# Introductory Chapter: Mangrove Ecosystem Research Trends - Where has the Focus been So Far

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Additional information is available at the end of the chapter

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Mangroves are trees and shrubs grow in intertidal zone or brackish water of tropical and subtropical coastal areas between 5°N and 5°S latitude spanning over 118 countries. Mangroves grow in harsh environmental conditions such as high saline conditions and are therefore also called halophytes. They can grow in extreme environment due to their morphological and physiological adaptations, including complex root and salt filtration abilities to cope with inundation of salt water and wave action. Mangroves are well adapted to grow in anoxic conditions as they experience regular inundation and saturated soil conditions. There are around 70 known species of mangroves around the globe, out of which 11 are threatened species and are listed in IUCN Red List [1]. Mangrove species have its own ecosystem services; therefore, mangrove loss can impact surrounding coastal ecosystem and associated ecosystems. Mangrove ecosystem has several faunal species because they create characteristics and productive habitat for them. The biodiversity of fauna in mangrove ecosystem is high due to the availability of food resources and their detritus food cycle.

Mangrove forests provide many ecosystem services that include provisioning, regulating, culture, and supporting services. Mangrove forests provide several provisioning services such as food, timber, fuelwood, etc., which provides economic benefits and security to local coastal communities [2]. It was recognized better after 2004 Asian tsunami wave attenuation became one of the regulating services [3]. Mangroves blue carbon storage and sequestration capability are important regulatory services since 2011 because of global climate change mitigation [4]. Mangroves also play an important role in enhancing coastal water quality by stabilizing fine sediment and by absorbing pollutants (like heavy metals) [5]. Mangrove forests also provide a slew of cultural services such as tourism and education as well as cultural heritage and esthetic values to local communities as well as visiting tourists [6, 7].

Though mangroves provide many important ecosystem services, they are one of the most threatened ecosystems in the world [8]. Mangrove forests are being deforested and degraded due to extensive aquaculture pond creation, agriculture, urban development, palm oil production, and conversions to other land use types [9]. Anthropogenic factors are big threats to mangroves; however, they are also threatened due to climate change impacts such as sea level rise, rising temperature, and increasing storm intensities [10]. These threats are causing variations in river run-off and fresh water inputs which result in species loss and productivity, that eventually will alter aquatic food webs in coastal setting.

Therefore, many researchers, scientists, academicians, stakeholders, and policy makers are involved to maintain the remaining mangrove forest area cover globally. Many government and nongovernment organizations are involved in increasing mangrove area cover such as the IUCN (https://www.iucn.org/news/forests/201707/mangroves-make-great-conservation-allies) and the International Timber Trade Organization (ITTO) (http://www.itto.int/files/user/pdf/E-BROCHURE-Bali%20Call%20to%20Action.pdf) have identified effective mangrove restoration as a key priority.

Past study reassessed ecological role and services of mangrove forest, where authors mainly discussed carbon dynamics, nursery role, shoreline protection, and land building capacity of mangroves [11]. Consequently, this chapter contains information pertaining to mangrove carbon research—how it has evolved over time and also their role in mitigating climate change. In this chapter, important research topics are discussed to enhance our understanding of the global mangrove research covering topics such as climate change, blue carbon, deforestation and degradation, fauna and flora losses, etc. As one might think, all these topics are interrelated and a clear overlap is visible in search engine results. This provides a clear indication of mangrove carbon research trend in the recent years.

## 1. Methodology

The Web of Science® online database was used to access the mangrove forests research published between years 1980 and 2017. We searched various topics using specific keywords: (1) mangrove, (2) mangrove climate change, (3) mangrove carbon, (4) mangrove blue carbon, (5) mangrove biomass, (6) mangrove litter, (7) mangrove productivity, (8) mangrove deforestation and degradation, (9) mangrove remote sensing, (10) mangrove fauna, (11) mangrove invertebrate, (12) mangrove Polychaeta, (13) mangrove bird, and (14) mangrove mammals.

## 2. Result and discussions

A total of 14,741 records on keyword "mangrove" were found in the Web of Science. **Figure 1** shows different fields of research within mangrove ecosystem. Approximately, 50% research was done in the field of marine freshwater biology, environmental sciences, and ecology. About 50% of mangrove research fields are broad and comprised many particular research fields such as climate change, productivity, water quality, pollution, physiology, ecology, carbon dynamics, etc.

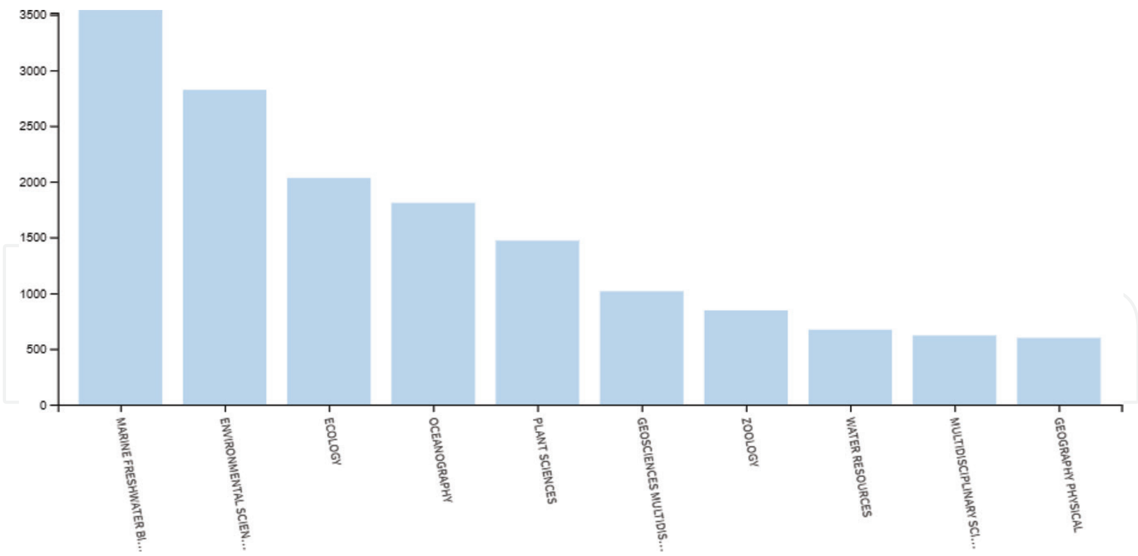


**Figure 1.** Number of publication belongs to different research field with in mangrove forest.

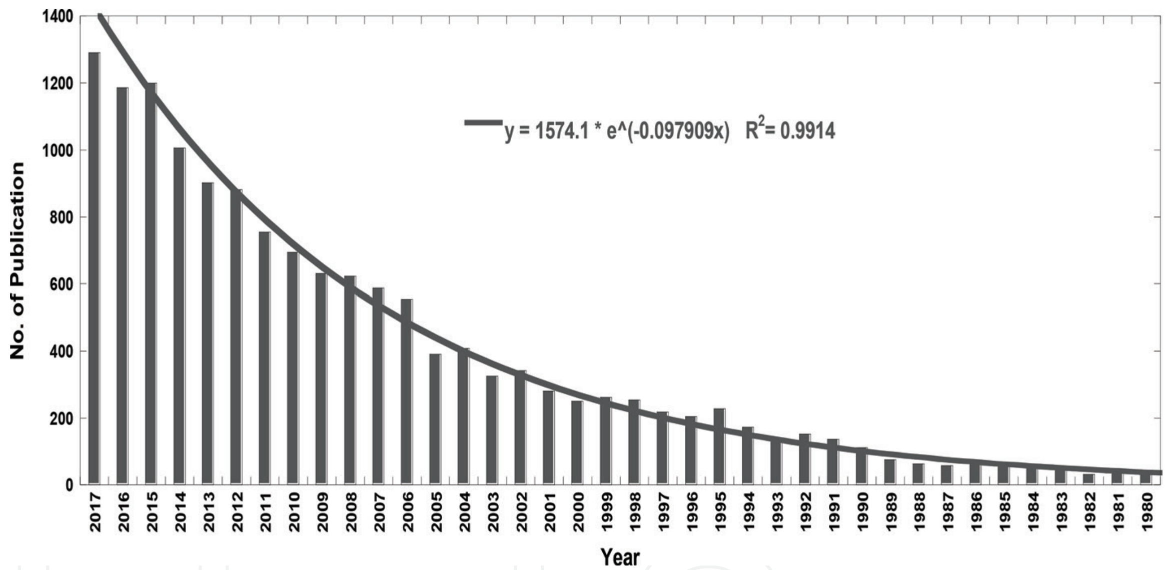


**Figure 2.** Number of publication records for keyword "mangrove" from 1980 to 2017.

Mangrove research has increased exponentially from 1980 to 2017, although year 2016 and 2017 shows a bit lower publication record as per the curve fitting (**Figure 2**). Year 2015 shows higher publication than year 2016, yet they might not be statistically significantly different.

Mangrove climate change search showed total 1053 publication records. Mangrove climate change research exponentially increased since year 1991 (**Figure 3**). Climate change or global warming is directly related to carbon cycle [12]. Therefore, mangrove carbon keyword was searched and a total of 1927 records were found, which was higher than climate change records. That means researchers were involved in mangrove carbon research than ecological, biological, environmental, and physiological aspects of mangrove research.

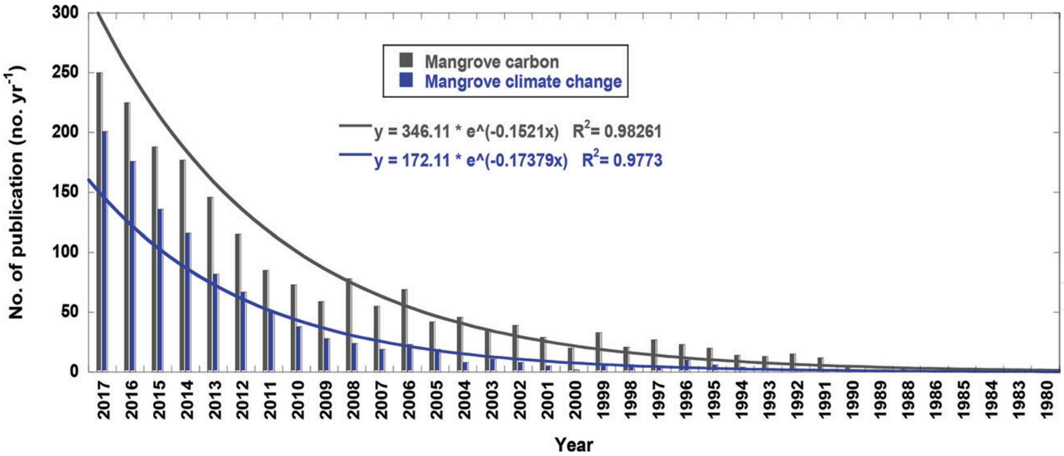


**Figure 3.** Number of publication records for key words "mangrove climate change" and "mangrove carbon" from 1980 to 2017.

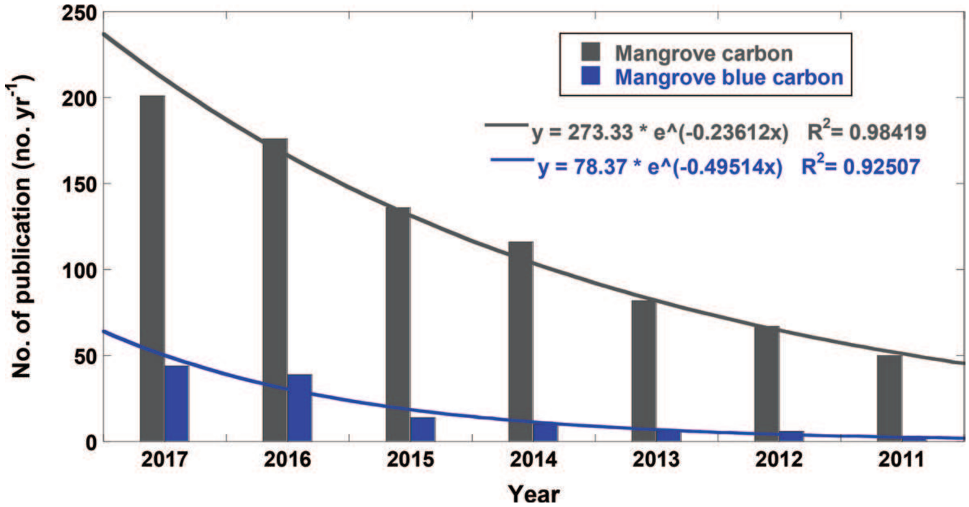


**Figure 4.** Number of publication records for keywords "mangrove climate change" and "mangrove blue carbon" from 2011 to 2017. Since Nature Geoscience publication [4] and blue carbon term (2009) [13].

Carbon stored in coastal and marine living organism such as mangrove forests, salt marshes, seagrass meadows, and intertidal flats is called "blue carbon," as termed by UNEP in 2009 [13]. The keyword mangrove blue carbon was searched, and a total of 124 records were found on Web of Science. Since 2011, publications on mangrove blue carbon have increased exponentially in terms of mitigating climate change (**Figure 4**). Mangrove climate change research showed very high number of publication after year 2011 (**Figure 3**), while mangrove carbon research showed lower publication as per the exponential graph (**Figure 3**). Mangrove carbon research got a boost since 2011 after a paper was published in the Nature Geoscience Journal [4] and after blue carbon term was coined/introduced [13] (**Figure 4**). **Figure 4** shows exponential increase in publication in the field of mangrove climate change research since year 2011. From **Figure 3**, it is clear that mangrove carbon research was primarily conducted in the field of climate change after year 2011.

Biomass is a measure of carbon stored in mangrove vegetation. Researchers have been measuring mangrove carbon indirectly through biomass [14–18] that is estimated using allometric models [19–21]. A total of 1180 publications were identified using mangrove biomass keyword. Mangrove biomass research showed an exponential increase in the number of publication (**Figure 5**), although after year 2008, it seems biomass research has decreased. This decrease might be due to that researchers started to convert biomass into carbon for estimating total ecosystem carbon stocks. Measurement of litter fall is an important component of mangrove forest productivity [22–24]. Litter is also an indicator of episodic climate event such as storm [25], phenology [25–28], coastal productivity [29], detritus food cycle [30], etc. Measurement of litter quantity is a traditionally accepted method for measuring mangrove forest productivity. Mangrove litter research publication showed linear increment rather than an exponential increment (**Figure 5**).

Mangrove productivity estimation includes both biomass increment and litter fall production. Mangrove litter and productivity show same exponential rate of publication from year 1981 to 2006 (**Figure 5**), while after year 2006, the number of publications on mangrove productivity still shows an exponential growth (**Figure 5**). These mangrove productivity publications could be from different fields such as marine, phytoplankton, coastal, productivity, etc.

Mangrove deforestation and degradation lead to the loss of carbon that has been stored in the mangrove ecosystems. Keyword mangrove deforestation and degradation show a total of 59 publications from 1996 to 2017. **Figure 6** showed exponential trend but data are fluctuating over years. Earlier studies in the field of deforestation were done to study species loss, area cover loss, loss of ecosystem services, etc., while year 2016 and 2017 showed higher number of publications as compared to earlier years possibly due to climate change research and carbon loss due to deforestation (**Figure 6**).

It is sometimes difficult to work inside mangrove forest due to accessibility, high number of mosquitoes, difficult to walk due to muddy condition, etc. **Figure 5** describes mangrove litter publication that showed weak exponential growth, because for litter studies, researchers need to go every month to field collect litter to understand seasonal trend and production of litter fall [28]. Many researchers started to use technology-based research such as using remote sensing [31], drone [32], camera, and different kind of sensors, eddy covariance system [33],

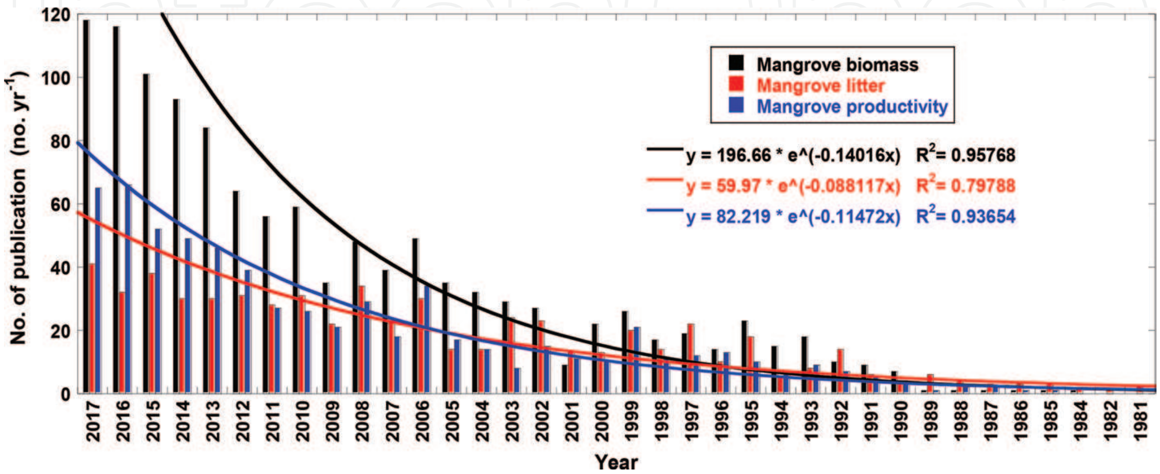


**Figure 5.** Number of publication records for keywords "mangrove biomass," "mangrove litter," and "mangrove productivity" from 1981 to 2017.

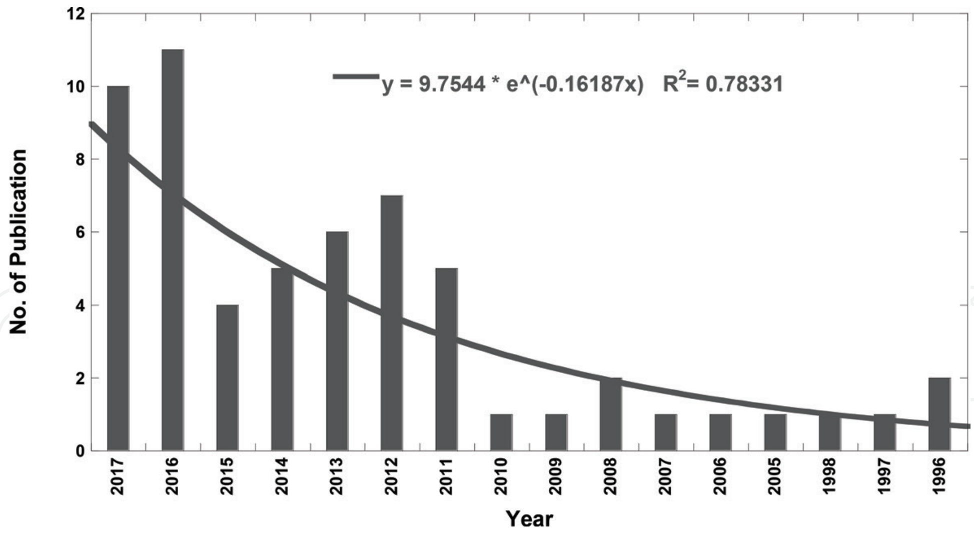


**Figure 6.** Number of publication records for keywords "mangrove deforestation and degradation" from 1996 to 2017.

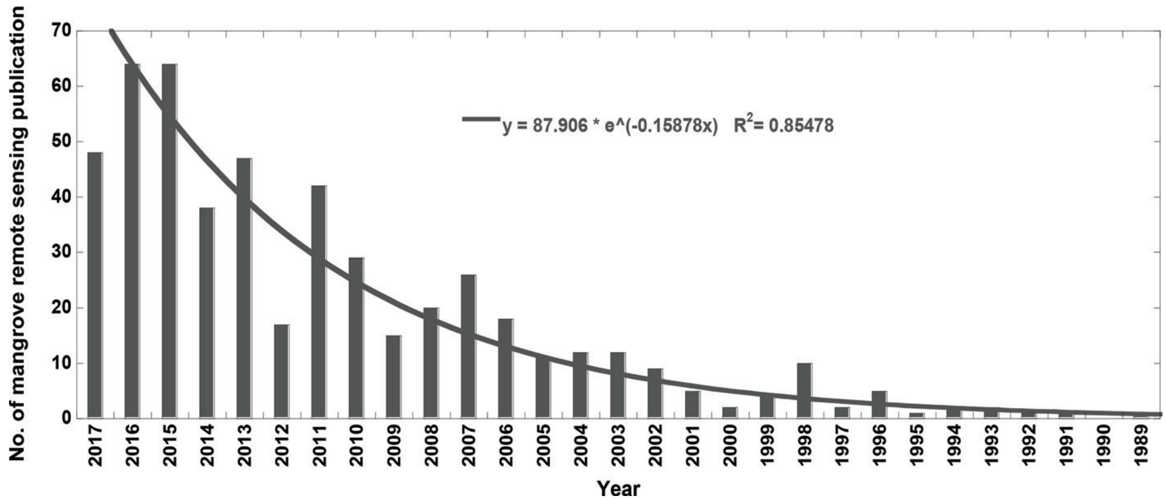


**Figure 7.** Number of publication records for keyword "mangrove remote sensing" from 1989 to 2017.

etc. Remote sensing is very useful technology to estimate mangrove forest deforestation rate and area cover [34, 35]. Therefore, search was performed for keyword "mangrove remote sensing." Mangrove remote sensing research publications have increased exponentially over time, although it shows some interesting trends (**Figure 7**). Both mangrove remote sensing and deforestation and degradation figures show higher number of publication after year 2015 that means researchers are using remote sensing technology to estimate several parameters such as biomass, carbon stock, leaf area index, area cover, deforestation rate, etc. from mangrove forest.

Overall mangrove fauna research has been increasing every year (**Figure 8**). Several fauna found in and surrounding mangrove forest area such as fish, crabs, birds, large and small mammals, reptiles, amphibians, etc. These organisms play an important part in ecological function and coastal food web. Search results from Web of Science show that majority of

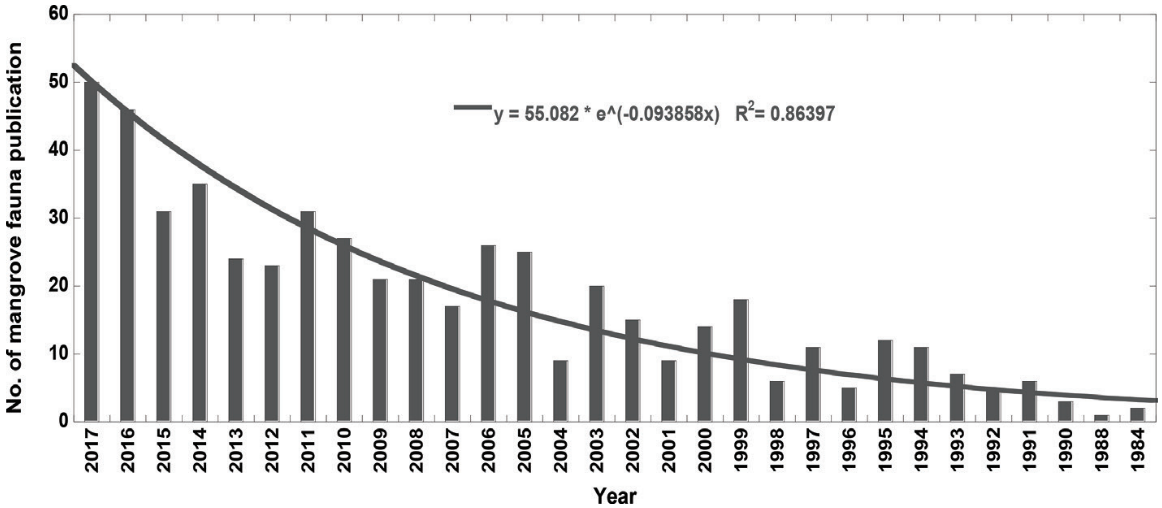


Figure 8. Number of publication records for keyword "mangrove fauna" from 1984 to 2017.

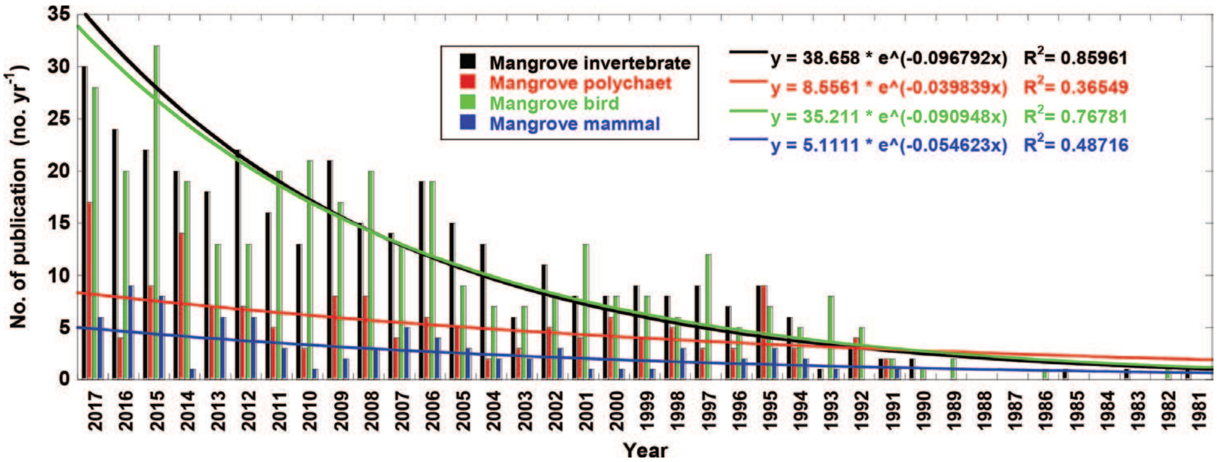


Figure 9. Number of publication records for keywords "mangrove invertebrate," "mangrove polycheat," "mangrove bird," and "mangrove mammal" from 1981 to 2017.

the studies have been conducted on mangrove birds and invertebrates (**Figure 9**) and show exponential increment of publication. Invertebrates, macrofauna (mainly crabs), are an important component of mangrove ecosystem and called ecosystem engineers due to their habit of digging burrows. These invertebrates feed on leaf litter, detritus, plankton, etc. and play a key role in litter breakdown and decomposition of detritus material. Birds are important component in deciding wetland site under Ramsar convention. Most of the mangrove forests are under Ramsar sites. Therefore, mangrove bird research is important in terms of conservation and protection of mangrove forest. On the other hand, mangrove polycheats and mammals show lower and fluctuating publication rate, consequently weak exponential increment (**Figure 9**).

Past studies have showed that literature review could provide important research outputs. In mangroves research, many studies in different fields have been done through literature reviews [36–40].

## 3. Conclusion

Mangrove research has increased over time around the world in all kind of research areas. From results, it is confirmed that mangrove research is increasing exponentially around the globe. Also number of mangrove researcher is also increasing in the world. There was a time when very few researchers were involved in mangrove forest-related research. The Web of Science search engine can be helpful in quick identification of key research area as well as evolving trends. Also other search engines such as Scopus, Google Scholar, CiteSeer, BioOne, etc., should be taken into account for finer search results.

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