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Mangroves: A Threatened Ecosystem Under-Utilized as a Resource for Scientific Research

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Abstract

Nearly half of the global population lives within 150 km of a coastline, placing mangrove forests under incessant anthropogenic pressure. The mangrove ecosystem is one of the most productive ecosystems on the globe, despite being one of the most threatened. The land area covered by the mangrove ecosystem has been reduced by more than half in the last 40 years. This work evaluated the international scientific production of articles focusing on mangroves, connecting the current lack of knowledge with the observed rapid mangrove degradation rates. The Antarctic and Coral Reef ecosystems were used as comparative environments, and this paper found that in the past century, mangrove forests have not attracted the same level of worldwide scientific attention or interest. This lack of research on mangroves is primarily shared by the countries that contain large mangrove land areas, such as Australia, Brazil, Indonesia, Malaysia and Mexico. Increasing our knowledge of mangrove forests through scientific research could help preserve this valuable ecosystem by increasing public awareness and driving new policies and protection arrangements. This important ecosystem, with its rich biodiversity, bio-technological potential and related ecological and social benefits, must be saved on a global scale.

Keywords: Antarctica, coral reef, loss of biodiversity, mangrove forest, science production, threatened ecosystem

1. Introduction

Mangrove ecosystems, which are composed of mangrove forests, are among the most productive and biologically important ecosystems in nature (Giri et al., 2011; Sandilyan & Kathiresan, 2012). They provide important and unique ecological benefits to human society as well as to coastal and marine systems. Specifically, mangrove forests provide breeding, shelter and nursing grounds for marine species, and food, medicinal substances and fuel for coastal communities. Recently, another important function of mangrove ecosystems, protection against coastal disasters, has been identified (Das & Vincent, 2009). In addition, mangroves sequester up to 5.5 million tons of carbon per year (Ong, 1993) and provide oceans with more than 10% of their essential organic carbon (Dittmar, Hertkorn, Kattner, & Lara, 2006); they are considered environments of intense carbon flux (Siikamakia, Sanchiricoa, Jardinec, 2012). Mangrove forests are essential for the economy of many coastal regions, providing at least 1.6 billion U.S. dollars per year in ‘‘ecosystem services’’ worldwide (Costanza et al., 1997). It is estimated that nearly 80% of all global fish catches are directly or indirectly dependent on mangroves (Ellison, 2008; Polidoro et al., 2010).

Almost half of the global population lives within 150 km of a coastline (Cohen, Small, Mellinger, Gallup, Sachs, 1997); thus, anthropogenic influences strongly affect mangrove ecosystems. The global area of mangrove forests has been reduced by more than half, and most of what remains shows high levels of degradation (Spiers, 1999; Spalding, Kainuma, Collins, 2010). Approximately 35% of all mangrove trees were lost between 1980 and 2000, and mangrove forests have been declining at a faster rate than both inland tropical forests and coral reefs (Duke et al., 2007). Recent predictions suggest that 100% of mangrove forests could be lost in the next 100 years if the present rate of loss continues (Duke et al., 2007). Consequently, important ecosystem products and services that are provided by mangrove forests (e.g., natural barrier formation, carbon sequestration and biodiversity richness) will be diminished or completely lost. The rapid degradation or disappearance of mangroves could also have negative consequences for the transfer of organic and inorganic materials into marine systems, strongly influencing atmospheric composition, climate changes and the relative sea level.

Mangrove ecosystems are found on almost all continents. However, according to Giri et al. (2011), a small group of only 19 countries contains 79.1% of the global mangrove area. Among these countries, Indonesia, Australia and Brazil play a remarkable role because they contain 22.6, 7.1 and 7.0%, respectively, of the world's mangroves, or 36.7% together. Unfortunately, the ecological degradation of this ecosystem is not different among these countries; many mangrove regions have become completely degraded or are under constant environmental stress, primarily due to the expansion of urban centers and agricultural production. This damaging scenario is shared by several countries, making mangrove degradation a global issue with worldwide consequences (Giri et al., 2011; Polidoro et al., 2010). In fact, lack of specific laws applicable to protect and to allow sustainable exploitation of this environment increases the probability for expanding degradation of mangrove forests.

Measuring and evaluating the global scientific knowledge of a natural environment or a specific biome, ecosystem, plant or animal is particularly helpful to confirm its actual relevance for countries, governments and their populations. Such data could also help society and the scientific community establishes public policies and economic measures to protect neglected and impacted natural resources. The scientific production of papers related to mangrove systems could reflect the actual condition of this environment and its conservation locally or globally. Thus, this work aims to evaluate the global research and scientific production concerning mangroves and specifically examines three things: a) the possible technological applications of the obtained data; b) the role that the most prominent mangrove countries play in this scenario; and c) the state of mangrove degradation in various countries. The results presented here reinforce the need for a favorable evaluation of this scientific area of study. We expect to stimulate the interest in researching mangrove forests and also to spread out the concept of its economic, biotechnological and ecological importance. Altogether this effort may end up improving the collaboration between the scientific community and governments to aid the preservation of this unique ecosystem.

2. Methods

The database of scientific papers used in this work was the Web of Science, ISI from Thomson Reuters, Philadelphia, USA. The data were obtained from the ISI Web of Science by a search using "mangrove" for publications that were published by select countries between 1901 and 2012. The same scientific publication searches over the same periods were performed by "Antarctica" and coral reefs were used only as "comparative ecosystems". Antarctica and coral reef were chosen because they also have unique features and presents global relevance, being as important as mangroves, but with particular differences in terms of research efforts and costs. It is well perceived that research in Antarctica requires higher funding resources and more strategically planned efforts. All of the barriers and limitations associated with field research in Antarctica make it a good ecosystem to compare with mangroves by studying the worldwide interest, as represented by scientific research and publications. Additionally, Antarctica is an uninhabited and isolated continent with extreme weather conditions. In contrast, mangrove areas are found in 118 countries and territories (Giri et al. 2011).

The database searches were started in May 2012, and all data were reviewed and analyzed from May 1 to May 15, 2013. The papers included in this analysis were articles, proceeding papers and reviews published during this period (1901-2012). Twenty-five countries were selected according to two parameters: a) the highest numbers of publications related to mangroves (15 countries) and b) the largest areas of mangrove forests (10 countries). The search using coral reef as subject was made in August 2014, including articles, proceeding papers and reviews published until 2012, as the same way as used to search mangrove.

All of the Antarctica results are presented, excluding publications related to the yeast *Candida antarctica.* All searches for *C. antarctica* were performed in exactly the same way as those for the ecosystems, and the quantities found were excluded from the Antarctica search results.

To determine the number of publications produced, some important aspects related to the results must be considered. Some technical problems exist with simply counting publications (Gauffriau, Larsen, Maye, Roulin-Perriard, von Ins, 2007). In the whole counting method, one credit is conferred to each country that contributed to a publication. As described previously (Larsen and von Ins 2010), whole counting is problematic: the numbers are non-additive; therefore, the publication number for a union of countries or for the world can be smaller than the sum of the publication numbers for the included countries. The indiscriminate use of whole counting leads to double counting. Thus, all of the results presented here that are related to world counting are only from the main Web of Science results, and the sums of country counts, are never used in order to avoid double counting issues.

We have to state that we are not claiming that mangroves are more important than Antarctica or coral reef or that mangroves should be more studied, but at least studied at same level, facing all reasons we will discuss in this manuscript. Antarctica and coral reef were chosen only for comparative matters.

3. Results and Discussion

As previously highlighted, mangroves present unique features and show wide biological and genetic diversity, reaching an estimated economic value of 900,000 U.S. dollars ha^{-1} for their by-products (Sandilyan & Kathiresan, 2012). Because of the proximity with densely populated cities, it is expected that mangroves would be well studied and that their characteristics and technological potentialities would be thoroughly known. However, as we showed here, it is not the real scenario. In this work, we aim to determine the actual scientific production concerning mangroves and relate this production to the primary countries with mangrove areas. We also attempt to elucidate the primary fields of research in which the published scientific papers occur. With this study, we stress the need to address the alarming state of mangrove ecosystem conservation. Mangrove ecosystems are certainly at risk, and we believe that the improvement of knowledge about this ecosystem is one of the keys to protect and to explore it rationally.

The scientific data published on mangroves, as a subject of research is shown in Table 1. For comparison, the publications on Antarctica, which represent another ecosystem as ecologically important as mangroves, are also shown in Table 1. This table depicts the number of scientific articles published over several different but continuous periods beginning in 1901. In fact, the first paper about mangroves was published in 1903. Three main types of publications from the Web of Science database are included in this study: scientific articles (96.6%), of which 6.8% are papers from proceedings, and reviews (3.4%), which are all generically termed articles for the purposes of this paper. Over the course of nine decades (1901 – 1990, Table 1), few articles were published on mangroves. However, in the last 22 years (1991 – 2012), there has been an 11.4-fold growth in the number of publications related to mangroves (667 papers in the former period and 7,621 in the latter). Between those same periods, the number of publications on Antarctica (from 1,939 articles to 17,931) increased 9.2-fold. However, a much greater number of articles have been published concerning Antarctica than on mangrove ecosystems throughout the entire period, as shown in Table 1 (a 2.4-fold higher average publication rate). Notably, the first article on Antarctica was published in 1901. Altogether, these data clearly indicate that mangrove ecosystems were relatively unnoticed by scientists for more than 80 years. In fact, the importance of mangrove wetlands was acknowledged by the scientific community only after 1978, when the United Nations Educational, Scientific and Cultural Organization (UNESCO) scientific committee established a working group on mangrove ecology to assess its importance (Sandilyan & Kathiresan, 2012). This fact may explain the continuing lack of thorough scientific knowledge of mangroves, and such a dearth of information only increases the risk of losing mangrove forests in the next century, as predicted (Duke et al., 2007). The great difference in scientific production between the two environments, favoring Antarctica, is surprising. Because the effort and cost to study Antarctica's environment is so much higher than that of mangrove research, an opposite situation would be expected. Additionally, mangrove studies do not occur in extreme climate conditions or require the large logistic and financial investments that research in Antarctica entails. The idea here is not to put down the importance of researching Antarctica ecosystem. Differently, we want to stress that the mangrove, though been located in urban and easily accessible areas has been little exploited scientifically. Moreover it has been highly degraded. A greater and more collaborative work through ecological and economic research on the value of estuarine and coastal ecosystems could help to change this scenario, as proposed by Barbier et al. (2011).

In order to explore some other comparison, the same described search was performed using "coral reef", another important researchable ecosystem as subject. Table 2 shows that using coral reef as subject, 18,722 articles were published in the whole world covering the available period (1945 – 2012) by the 15 countries listed in the Web of Science database which contained highest number of publications in mangrove. These numbers for Antarctica and mangrove were 19,870 and 8,288, respectively. The data indicate that coral reef, an ecologically similar ecosystem, though having a much smaller global area, it presents a 2.4-fold higher average publication rate as compared to mangrove. As with Antarctica a 2.5-fold higher publication number was found but in both cases comparing country by country, a much higher proportion to mangrove was found, specially among the most developed countries such as England, Germany, France, Canada and USA. In summary, altogether the research data for the three ecosystems reinforce our proposition that mangrove wetlands are under-utilized as resource for scientific research.

Table 1. The numbers of worldwide publications related to mangrove forests and to Antarctica from 1901 - 1975 and 1976 - 2012, in five-year periods

Period	Years	Number of publications*		Ratio of Antarctica to Mangrove
		Mangrove	Antarctica	
1	1901-1975	90	574	6.4
2	1976-1980	96	253	2.6
3	1981-1985	165	415	2.5
4	1986-1990	316	697	2.2
5	1991-1995	744	2,328	3.1
6	1996-2000	1,130	3,437	3.0
7	2001-2005	1,600	4,414	2.8
8	2006-2012	4,147	7,752	1.9
Total Publications		8,288	19,870	2.4

*Publications include articles, proceeding papers and reviews. The data were acquired by searching for publications with mangroves and Antarctica as the subjects.

Source: Web of Science, ISI

Table 2. Comparative scientific production in the ecosystems: coral reef, Antarctica and mangrove

COUNTRY	NUMBER OF ARTICLES					
	ECOSYTEMS			RATIOS		
	Coral Reef* A	Antarctica** B	Mangrove** C	A / B	A / C	B / C
USA	7,229	6,509	1,857	1.11	3.89	3.51
Australia	4,559	2,859	1,061	1.59	4.30	2.69
England	1,338	2,909	368	0.46	3.64	7.90
France	1,287	1,435	311	0.90	4.14	4.61
Japan	1,114	1,085	491	1.03	2.27	2.21
Germany	947	2,188	443	0.43	2.14	4.94
Canada	918	835	201	1.10	4.57	4.15
Netherlands	567	538	188	1.05	3.02	2.86
Mexico	497	45	289	11.04	1.72	0.16
Brazil	370	254	704	1.46	0.53	0.36
China	358	669	870	0.54	0.41	0.77
India	198	574	837	0.34	0.24	0.69
Belgium	186	375	181	0.50	1.03	2.07
Malaysia	76	30	217	2.53	0.35	0.14
Thailand	73	6	244	12.17	0.30	0.02
World	18,722	19,870	8,288	0.94	2.26	2.40

The 15 countries included were selected by the highest number of publications related to mangrove forests.

Source: ISI web of Science - Thomson Reuters. Number of publication from *1945-2012 and **1901-2012 and included articles, proceedings and reviews.

Table 3. The countries* with the largest mangrove land area and those with the highest number of publications related to mangrove forests: 1901 – 2012

Publications**				Area		
World Ranking	Country	Number (A)	%	(ha)***	%	Ratio of (A) per 1000 ha
1	USA	1,857	22.41	197,648	1.38	9.4
2	Australia	1,061	12.8	977,975	7.1	1.08
3	China	870	10.5	22,480	0.16	38.7
4	India	837	10.1	368,276	2.7	2.27
5	Brazil	704	8.49	962,683	7	0.73
6	Japan	491	5.92	800	0.006	613.75
7	Germany	443	5.35	0	0	----
8	England	368	4.44	0	0	----
9	France	311	3.75	0	0	----
10	Mexico	289	3.49	741,917	5.4	0.39
11	Thailand	244	2.94	244,085	1.77	1
12	Malaysia	217	2.62	505,386	3.7	0.43
13	Canada	201	2.43	0	0	----
14	Netherlands	188	2.27	0	0	----
15	Belgium	181	2.18	0	0	----
23	Philippines	100	1.21	263,137	1.9	0.38
27	Nigeria	76	0.92	653,669	4.7	0.12
32	Bangladesh	70	0.84	436,570	3.2	0.16
35	Indonesia	67	0.81	3,112,989	22.6	0.02
41	Mozambique	41	0.49	390,500	2.3	0.1
49	Cuba	27	0.33	421,538	3.1	0.06
76	Papua New Guinea	7	0.08	480,121	3.5	0.01
94	Myanmar	5	0.06	494,584	3.6	0.01
114	Guinea Bissau	0	0	338,652	2.5	0
101	Madagascar	3	0.04	278,078	2	0.01
Total Table		8,658	104.47	10,891,088	79.06	
Other (99) Countries				2,883,207	20.94	
World		8,288	100	13,774,295	100	

*The 25 countries included were selected by one of two parameters: the highest number of publications related to mangrove forests (15 countries) or the largest area of mangrove forests (10 countries).

**The number of publications was obtained from the ISI Web of Science by a search using mangrove as the subject. Publications included articles, proceedings and reviews.

***Data from (FAO, 2011; Giri et al., 2011).

Table 3 shows the number of publications from the most productive countries and compares those numbers with the sizes of their mangrove forests. A total of 8,288 articles about mangroves were published in the 112 years covered in this study. Table 3 also shows that a group of 15 countries is responsible for the majority (82.38%, excluding 21% due to double counting) of these publications. Among that group, seven countries (Japan, Germany, England, France, Canada, the Netherlands and Belgium) have no mangrove forests or, in the case of Japan, very few. On the other hand, ten countries (the Philippines, Nigeria, Bangladesh, Indonesia, Mozambique, Cuba, Papua New Guinea, Myanmar, Guinea Bissau and Madagascar) contain very large areas of mangrove ecosystems (49.4% of the global mangrove area) but have produced an insignificant number of scientific articles concerning them. In fact, among the countries with a significant area of mangroves, Brazil is the only one dedicating any attention to the study of mangroves (704 articles). Table 3 also indicates that there is a difference in the number of total articles when double counting is removed. According to our search of the ISI Web of Science, when we exclude double counting the total number of mangrove articles across the 25 countries in this study drops to 7,038 articles. Thus, 23% of the articles were double counted, indicating that 23% of mangrove studies were collaborative work among authors from different countries. This percentage is smaller than the 28% international collaboration rate observed for all scientific articles worldwide (Almeida & Guimarães, 2013). With the little knowledge of mangroves available to us, there is no way to fully comprehend the richness of such a system; thus, there is no way to fully explore its possibilities or understand what we are losing. By destroying this ecosystem, some of the countries discussed in this paper are losing great opportunities that can only be understood by acquiring more information concerning the characteristics and value of mangroves. As stated previously, it is crucial to study the potential of mangroves in order to help a better understand about the need for their preservation and sustainable use (Barbier et al., 2008), which is also important to increase collaborative biological/ecological and economic research thus providing better estimations on the value of ECE (estuarine and coastal ecosystems) (Barbier et al., 2011). The ratio of the number of publications in a country to its total mangrove area (described as the number of articles per 1,000 ha of mangrove ecosystem) (Table 3) reflects the country's actual scientific effort, or its knowledge production index for mangrove areas. Among the countries possessing some mangrove forests, Japan has the highest production ratio, followed by China and the USA, which each have much lower ratios. It is notable that scientists from Canada and some European countries, such as Germany, England, France, the Netherlands and Belgium, have been attracted to study this ecosystem and are producing an important number of articles on the subject, even though their countries have no mangroves (Table 3). A similar situation could be detected measuring the scientific production related to coral reef and, again, presenting much greater numbers than mangrove.

In the current global economic scenario, according to a ranking of national gross domestic products (GDP) (UN, 2011), Brazil, together with Russia, India, China and South Africa (The BRICS group), are classified as emerging nations with fast growing economies. Given its emerging national status, Brazil's low mangrove research index (0.73 articles per 1,000 ha) throughout the timeframe under study is worrying. The development of research projects about mangroves could generate more accurate knowledge on the subject that would benefit all countries. Thus, it is critical that the countries containing extensive mangrove forests take responsibility for developing research projects and other studies, alone or in productive collaboration with other countries, to better understand and protect this valuable environment.

The scientific publications on mangroves cover a great number of research fields. Most of the articles are related to basic disciplines, such as marine freshwater biology, environmental sciences/ecology, and plant sciences. Table 3 lists the number of publications in each of the main fields, ranked according to their quantitative weight for the 15 most productive countries and the world. With the exception of oceanography, geology and fisheries in some countries, this table emphasizes the relatively low number (in almost all countries) of publications in applied fields, including pharmacology/pharmacy, agriculture, biotechnology, applied microbiology, food science technology, business economics, materials science, energy fuels, and others. The small number of publications in these fields reflects the lack of interest in applying the great potential of mangrove ecosystems. As we have already noted, these data indicate that the opposite of the expected situation is occurring, as Antarctica is more often studied, regardless of the huge potential of mangrove biodiversity. Papers with Antarctica as the research subject (Table 3) are similar to mangrove research articles in many basic scientific fields. However, a different pattern is apparent in the articles on Antarctica in applied fields such as geology, meteorology/atmospheric sciences, oceanography, science technology and other topics, which appear to be highly motivated areas of research, particularly among the more developed countries. In fact, altogether those four applied fields represent the majority (55.6%) of the articles published in the studied period. As the mangroves have a well known high biodiversity, we should expect the same difference in favor of mangroves over specific areas within biotechnology and environment; but, in general, was not the case. By itself it is attesting the underestimation of mangrove environment as scientific source to produce science and technology. Recently, drug research groups have stated that mangroves are a source of new medicine and will be new frontiers for drug discovery in the future (Regunathan & Kitto, 2009). Furthermore, the potential of mangrove forests as sources of microorganisms for use in biotechnology is immeasurable (Sandilyan & Kathiresan, 2012; Thompson et al., 2013). Therefore, it is clear that increasing the knowledge about mangrove systems will be crucial to manage the rational exploration of all their potentialities.

Table 4. The research fields of papers related to mangrove forests and to Antarctica from the 15 countries with the highest number of publications (1903-2012)

Area	Ecosystem	Australia	Belgium	Brazil	Canada	China	England	France	Germany	India	Japan	Malaysia	Mexico	Netherlands	Thailand	USA	World
Biotechnology																	
Computer science	Mangrove	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	4
	Antarctica	1	1	0	2	1	5	2	3	0	2	1	0	0	0	11	31
Marine freshwater biology	Mangrove	485	83	179	46	153	125	72	113	104	104	56	95	93	70	596	2,381
	Antarctica	268	47	24	75	28	211	91	252	6	46	1	6	49	0	486	1,649
Biochemistry molecular biology	Mangrove	20	1	21	5	76	8	14	13	40	43	6	7	1	9	43	280
	Antarctica	38	8	11	27	21	32	24	46	17	21	4	2	16	1	94	367
Pharmacology pharmacy	Mangrove	10	2	6	1	147	10	2	27	35	13	5	3	0	12	17	258
	Antarctica	4	0	1	0	2	3	3	10	0	2	0	0	1	0	6	34
Microbiology	Mangrove	6	2	27	8	48	6	8	22	46	35	1	10	7	18	34	237
	Antarctica	67	27	17	41	44	67	34	107	63	37	0	2	15	1	159	719
Biotechnology applied microbiology	Mangrove	2	0	9	2	50	2	2	8	52	35	9	5	1	13	17	202
	Antarctica	12	4	3	21	18	17	9	26	18	27	2	3	1	0	51	249
Science technology other topics	Mangrove	17	2	22	4	17	9	18	11	75	3	15	4	2	2	37	220
	Antarctica	69	14	3	32	79	142	72	64	72	35	0	1	21	0	328	882
Mycology	Mangrove	8	0	8	1	22	15	1	1	20	13	5	1	2	17	20	117
	Antarctica	9	0	0	2	0	18	0	13	0	3	0	0	8	0	18	87
Tropical medicine	Mangrove	1	0	2	0	0	2	2	0	8	0	1	0	0	1	1	20
	Antarctica	0	0	1	0	0	3	1	0	0	0	0	0	0	0	2	5
Biophysics	Mangrove	3	0	1	0	1	0	0	0	6	0	0	0	0	1	2	13
	Antarctica	9	3	2	3	3	7	3	7	5	3	3	0	7	0	19	74
Reproductive biology	Mangrove	0	0	4	0	0	0	0	2	0	0	1	0	1	0	1	11
	Antarctica	2	0	0	0	0	0	0	0	0	0	0	0	0	0	3	5
Environment																	
Environmental sciences ecology	Mangrove	375	64	192	69	227	112	84	91	193	101	49	100	66	57	747	2481
	Antarctica	594	101	80	157	124	538	219	473	40	107	9	4	100	2	971	3919
Oceanography	Mangrove	265	34	60	19	36	34	50	44	125	44	20	33	53	24	293	1116
	Antarctica	246	65	14	73	27	251	129	264	32	73	0	0	61	0	616	1696
Water resources	Mangrove	28	5	33	3	16	12	11	17	36	17	10	18	6	9	49	274
	Antarctica	4	1	3	6	4	11	6	8	1	3	1	1	0	0	33	92
Geology	Mangrove	95	20	101	26	23	34	60	61	66	21	9	12	30	14	166	629
	Antarctica	956	125	61	285	211	1074	453	670	230	348	4	12	176	2	2,191	6,393
Toxicology	Mangrove	11	2	19	2	21	5	5	1	15	2	4	6	0	0	17	109
	Antarctica	8	3	0	5	1	6	4	10	3	1	0	0	1	0	4	53
Agriculture and Food																	

Plant sciences	Mangrove	139	30	28	16	153	42	22	80	112	76	18	32	17	39	183	1037
	Antarctica	136	12	3	31	23	76	15	94	8	18	0	7	33	0	238	757
Fisheries	Mangrove	84	5	38	3	7	7	7	19	15	44	10	16	10	26	37	333
	Antarctica	31	2	1	4	0	7	1	5	1	3	0	0	1	0	28	110
Food science technology	Mangrove	1	0	2	0	13	1	1	1	4	9	3	1	0	0	1	43
	Antarctica	0	0	0	1	0	0	0	1	0	10	0	1	0	0	5	22
Agriculture	Mangrove	13	1	16	1	30	3	10	11	16	30	6	11	4	5	16	176
	Antarctica	9	1	12	8	2	12	2	15	4	2	2	2	2	0	42	141
Economy																	
Business economics	Mangrove	1	0	1	0	0	4	1	1	0	0	0	2	1	1	5	21
	Antarctica	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Instruments instrumentation	Mangrove	1	1	0	1	1	0	0	0	0	1	0	0	0	0	3	6
	Antarctica	5	0	2	0	1	2	2	5	0	8	0	0	2	0	28	58
Public environmental occupation health	Mangrove	2	0	2	0	0	1	0	0	9	0	2	0	0	1	1	24
	Antarctica	4	0	0	3	2	10	3	0	3	2	0	0	0	0	22	53
Energy																	
Materials science	Mangrove	0	1	0	0	3	0	3	2	3	11	12	0	0	0	0	33
	Antarctica	1	1	0	0	15	0	3	1	0	10	0	0	2	0	5	44
Meteorology atmospheric sciences	Mangrove	4	2	12	1	2	2	2	8	10	3	4	2	4	1	20	68
	Antarctica	234	43	21	72	54	380	271	256	51	154	5	3	84	0	806	2075
Energy fuels	Mangrove	1	0	0	0	11	0	0	1	3	1	2	0	1	4	8	30
	Antarctica	3	0	2	1	1	1	2	1	2	1	0	1	1	0	6	31

Source: ISI web of Science - Thomson Reuters

As another comparison between research on mangroves and Antarctica, Table 4 shows the number of publications from the most scientifically productive countries on both ecosystems over several different periods. While there are 15 productive countries in mangrove research, as listed in Table 2, only 12 countries remain when Antarctica is the subject. Mexico, Thailand and Malaysia produced very few to no articles on Antarctica (Table 4). This is unsurprising because these countries are located in tropical regions and research in Antarctica demands considerable economic effort with limited tropically applicable results. In fact, as shown in Table 4, the interest in Antarctica as a research subject is very recent (the past two decades) for several countries: Brazil, Germany, Mexico, Thailand, Malaysia, the Netherlands and Belgium. However, putting research efforts into local areas, such as mangrove forests, would concentrate available and limited funding in subjects that are more relevant to the country's interests. Table 4 clearly illustrates the great preference among more developed countries to research Antarctica instead of mangrove ecosystems; the only exceptions among the top 15 countries are China, India, Brazil, Mexico, Thailand and Malaysia. These data in Table 4 confirm that the majority of these 15 countries, which are some of the most developed countries in the world and among the world's most productive in science and technology in general (Almeida & Guimarães, 2013), are not focusing as much attention as they could to study the individuality of mangrove ecosystems. Advanced research by these countries would contribute to a better understanding of the uniqueness of mangrove biodiversity and its potentially valuable capabilities.

Table 5. The numbers of publications related to mangrove forests and to Antarctica from 15 selected countries over several periods from 1901 – 2012

Mangrove Ranking	Country	Ecosystem	Period								Total per Country	Ratio of Antarctica to Mangrove
			1901-1975	1976-1980	1981-1985	1986-1990	1991-1995	1996-2000	2001-2005	2006-2012		
1	USA	Mangrove	18	26	29	68	224	290	339	863	1,857	3.51
		Antarctica	48	118	152	274	746	1,046	1,472	2,653	6,509	
2	Australia	Mangrove	1	16	51	82	119	197	217	378	1,061	2.69
		Antarctica	9	18	66	112	295	524	604	961	2,859	
3	China	Mangrove	0	0	0	2	5	44	139	680	870	0.77
		Antarctica	0	0	5	11	37	59	129	428	669	
4	India	Mangrove	2	7	11	28	52	107	144	486	837	0.69
		Antarctica	2	1	6	17	62	100	116	270	574	
5	Brazil	Mangrove	0	2	1	7	26	45	102	521	704	0.36
		Antarctica	0	0	0	1	9	28	53	163	254	
6	Japan	Mangrove	0	4	4	11	21	47	125	279	491	2.21
		Antarctica	3	7	26	39	114	164	304	428	1,085	
7	Germany	Mangrove	0	0	0	5	19	61	114	244	443	4.94
		Antarctica	0	0	0	22	281	400	523	962	2,188	
8	England	Mangrove	1	3	4	21	34	68	65	172	368	7.90
		Antarctica	8	13	60	78	298	521	677	1,254	2,909	
9	France	Mangrove	2	6	8	12	20	51	65	147	311	4.61
		Antarctica	0	5	11	17	144	243	349	666	1,435	
10	Mexico	Mangrove	0	0	0	9	14	28	62	176	289	0.16
		Antarctica	0	0	0	0	1	5	10	29	45	
11	Thailand	Mangrove	0	1	0	2	11	26	58	145	243	0.02
		Antarctica	0	0	0	0	0	0	1	5	6	
12	Malaysia	Mangrove	2	3	4	5	24	19	19	141	217	0.14
		Antarctica	0	0	0	0	0	0	2	28	30	
13	Canada	Mangrove	0	0	1	2	20	34	43	101	201	4.15
		Antarctica	3	10	7	8	74	130	191	412	835	
14	Netherlands	Mangrove	0	0	1	2	10	22	43	110	188	2.86
		Antarctica	0	0	0	7	54	80	134	263	538	
15	Belgium	Mangrove	0	2	0	3	10	22	42	102	181	2.07
		Antarctica	0	0	0	1	20	58	107	189	375	
World		Mangrove	90	96	165	316	744	1,130	1,600	4,147	8,288	2.40
		Antarctica	574	253	415	697	2,328	3,437	4,414	7,752	19,870	

Source: ISI web of Science - Thomson Reuters

The comparisons of mangrove and Antarctica research presented in this work indicate that Antarctica has attracted, since the beginning of the last century, much more international research attention than has the mangrove ecosystem. This preference has been observed in several of the most developed countries. However, in terms of their degradation rate and social and environmental impact, mangrove forests are in urgent need for action to its protection; they are strongly threatened by the expansion of cities and agricultural activity (Sandilyan & Kathiresan, 2012). Unfortunately, the risk of quickly losing mangrove forests, as previously discussed (Duke et al., 2007; Sandilyan & Kathiresan, 2012), has not been sufficient to awaken authorities and researchers worldwide to the danger. This paper shows clearly the lower scientific interest in mangrove as a source of research, especially concerning to its biotechnological potentialities. It is assumed that increasing the scientific knowledge about an ecosystem of easy access for several countries is fundamental to raise their chances of preservation and will increase and can force international collaboration in biotechnological and economic researches on this ECE. Due to the importance of the mangrove ecosystem, this article attempts to clarify that its degradation and progressive land loss should be a global concern. As highlighted previously, 90% of marine organisms spend part of their lives in this ecosystem, and 80% of the global fish catches are dependent on mangroves (Sandilyan & Kathiresan, 2012). Additionally, several associated benefits of mangroves result from their incredible biodiversity and promising genetic resources, which increases the global need to protect this rich ecosystem. The coastal localization of mangrove ecosystems must also be examined. Mangrove-rich countries, such as Indonesia, Australia, Brazil and Mexico, which together contain 42% of the global mangrove land area, should assume the lead in mangrove study and protection.

4. Conclusion

The results presented in this study, which to our knowledge is the first work dedicated to analyzing the quantity of mangrove research, confirm the negligence of both the scientific community and national governments in properly studying mangrove forests. Mangroves provide a unique ecosystem that has many advantages over other ecosystems: they contain great biodiversity and biotechnological potential; they can produce many benefits for human beings; and they are often located near urban areas. Mangrove environments are spread over North, Central and South America as well as Asia, Africa and Oceania; they are present in many different countries and are easily accessible to populated regions. The increasing degradation of this environment observed in recent years could be related to the lack of scientific knowledge regarding its characteristics. In contrast, an increase in the protection and sustainable exploitation of this habitat could be reached if scientific articles on mangrove ecosystem benefits were more prevalent, particularly if research was distributed among many different research fields. Some other specific technological niches could be exploited including discovery of new molecules or prototype drugs for pharmaceutical industry, as well as in the field of Biotechnology, Agriculture, Food Sciences and Energy field, covering the development of alternative foods, discovery of new enzymes and/or a second generation of enzymes used in biofuel production. As suggested by Barbier et al. (2011), to design an action plan for the development of this ecosystem, some key elements are required: a) greater collaborative ecological and economic research on the value of estuarine and coastal ecosystems (ECE); b) improved institutional and legal frameworks for mangrove forest management; c) better control and regulation of destructive economic activities; and d) options for ecological restoration. It would be easily reached if a strong scientific effort over this subject on different scientific areas starts as soon as possible and in a global level. Scientific research could also bring awareness of this dying ecosystem to the public, causing society to pressure for preservation. Moreover the discovery of new molecules, drugs, enzymes and other biotechnological and food goods from mangrove forests could cause a decrease in their degradation rates and launch new economic interests and applications. Unfortunately, it seems to be true that new and relevant economic profits are more effective at stopping ecosystem degradation than species extinction, biodiversity loss, climate changes and environmental impacts.

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