



Moroccan aquatic ecosystem: A bibliometric review and research directions

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Abstract: Morocco's particular geographical situation gives it a wealth of aquatic environment. These environments require sustainable management to fight against the issues that may threaten our aquatic system. The future of the different types of water existing in our territory must be well treated and studied. We made a synthesis study on 360 papers to make an assessment and to know the research state of the art in the Moroccan aquatic ecosystems between 1989 and 2021. The analysis of our results showed the freshwater studies are higher than the marine ecosystem. The majority of the aquatic Moroccan environments studies focus mainly on biology and geology with a decreasing gradient from north to south of the country. On the other hand, a surprising result, it should be noted the absence of complete studies on the biogeochemical and fresh-marine water interactions.

Keywords: Aquatic ecosystems, freshwater, marine, Morocco, bibliographic analysis.

1. Introduction

Water is an important natural resource for sustaining production and life (Vörösmarty *et al.*, 2010; Zhao *et al.*, 2015). However, freshwater scarcity has threatened human society's sustainable development in the past few decades in the world (Gosling and Arnell, 2016; Liu *et al.*, 2017; Mekonnen and Hoekstra, 2016) and climate change. The health of aquatic resources is of critical importance for sustainable economic development and biodiversity. However, human activities, global population growth and climate perturbation can change aquatic systems, leading to degradation of water quality and aquatic habitat, and loss of biodiversity (Reid *et al.*, 2019). These environments require sustainable management to fight against the issues that may threaten our aquatic system.

The preservation of natural hydrological regimes is critical in developing countries, where a substantial portion of the population's subsistence is heavily reliant on ecosystem services (Reitberger and McCartney, 2011). Morocco's particular geographical situation gives it a wealth of aquatic environment (Damsiri *et al.*, 2017). These environments require sustainable management to fight against the issues that may threaten our aquatic system.

Bibliometrics measures are widely used as indicators of productivity, influence, impact, and research performance. Recently, numerous bibliometric approaches have been highlighted in a variety of domains and fields (Elyousfi *et al.*, 2023; Lrhoul *et al.*, 2023; Nandiyanto *et al.*, 2023). Hammouti *et al.* 2023, published an interesting overview of scientific production worldwide and in Africa, based on the SCImago. Efforts of China during last decade, make it the best country in the World since the year 2020 and Morocco achieves significant improvements in its scientific output, ranking fourth in Africa. Databases show that bibliometric studies acquire great importance and utility by making visible themes, authors, and scientific impact of the consulted works (Magadán-Díaz *et al.*, 2022; Delgado *et al.*, 2021; Demba N'diaye *et al.*, 2022). Bibliometric analysis measures the flow (quantity and quality) of publications through mathematical and statistical methods, and consequently, allow to evaluate and/or reorient the advancement of research and scientific development of each country (Castillo-Vergara *et al.*, 2023).

The articulation of world and scientific knowledge is one of the main challenges in implementing a participatory management of aquatic environments. Preservation research studies lead to the more specific consideration of knowledge relating to environmental evolutions. The future of the different types of water existing in our ecosystems must be well treated and studied. The evaluation of these ecosystems requires a solid research database in order to respond to several problems and environmental issues, hence the need to make a review of the studies carried out at the level of these ecosystems.

This paper reviews the research science in Moroccan aquatic ecosystem via bibliographic synthesis. A total of 360 documents were selected from 1989 to May 2021. Therefore, the distribution of records by year of publication, document type, publication language, and journal cover are addressed and the co-occurrence analysis of keywords.

1. Methode

2.1. Data source

A literature review of available documents was conducted through including Scopus (<https://www.scopus.com/>), Science direct (<https://www.sciencedirect.com/>), Web of Science (<https://clarivate.com/webofsciencegroup/solutions/web-of-science-core-collection/>), and Google Scholar (<https://scholar.google.com/>). In addition, more websites were used in searching the defended PhDs, such as: theses.fr (<http://www.theses.fr/>), Hal (<https://hal.archives-ouvertes.fr/>), and Otrohati (<https://otrohati.imist.ma/>). The keywords "Moroccan aquatic ecosystem" were explored without language restriction to generate a well-defined database of the literature published between 1989 to May 2021. The documents general information includes the year of publication, document type, language, journal coverage and aquatic ecosystem type was selected as metadata. We considered document types: journal article, book section, scientific report, conference paper, scientific bulletin and thesis (Figure 1).

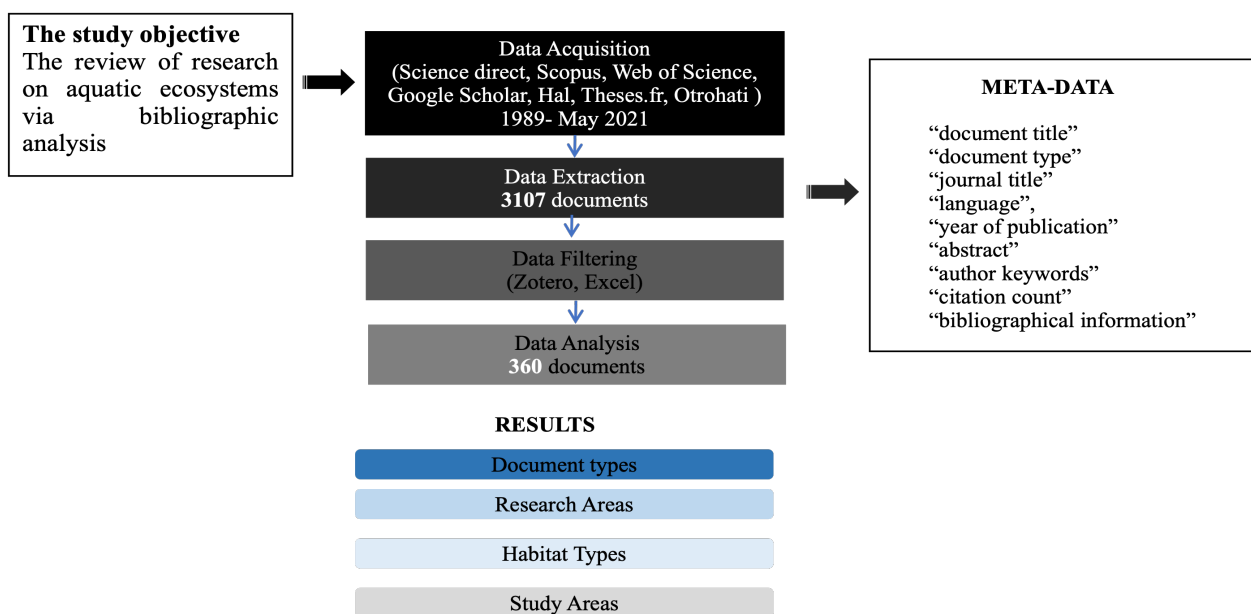


Figure 1. Bibliographic analysis procedure

2. Results and discussion

3.1. Moroccan aquatic ecosystem: state of the art

3.1.1. Geographical distribution and research tendencies

The contour maps created by operating ArcGIS (version 10.x, Esri), which used number of studies of each type of Moroccan aquatic environment studied.

a. Lake

According to the bibliographic synthesis carried out during this study, the existence of 70 Moroccan lakes has been established, of which 28 occupy the northern regions and 42 are distributed between the central and southern parts of the country, of which 24 have been investigated (Figure 2A). Based on the bibliographic synthesis analysis performed on the number of studies on this type of water environment, the most studies were recorded at these environmental levels, with 89 studies recorded (Figure 3A). The greatest number of studies has been found at El Massira, El Kansera (10 studies) and Lala Takerkoust (8 studies) followed by Lake Allal El Fassi, El Maleh, Hassan 1st, Hassan 2nd and Lake Smir.

b. Oued

According to the bibliographic integration carried out during this study, the existence of 25 Moroccan rivers has been recorded, 9 of which occupy the northern regions and 16 are distributed between the central and southern parts of the country. Only 17 Moroccan oueds have been investigated (Figure 2B). The analysis of the results of our bibliographic synthesis showed the presence of 50 scientific papers published at the level of Moroccan rivers with the highest studies number recorded at the level of oued Hassar (8 studies) followed by oued Boufekrane, oued Moulouya (7 studies) and oued Sebou (5 studies) (Figure 3B).

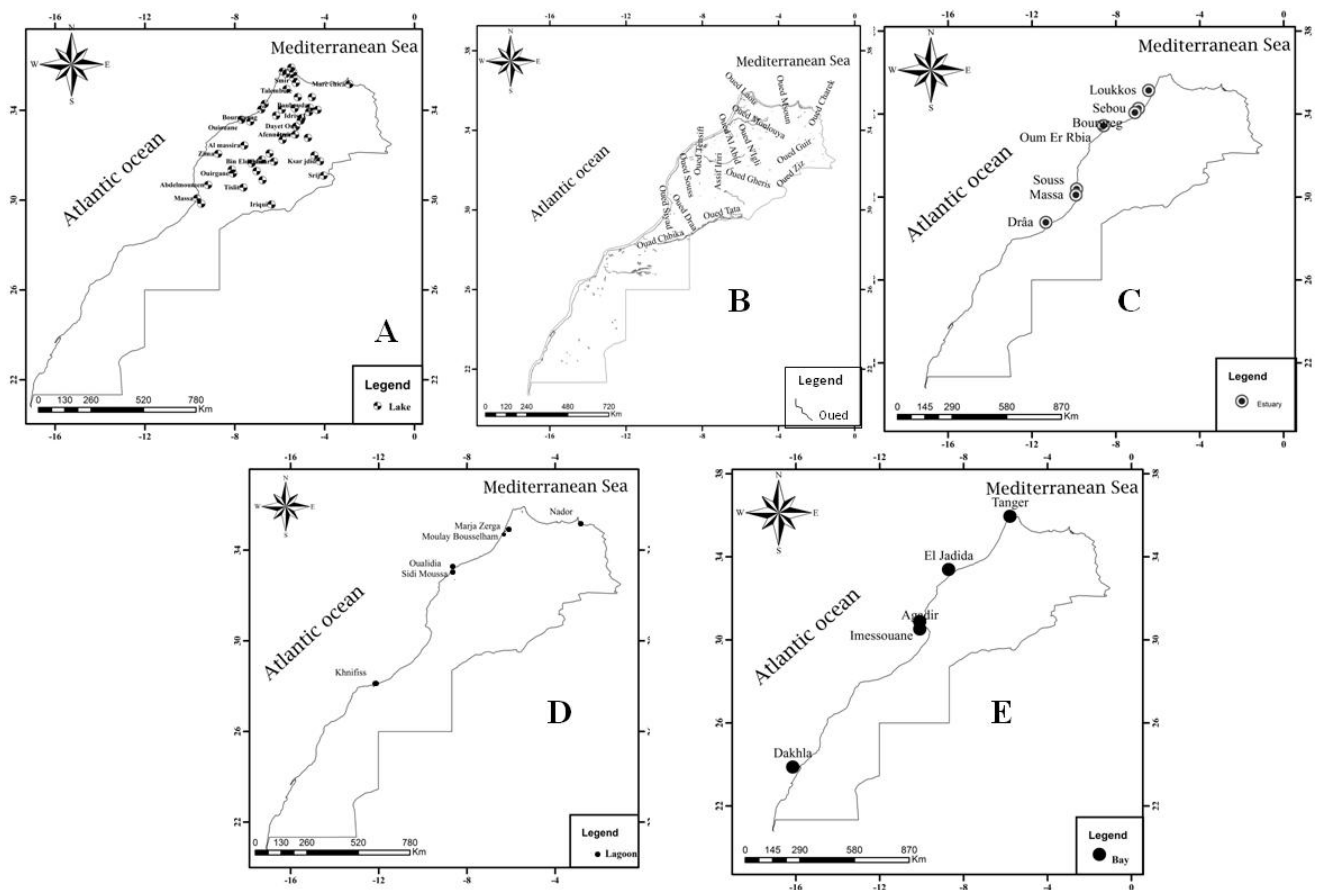


Figure 2. Geographic distribution of the studied Moroccan aquatic ecosystem: **A:** Lakes, **B:** Oued, **C:** Estuary, **D:** Lagoon, **E:** Bay

c. Estuary

A bibliographic synthesis was performed to aggregate all estuaries to determine their geographic distribution. Based on the data collected in the Moroccan estuaries studied, we found that we have 8 estuaries (Figure 2C), 5 of which occupy the northern and 3 are distributed between the central and southern parts of the country. The results of the synthesis carried out showed the presence of 50 published scientific papers. The greatest number is noted at the level of the Loukkos (17 papers), Sebou (8 studies) and Souss estuary (7 studies) (Figure 3C).

d. Lagoon

According to the analysis of the data collected on the Moroccan lagoons, we noticed the presence of 5 lagoons, one in the Mediterranean (Nador) and 4 in the Atlantic (Moulay Bouselham, Khnifiss, Sidi Moussa and Oualidia) (Figure 2D). With three semi-closed lagoons (Nador, Moulay Bouselham and Khnifiss) and two neutral ones (Sidi Moussa, Oualidia). The synthesis analysis of information performed showed the presence of 149 studies with the greatest number of studies has been found at Oualidia lagoon (45 studies) and Nador (40 studies) (Figure 3D).

e. Bay

Morocco has 4 bays (El Jadida, Imessouane, Agadir and Dakhla) on the Atlantic coast and 1 bay (Tangier) on the Mediterranean Sea (Figure 2E). Our results indicate the existence of 22 published

scientific papers, with many of these studies documented in Agadir Bay (8 studies), followed by Tangier Bay (5 studies), El Jadida, Dakhla and Imessouane Bay (3 studies) (Figure 3E).

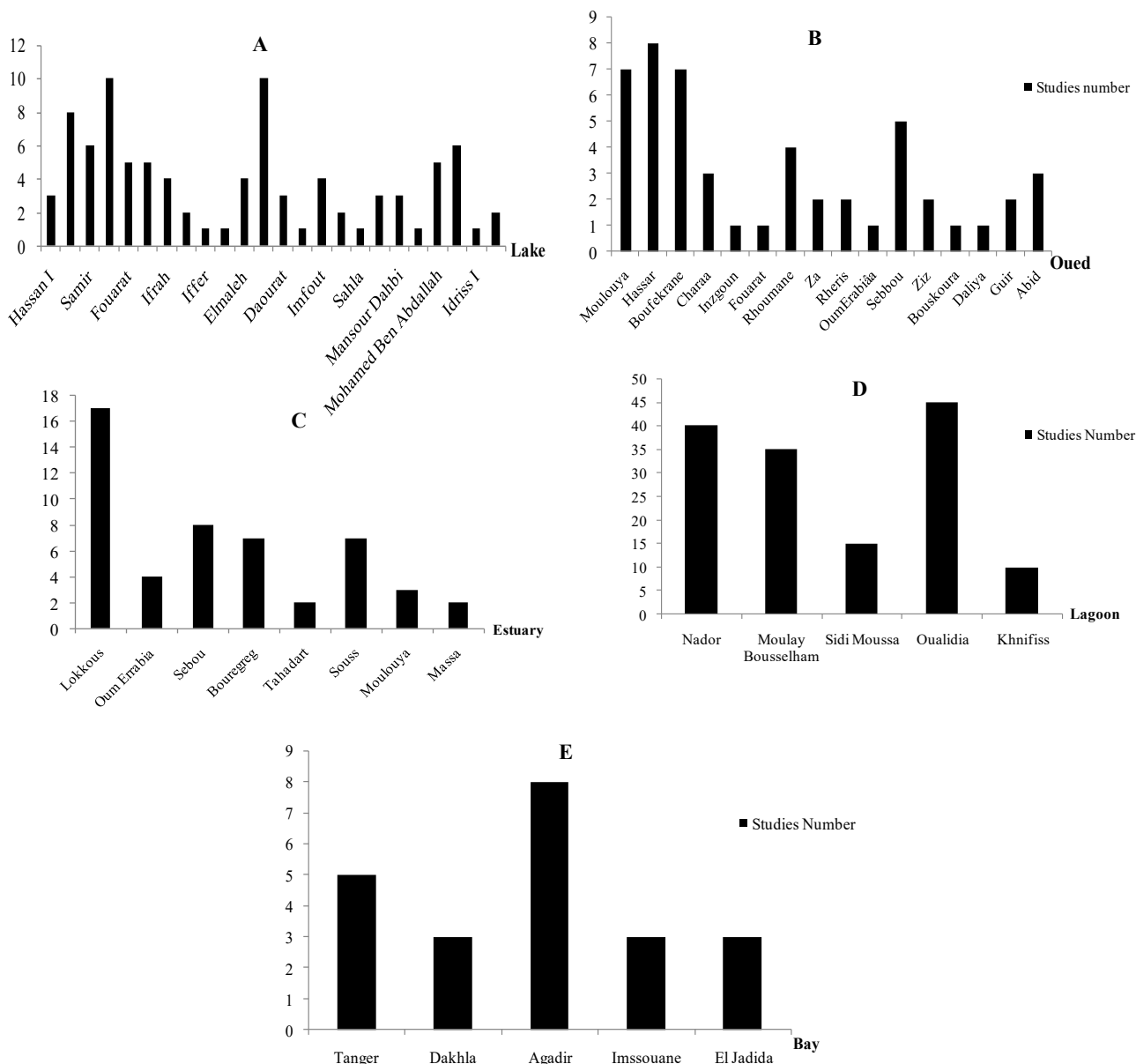


Figure 3. Studies number on Moroccan aquatic ecosystem between 1989 and 2021: **A:** Lake, **B:** Oued, **C:** Estuary, **D:** Lagoon, **E:** Bay

3.1.2. Publication years, document type

The annual distribution of the published-document number expresses the overall situation and research problematic, while the latter highlights the overall trend features considering different development time periods. Thus, the combination of the published literature referring to the Moroccan aquatic ecosystems and fixed time window was achieved (Figure 4). Due to the small number of early publications, the present study uses 1989–1998, 1999–2008, 2009–2018 and 2019–2021, respectively, as first to fourth research periods. In the first decade (1989–1998), the increasing number of published documents per year was no more than 36 publications. In the second decade (1999–2008), research grew slowly but steadily, and the annual average document number varies slightly between years.

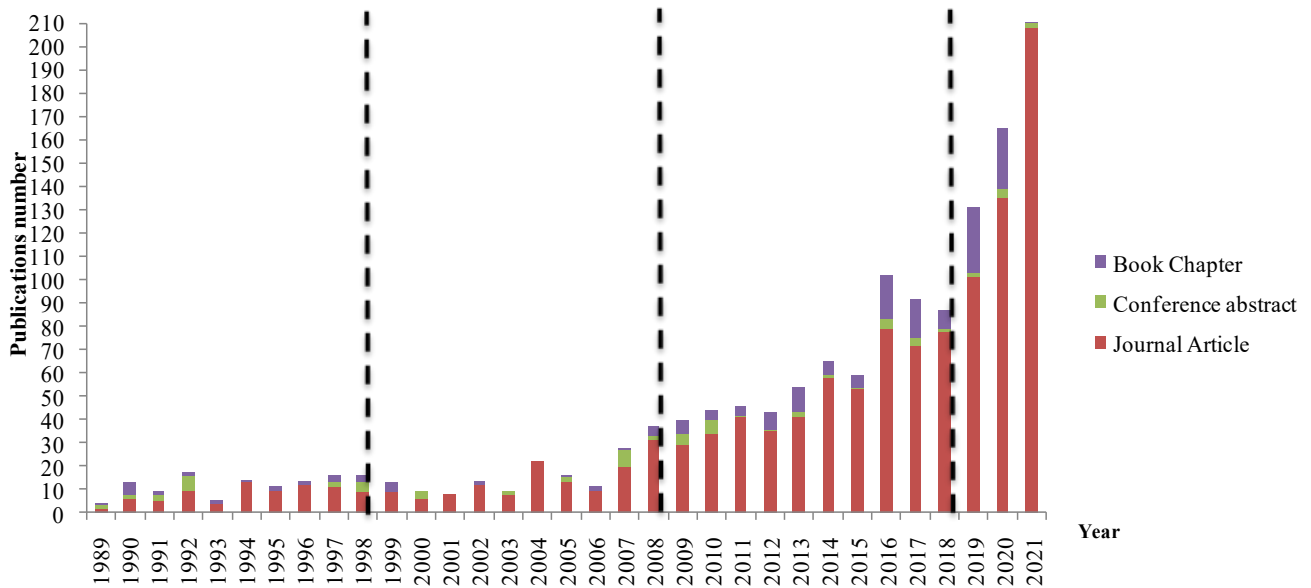


Figure 4. Publications number on Moroccan aquatic ecosystem per document type by years (1989-2021)

In third decade (2009–2018), the number of research documents increased rapidly, reaching a peak of 202 publications in 2016. In the last research period in this study (2019-2021), research grew slowly but steadily, and the annual average document number varies slightly between years reaching a peak of 208 publications in 2021, signaling a surge in research activity throughout the aquatic Moroccan ecosystems over the last years (2016-2021). It is worth mentioning that the year 2021 was represented by 208 publications. Our results showed that the total documents analysis in this study was published as journal articles (1182 publications) and more than 60 documents as conference abstracts and more than 200 book chapters.

Water scarcity in recent years, scientific management of aquatic ecosystem has emerged worldwide. However, significant efforts have been made to collect information needed to understand better aquatic ecosystems functioning, such as integrating various data sources, monitoring observatories, etc.... Although scientists are more aware of the research needs of aquatic management, they are expected to provide robust and reliable research pertinent to managers (Roux *et al.*, 2015). Many differences between data generated by science and data used during the implementation of a management plan. Therefore, scientists and managers have called for more flexible management forms by building new relationships, increasing knowledge exchange, creating internal and external collaborations, and increasing research productivity. Difficulties have been encountered when collecting studies related to assessing research state on the Moroccan aquatic ecosystem via the quantitative analysis of the research productivity. However, to our knowledge, no attempts have been made to investigate Moroccan aquatic ecosystem research efforts.

In the present document, we provide a bibliographic analysis to review 360 papers published from 1989 to 2021. We identify the research trend and hotspots for future directions (Table 1). According to the synthesis of almost all the scientific articles collected, it can be seen that the prospecting rates have remained low in the aquatic environment (Table 1). This can be explained by the complexity of these ecosystems and the high cost of carrying out research in these environments, with higher numbers recorded in the northern zone compared to the southern zone. This may be explained by the number of projects developed in the northern zone are more important compared to those in the

southern zone and the high costs. The analysis of our results also indicated that the majority of research on Moroccan waters are related to biology (Hasnaoui 2017; Belokda *et al.*, 2018; Natij *et al.*, 2021) and geology (Aknaf *et al.*, 2018)). On the other hand, it is necessary to note a surprising result, the lack of complete studies on biogeochemical interactions and fresh water.

The number of studies varies depending on the aquatic system due to the complexity of the processes characterizing these environments. Lagoons are the most studied (149 studies), followed by lakes (89 studies), estuaries (51 studies), rivers (50 studies) and bays (22 studies) (Table 1). Our research is an assessment of the state of research and could therefore serve as a direction for future research in our country. Research should be diversified by developing research projects in the fields of aquatic biogeochemistry, coastal management, ecosystem services, fisheries, bibliometric analysis, fresh and marine water interactions and ecosystem modeling.

Table 1. Types, number of Moroccan aquatic area and studies carried from 1989 to 2021

| | Aquatic ecosystem | Aquatic ecosystem number | Studies areas Number | Studies total number |
|-----------------|-------------------|--------------------------|----------------------|----------------------|
| Freshwater zone | Lake | 70 | 24 | 89 |
| | Oued | 25 | 17 | 50 |
| | Estuary | 8 | 8 | 51 |
| Marine zone | Lagoon | 5 | 5 | 149 |
| | Bay | 5 | 5 | 22 |

Conclusion

One of the main results of this study is the identification of the different types of Moroccan aquatic ecosystems, the number of studies and disciplines. In this work the co-occurrence of keywords revealed that the main research hotspot was in biology and geology. Though, the application of new monitoring methods for aquatic ecosystem investigation, new technologies, processes, and models of ecological and biogeochemical restoration received little attention. In conclusion, this short investigation is expected to benefit researchers interested in Moroccan aquatic ecosystem. Furthermore, we believe our findings can provide ideas about the development trends and research new hotspots in aquatic areas.

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