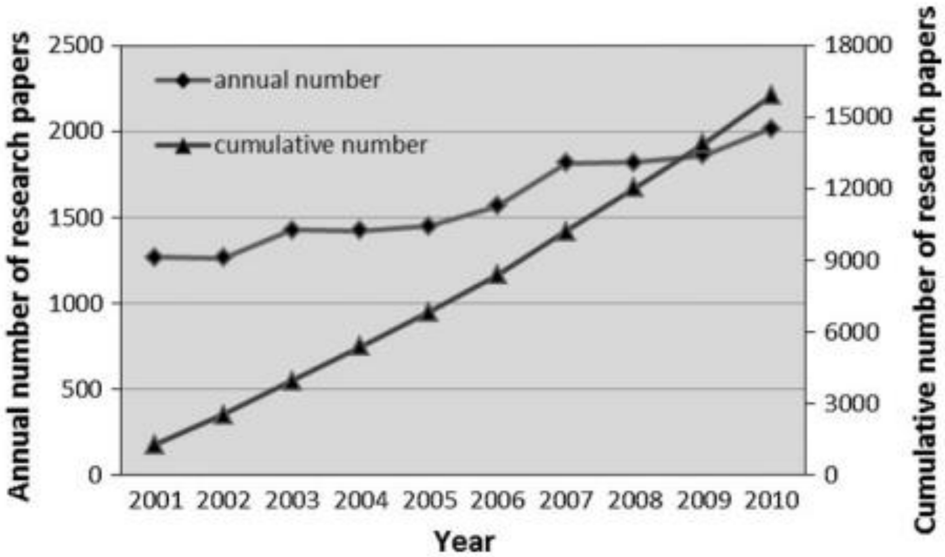

Figure 10. Annual distribution of research papers in journals under SCI category of Limnology from 2001 to 2010. Cao et al. (2012).

9.2. Publications on Limnology

It is possible to create a number of tables to give a general idea of the state of publication on Limnology in recent years from recompiled data by Scopus from 2001 to 2010. Specifically, these tables mention the first five exponents of each category, because they contain the major part of the publications, and the next 15 exponents are grouped in the name ‘Others’. The work has considered a total of 20 exponents to establish the same extension for each category.

9.2.1. Journals

The Table I summarizes the number of publications on Limnology distributed by journals from 2001 to 2010. Figure 11 represents the values of Table I expressed in percentages.

Journal	Total publications
Hydrobiologia	263
Freshwater Biology	167
Limnology and Oceanography	127
Applied and Environmental Microbiology	80
Aquatic Microbial Ecology	77
Others	771

Table I. Number of publications on Limnology distributed by journals.

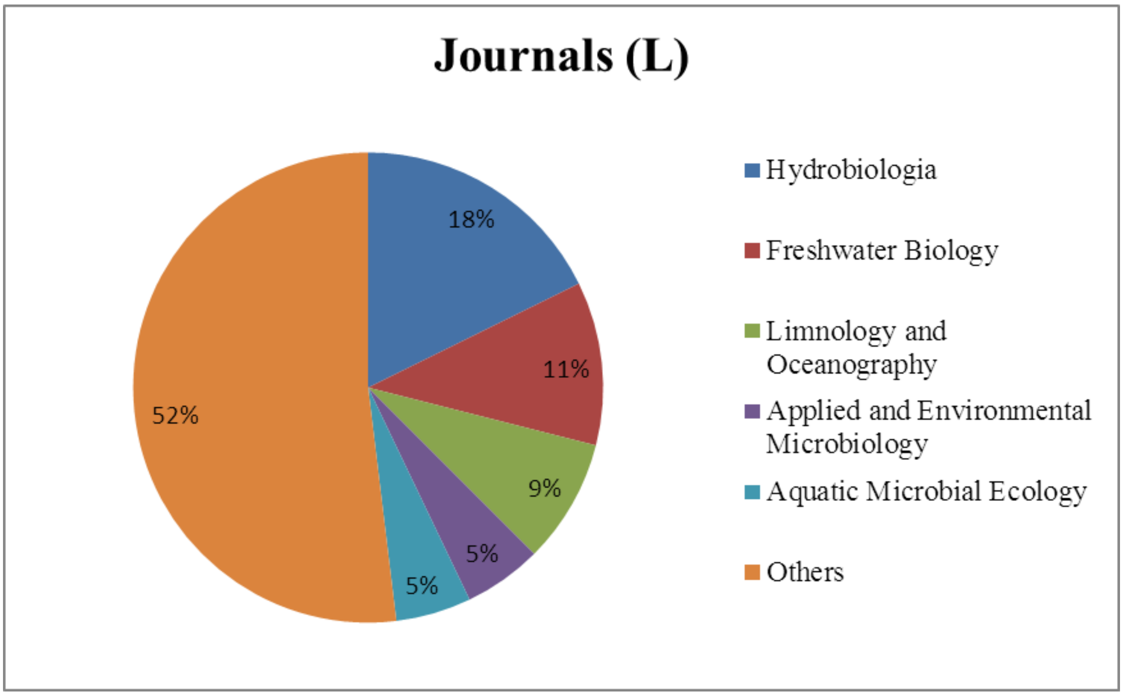

Figure 11. Representation of Table I expressed in percentages. L: Limnology.

In this category *Hydrobiologia* has the 18% of published articles but the second exponent possesses the 11%, thus there is no clear predominance of the first journal over the rest.

9.2.2. Countries

The Table II summarizes the number of publications on Limnology distributed by countries from 2001 to 2010. Figure 12 represents the values of Table II expressed in percentages.

Country	Total publications
China	1,085
Germany	1,052
United States	998
Sweden	616
Austria	498
Others	2,697

Table II. Number of publications on Limnology distributed by countries.

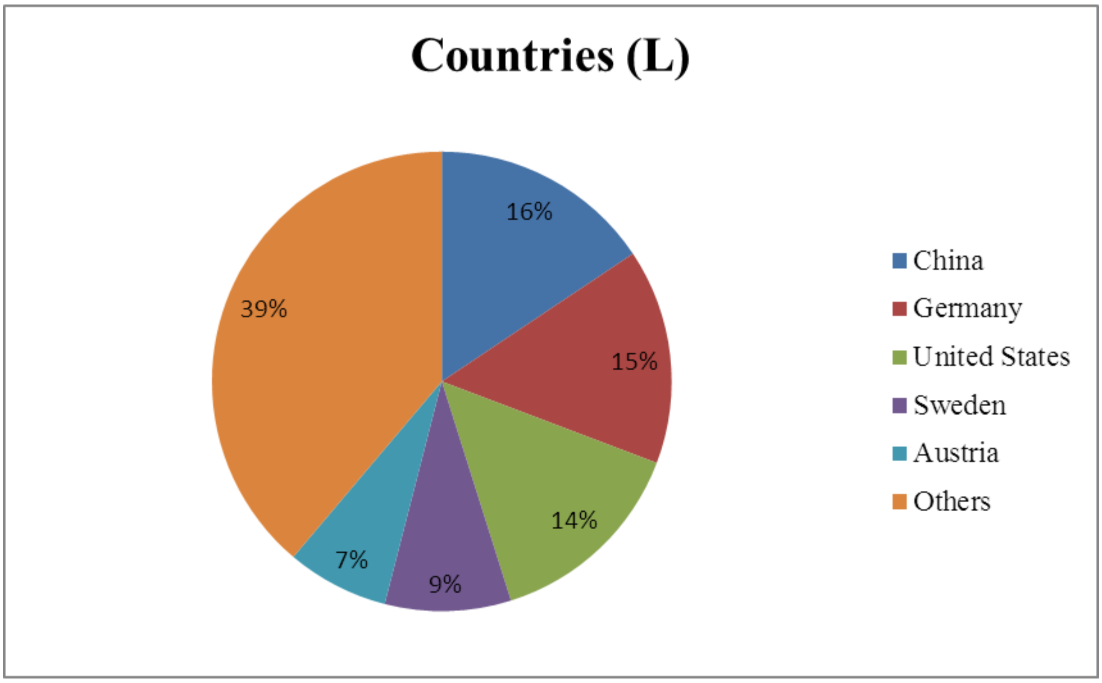

Figure 12. Representation of Table II expressed in percentages. L: Limnology.

China, Germany and USA are the dominant countries with a similar number of publications on Limnology.

9.2.3. Institutions

The Table III summarizes the number of publications on Limnology distributed by institutions from 2001 to 2010. Figure 13 represents the values of Table III expressed in percentages.

Institutions	Total publications
Nanjing Institute of Geography and Limnology	954
University of Wisconsin Madison	444
NIOO Centre for Limnology	378
Max Planck Institut für Limnologie	378
Chinese Academy of Sciences	258
Others	2,209

Table III. Number of publications on Limnology distributed by institutions.

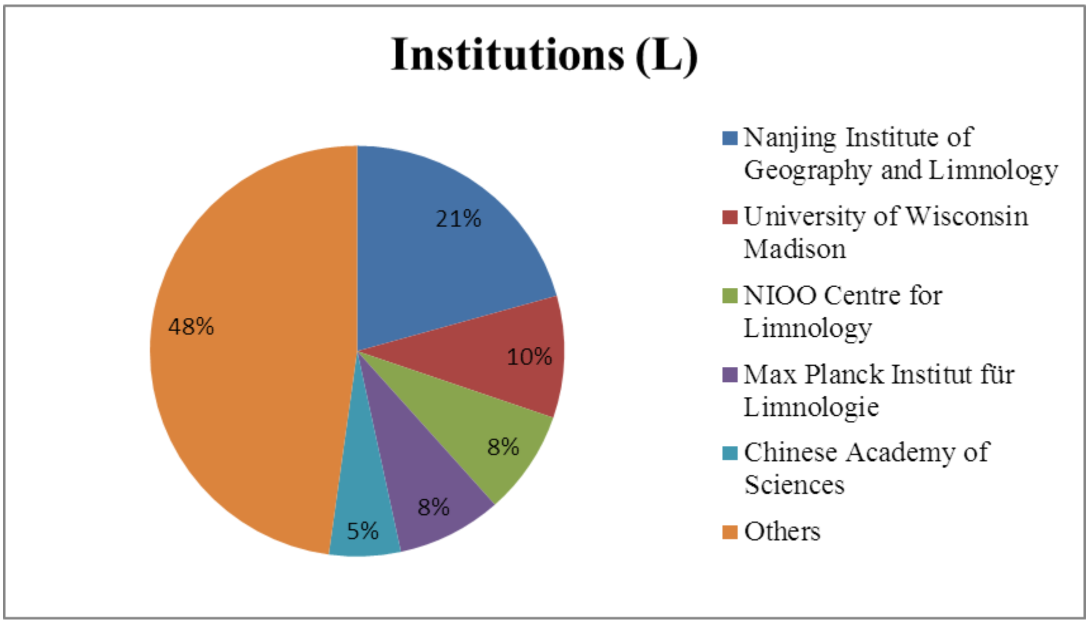

Figure 13. Representation of Table III expressed in percentages. L: Limnology.

In this category *Nanjing Institute of Geography and Limnology* clearly dominates the amount of publications with the 21% of papers.

9.3. Publications on Oceanography

To contextualize the Oceanography, the work uses again data from Scopus. The temporal interval is 2001-2010 to act in consonance with the last section. Furthermore, the work only takes into account the first twenty values to calculate the tables as those taken into account in the previous section.

9.3.1. Journals

The Table IV summarizes the number of publications on Oceanography distributed by journals from 2001 to 2010. Figure 14 represents the values of Table IV expressed in percentages.

Journal	Total publications
Journal of Geophysical Research C Oceans	924
Geophysical Research Letters	825
Journal of Physical Oceanography	581
Deep Sea Research Part II Topical Studies in Oceanography	551
Marine Ecology Progress Series	454
Others	3,778

Table IV. Number of publications on Oceanography distributed by journals.

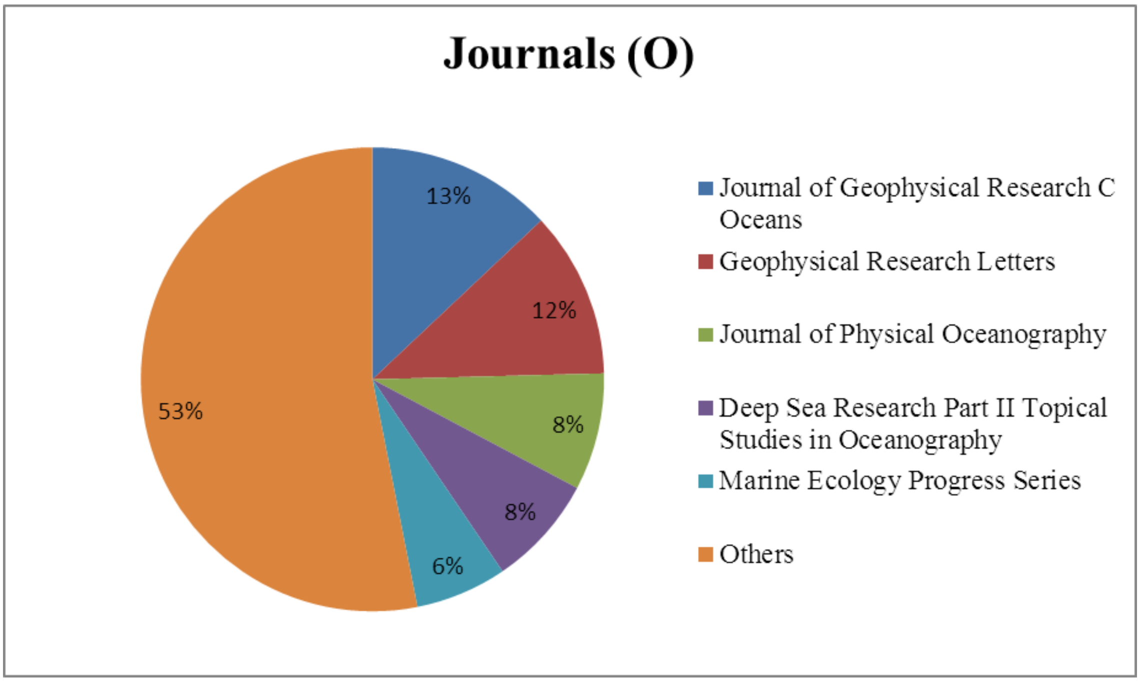

Figure 14. Representation of Table IV expressed in percentages. O: Oceanography.

Journal of Geophysical Research with 13% and *Geophysical Research Letters* with 12% are the dominant journals in this sector.

9.3.2. Countries

The Table V summarizes the number of publications on Oceanography distributed by countries from 2001 to 2010. Figure 15 represents the values of Table V expressed in percentages.

Country	Total publications
United States	11,965
United Kingdom	3,481
China	2,810
Canada	2,535
Germany	1,585
Others	10,127

Table V. Number of publications on Oceanography distributed by countries.

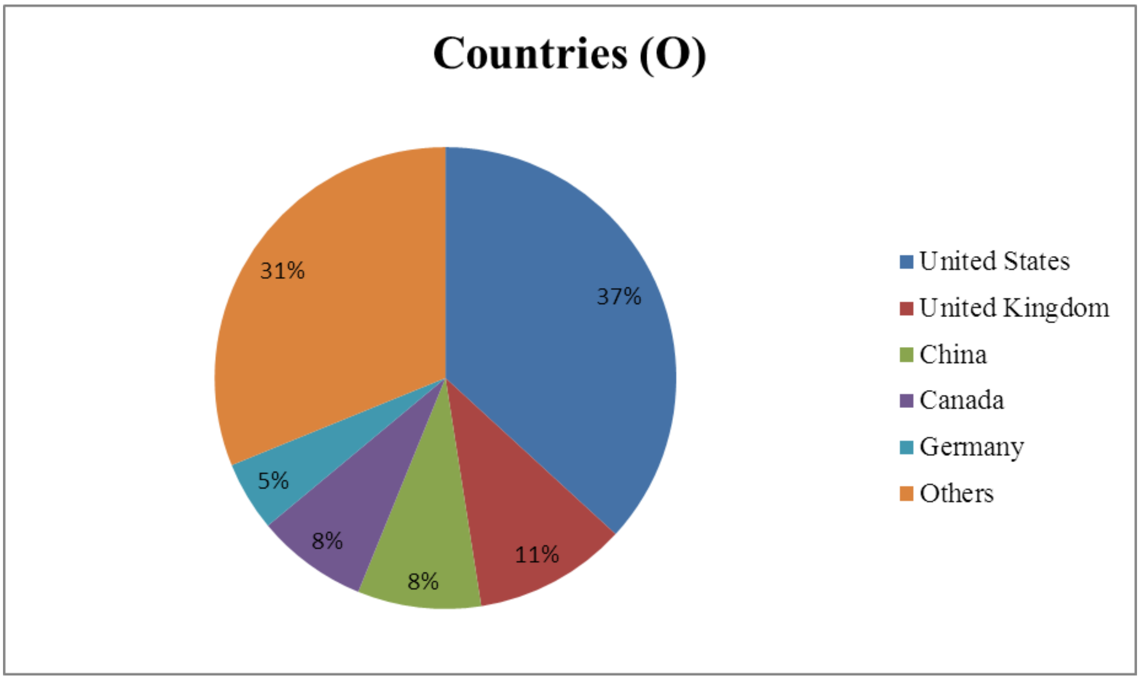

Figure 15. Representation of Table V expressed in percentages. O: Oceanography.

United States is the most productive country on Oceanography with the 37%, clearly dominating the sector.

9.3.3. Institutions

The Table VI summarizes the number of publications on Oceanography distributed by institutions from 2001 to 2010. Figure 16 represents the values of Table VI expressed in percentages. This data has been obtained in a query in Scopus.

Institution	Total publications
Scripps Institution of Oceanography	5,193
State Oceanic Administration China	1,730
University of Washington Seattle	1,211
National Institute of Oceanography India	1,198
Woods Hole Oceanographic Institution	1,116
Others	11,068

Table VI. Number of publications on Oceanography distributed by institutions.

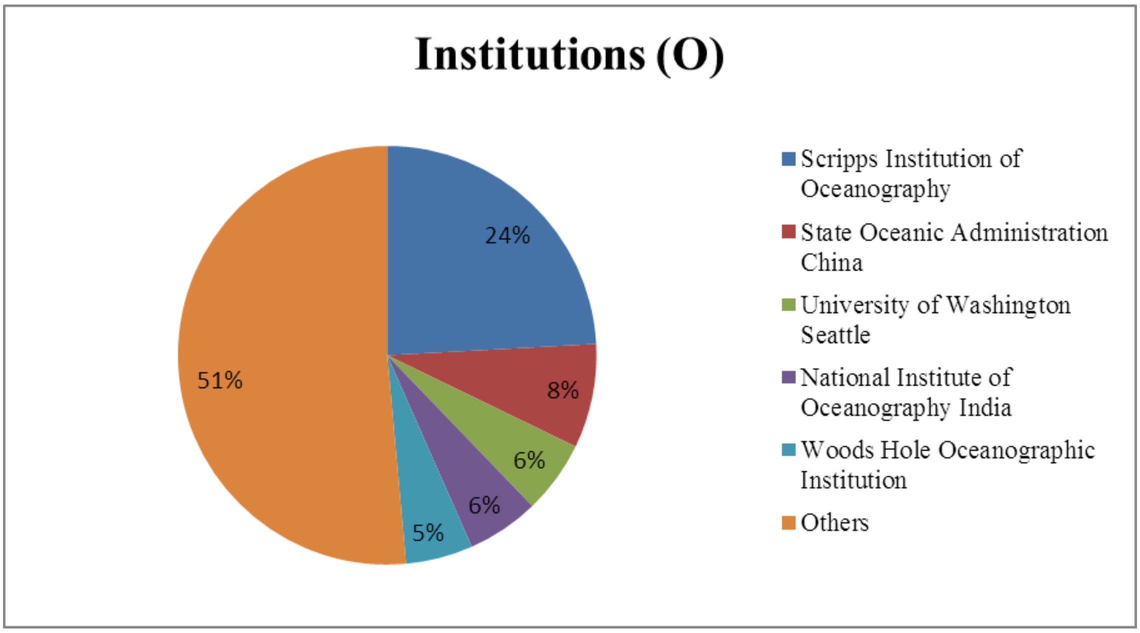

Figure 16. Representation of Table VI expressed in percentages. O: Oceanography.

Scripps Institution of Oceanography was the most productive institution in Oceanography with the 24% of the published articles from 2001 to 2010.

9.4. Comparison between Limnology and Oceanography

In this section the five first exponents and the 'Others' of each category are compared in both disciplines to give an idea of difference in the amount of publications.

9.4.1. Journals

Using the data obtained in the last two sections is possible to compare the total number of publications on Limnology and Oceanography between journals (Table VII) to know which sector was the most investigated (Figure 17).

Journal	Total publications (L)	Total publications (O)	Total (L)	Total (O)
H	263	-	1,485	7,113
FB	167	-		
LO	127	-		
AEM	80	-		
AME	77	-		
O (L)	771	-		
JGRCO	-	924		
GRL	-	825		
JPO	-	581		
DSRPTSO	-	551		
MEPS	-	454		
O (O)	-	3,778		

Table VII. Comparison between the number of publications in both disciplines distributed by journals. L: Limnology, O: Oceanography, H: Hydrobiologia, FB: Freshwater Biology, LO: Limnology and Oceanography, AEM: Applied and Environmental Microbiology, AME: Aquatic Microbial Ecology, O (L): Others (Limnology), JGRCO: Journal of Geophysical Research C Oceans, GRL: Geophysical Research Letters, JPO: Journal of Physical Oceanography, DSRPTSO: Deep Sea Research Part II Topical Studies in Oceanography, MEPS: Marine Ecology Progress Series, O (O): Others (Oceanography).

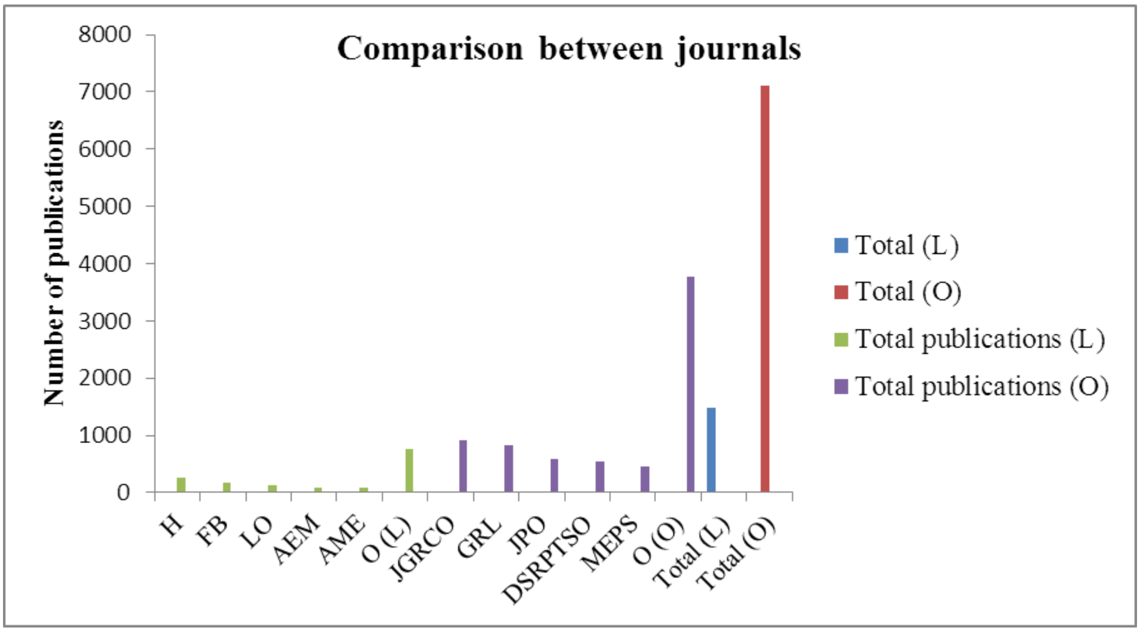

Figure 17. Comparison between journals in both topics. L: Limnology, O: Oceanography, H: Hydrobiologia, FB: Freshwater Biology, LO: Limnology and Oceanography, AEM: Applied and Environmental Microbiology, AME: Aquatic Microbial Ecology, O (L): Others (Limnology), JGRCO: Journal of Geophysical Research C Oceans, GRL: Geophysical Research Letters, JPO: Journal of Physical Oceanography, DSRPTSO: Deep Sea Research Part II Topical Studies in Oceanography, MEPS: Marine Ecology Progress Series, O (O): Others (Oceanography).

The total number of publications on Limnology is dominated by *Hydrobiologia*, but this number is approximately 4 times lower than the published articles on Oceanography by

Journal of Geophysical Research C Oceans. When the totals are compared, the total number of publications distributed by journals on Oceanography is 4.78 times larger than the publications on Limnology.

9.4.2. Countries

Using the data obtained in the last two sections is possible to compare the total publications on Limnology and Oceanography between countries (Table VIII) to know which sector was the most investigated (Figure 18).

Country	Total publications (L)	Total publications (O)	Total (L)	Total (O)
China (L)	1,085	-	6,946	32,503
Germany (L)	1,052	-		
USA (L)	998	-		
Sweden	616	-		
Austria	498	-		
O (L)	2,697	-		
USA (O)	-	11,965		
UK	-	3,481		
China (O)	-	2,810		
Canada	-	2,535		
Germany (O)	-	1,585		
O (O)	-	10,127		

Table VIII. Comparison between the number of publications in both disciplines distributed by countries. L: Limnology, O: Oceanography. O (L): Others (Limnology), O (O): Others (Oceanography).

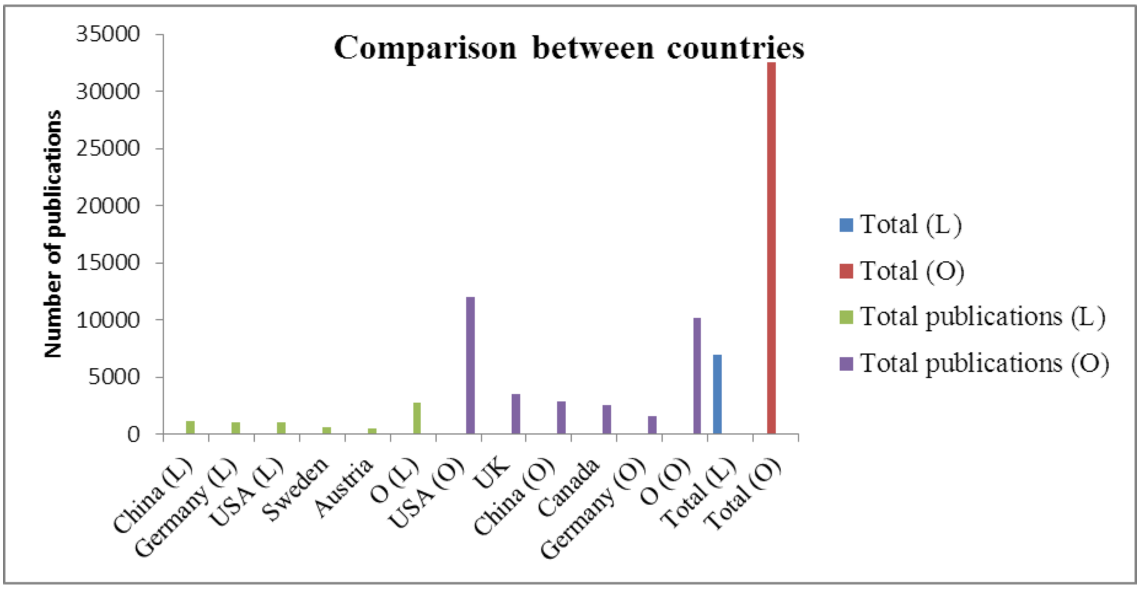

Figure 18. Comparison between countries in both topics. L: Limnology, O: Oceanography, Others (Limnology), O (O): Others (Oceanography).

This figure shows that China, Germany and United States, the three common countries in both topics, produce individually more publications on Oceanography. When the totals are compared, the total number of publications distributed by countries on Oceanography is approximately 4.67 times larger than on Limnology.

9.4.3. Institutions

Using the data obtained in the last two sections is possible to compare the total publications on Limnology and Oceanography between institutions (Table IX) to know which sector was the most investigated (Figure 19).

Institution	Total publications (L)	Total publications (O)	Total (L)	Total (O)
NIGL	954	-	4,621	21,516
UWM	444	-		
NIOOCL	378	-		
MPIL	378	-		
CAS	258	-		
O (L)	2,209	-		
SIO	-	5,193		
SOAC	-	1,730		
UWS	-	1,211		
NIOI	-	1,198		
WHOI	-	1,116		
O (O)	-	11,068		

Table IX. Comparison between the number of publications in both disciplines distributed by institutions. L: Limnology, O: Oceanography, NIGL (Nanjing Institute of Geography and Limnology), UWM: University of Wisconsin-Madison, NIOOCL: NIOO Centre for Limnology, MPIL: Max Planck Institut für Limnologie, CAS: Chinese Academy of Sciences, O (L): Others (Limnology), SIO: Scripps Institution of Oceanography, SOAC: State Oceanic Administration China, UWS: University of Washington Seattle, NIOI: National Institute of Oceanography India, WHOI: Woods Hole Oceanographic Institution, O (O): Others (Oceanography).

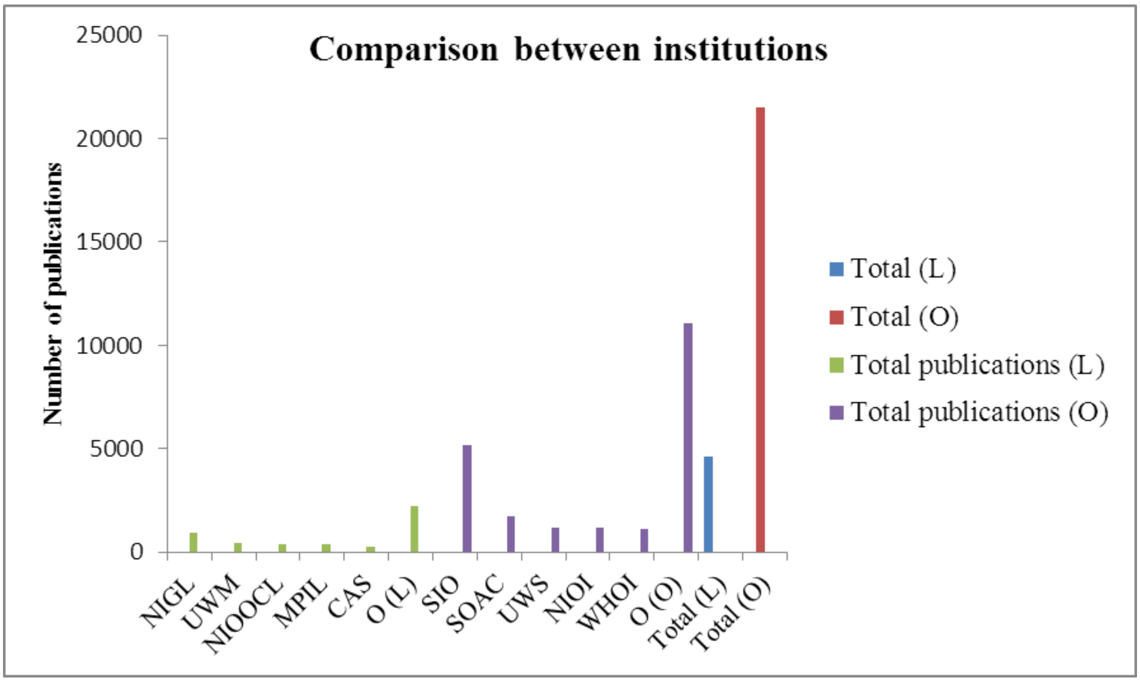

Figure 19. Comparison between institutions in both topics. L: Limnology, O: Oceanography, NIGL (Nanjing Institute of Geography and Limnology), UWM: University of Wisconsin-Madison, NIOOCL: NIOO Centre for Limnology, MPIL: Max Planck Institut für Limnologie, CAS: Chinese Academy of Sciences, O (L): Others (Limnology), SIO: Scripps Institution of Oceanography, SOAC: State Oceanic Administration China, UWS: University of Washington Seattle, NIOI: National Institute of Oceanography India, WHOI: Woods Hole Oceanographic Institution, O (O): Others (Oceanography).

When the totals are compared, the total number of publications distributed by institutions on Oceanography is 4.65 times larger than on Limnology.

10. Discussion

It is observed that existed 4.7 times (mean of journals (4.78), countries (4.67) and institutions (4.65)) more publications on Oceanography than on Limnology from 2001 to 2010. Not surprisingly, the countries that published more in both disciplines tended to belong to the G8, e.g. USA, UK, Germany and Canada, as they have more money to research. United States clearly was the most productive country on Oceanography, dominating the three categories. However, there was no country that dominated in all categories on Limnology although China was the better candidate because it led two (countries and institutions).

It is important to be aware that the statements drawn from these results have an error determined by a number of limitations that the work have been tried to minimize to compare the two disciplines (Limnology and Oceanography): the time, data were limited to a time period between 2001-2010; the extension, the work takes into account only the first 20 exponents of each category for the realization of tables and graphics;

the simultaneity, there are exponents in one discipline that are not present in the other discipline; the lack of citation of all publications, the source that provided the data do not take into account all existing articles in both disciplines but yes the majority. However, the error introduced by these factors does not change the final conclusion at qualitative level: Oceanography was more investigated than Limnology during the period 2001 to 2010.

It was not found similar studies because the bibliometric analysis often do not refer to Oceanography as a whole, unlike the Limnology, but only to certain disciplines related to the sea as biodiversity (**Liu et al., 2011**), ocean technology (**Dastidar & Ramachandran, 2005**), climate change (**Li, et al., 2011**) and others, or these analysis are usually concentrated in certain geographical regions such as Iberian Peninsula (**Borja, et al., 2013**), Adriatic sea (**Vilibić, 2009**), etc., and they do not comment the Oceanography at global level.

11. Conclusion

The work has shown that the initial hypothesis was correct; there were more publications on Oceanography than on Limnology from 2001 to 2010. Specifically, there were 4.7 times more publications on Oceanography. Therefore, is necessary to increase the number of publications on Limnology during this current decade, because the concepts that can be drawn in a sector can apply in another sector as the paradigm shifts section has shown, whose concepts such as the biodiversity and the food webs also affect the Oceanography, although the ideas of paradigm shift arose in the field of Limnology.

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14. Description of the activities undertaken during the TFT

The realized activities were the recompilation of the information, the interpretation, the synthesis and the redaction.

15. Training received

I have not received any extra course. The information gathering was performed using computing resources learned during the college career as Scopus, ScienceDirect, Faro and others.

16. Positive and negative aspects related to the development of TFT

Positive aspects: I especially liked learning the different types of lakes in the world and their features. Furthermore, I have learned to develop a bibliographic work providing my personal contributions to the author's data and combine them thanks to the advices of teachers during the presentation of the previous version of this work.

Negative aspects: I would have liked to come to a better understanding with those who reviewed my work to maximize their aid.

17. Personal assessment of learning achieved throughout the TFT

Thanks to the advice of teachers I have learned a lot about Limnology and this has allowed me to satisfy my intellectual interest in this subject. Furthermore, although I was a little bit astonished at first, now I think that it has been positive to have done this second version of the work, because I have corrected wrong ideas, which is good for the workplace, and I have learnt how to do a better bibliographical work.