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The global research on meiofauna associated to seagrasses: a bibliometric network analysis

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Abstract. To better understand the state of the art of the research on meiofauna (small metazoan between 500 and 30μm) and seagrasses, a bibliometric network analysis was performed exploring the period from 1981 to 2021 from the Scopus database. The indexed global scientific literature on this topic was explored using VOSviewer software, which allowed us to obtain a comprehensive overview on these topics. A total of 101 publications were identified, revealing that scientific research on meiofauna related to seagrasses is still relatively limited. Results showed that the scientific documents were published by 15 countries, leaded by Australia, Italy, and USA, 50 researchers, and only 7 journals (with a maximum of 8 documents each). De Troch was the most productive author with 14 published documents. Following the most common keywords (meiofauna, seagrass, nematode, and copepoda), "community structure" occurred 25 times, suggesting that the main research field linked to meiofauna and seagrasses is community ecology. The analysis of co-authorship (among researchers and countries), the co-occurrence of keywords and cited journals showed an increasing attention to this topic worldwide and over time. Indeed, although meiofauna is still relatively poorly studied, the awareness of its crucial role in key coastal habitats, such as seagrass beds, is growing.

Keywords: Meiobenthos, nematodes, Posidonia oceanica, marine ecosystems, monitoring tools, social network analysis, VOSviewer.

1. Introduction

The term meiofauna (Mare, 1942), from the Greek "μείων" smaller, defines the group of benthic metazoans ranging between 500 μm and 30 μm (Giere, 2009; Semprucci and Sandulli, 2020). Meiofauna represents the most diversified group in the marine environment, with 24 out of the 35 animal phyla belonging to this group (Giere, 2009). Meiofaunal taxa are well known to play an important role in benthic food webs, not only as consumers, (Mateo and Romero, 1997; Gwyther, 2003; Torres-Pratts and Schizas, 2007; Mascart et al., 2013), but also as producers, being a food source for macrofauna and for commercially important species (Gerlach, 1978; Carpentier et al., 2014). The most abundant taxon in a meiofauna sample is Nematoda, and this group shows very diversified feeding behaviors: deposit feeding, bacterivor, epistrate feeding, and predation (Wieser, 1953), driving the energy flow from lower levels through the whole benthic food web (Schratzberger and Ingels, 2018).

Meiofauna is characterized by short generation times, lack of pelagic larval dispersion for the dominant groups, and fast metabolic rates (Bongers and Ferris, 1999). Moreover, their ubiquitous distribution and high abundance allow to collect a small volume of sediment-sample to obtain a representative figure of their density (Carriço et al., 2013). Meiofauna is also considered a valuable tool in biomonitoring studies, due to their biological characteristics and to the possibility to identify them at a taxonomic level higher than species, obtaining sufficient ecological information (Moore and Bett, 1989; Sandulli et al., 2010, 2015; Semprucci et al., 2019). Nevertheless, because of their small size, meiofaunal organisms require a notable effort of sorting and identification (Kennedy and Jacoby, 1999). Indeed, meiofauna often represents a neglected component of marine biodiversity (Curini-Galletti et al., 2012), and it is generally overlooked compared to macrofauna, which is more easily countable and identifiable (Schratzberger et al., 2000). A huge issue related to meiofaunal research is the lack of information on both taxonomy and community structure, especially in certain habitats, such as seagrass beds.

Seagrasses are habitat-forming species highly studied all around the world. *Posidonia oceanica* (L.) Delile is the endemic dominant seagrass species in the Mediterranean Sea and builds dense underwater beds that support a high biodiversity of associated organisms (Boudouresque et al., 2015). Indeed, these beds offer shelter, feeding and nursery areas for a large variety of species, many of them of commercial interest (Buia et al., 2000; Boudouresque, 2004; Costanza et al., 2014; Bedini et al., 2021; Vasarri et al., 2021; Appolloni et al., 2023). Seagrass beds also play a key role in prevention of coastal erosion, oxygen production and carbon sequestration/storage within their sediments (Alcoverro et al., 2001; Fourqurean et al., 2012). Although seagrasses' associated macrofaunal communities have been widely studied over the years (Orth et al., 1984; Dimech et al., 2002; Duffy et al., 2003; Como et al., 2008; Honkoop et al., 2008; Kalogirou et al., 2010; Whippo et al., 2018), meiofaunal communities have often been overlooked, despite their abundance, both in sediments and on leaves/rhizomes (Novak, 1982; Mascart et al., 2013). Moreover, meiofauna could be included in

natural capital assessment studies together with the other components of the marine environment, enriching the models already used (Appolloni et al., 2018; Buonocore et al., 2020).
The aim of this study is to investigate the global scientific literature on marine meiofauna associated with seagrasses by using bibliometric network analysis. Bibliometrics is a statistical method which could quantitatively analyze the research papers concerned about a special topic via mathematical methods (Pritchard, 1969). If applied to academic literature, bibliometric network analysis allows for the quantitative investigation of network structures based on the relationships among researchers, organizations, countries, and keywords dealing with the investigated topic (Donthu et al., 2021).

2. Methodology

The dataset for this study was extracted from the Scopus bibliographic database. Documents were collected on January 30th, 2023, by searching on Scopus the terms “meiofauna” OR “meiobenthos” in order to include all publications on the topic, AND “seagrass”. The search produced 138 results, that have been individually selected for a final database of 101 relevant papers related to the investigated topic. Results were saved as .csv files after selecting all the possible information and including the references. The .csv files were then exported to the VOSviewer software (version 1.6.16) for the creation, visualization, and exploration of maps. Indeed, VOSviewer is used to generate different types of bibliometric networks and maps strongly based on visualizations to facilitate the analysis of clustering solutions, which are useful to display data (Waltman et al. 2010; Van Eck and Waltman, 2018; Di Ciaccio and Troisi, 2021; Rendina et al., 2022; Catani et al., 2022; Cocozza di Montanara et al., 2022).
In this study several analyses were carried out: the co-authorship among researchers and countries (in cluster and overlay visualization), the co-occurrence of keywords (in cluster and overlay visualization) and cited scientific journals (in overlay visualization). The main technical terms used by the VOSviewer software are explained in Table 1 (Van Eck and Waltman, 2018).

Table 1. Main technical terms used in the software VOSviewer.

Term	Description
Items	Objects of interest (e.g., publications, researchers, keywords, authors).
Link	Connection or relation between two items (e.g., co-occurrence of keywords).
Link strength	Attribute of each link, expressed by a positive numerical value. In the case of co-authorship links, the higher the value, the higher the number of publications the two researchers have co-authored.
Network	Set of items connected by their links.

Cluster	Sets of items included in a map. One item can belong only to one cluster.
Number of links	The number of links of an item with other items.
Total link strength	The cumulative strength of the links of an item with other items.

3. Results and discussion

3.1 Co-authorship analysis

In the co-authorship network analyses, researchers or countries are linked to each other based on the number of publications they have authored jointly.

3.1.1 Researchers

Of the 299 results, 50 met the minimum threshold of 2 papers per author. The 50 authors are divided into 16 clusters as shown in the network map (Fig. 1). The clusters are likely to reflect different laboratories or teams of researchers. The top 10 authors ranked by number of documents are reported in Table 2.

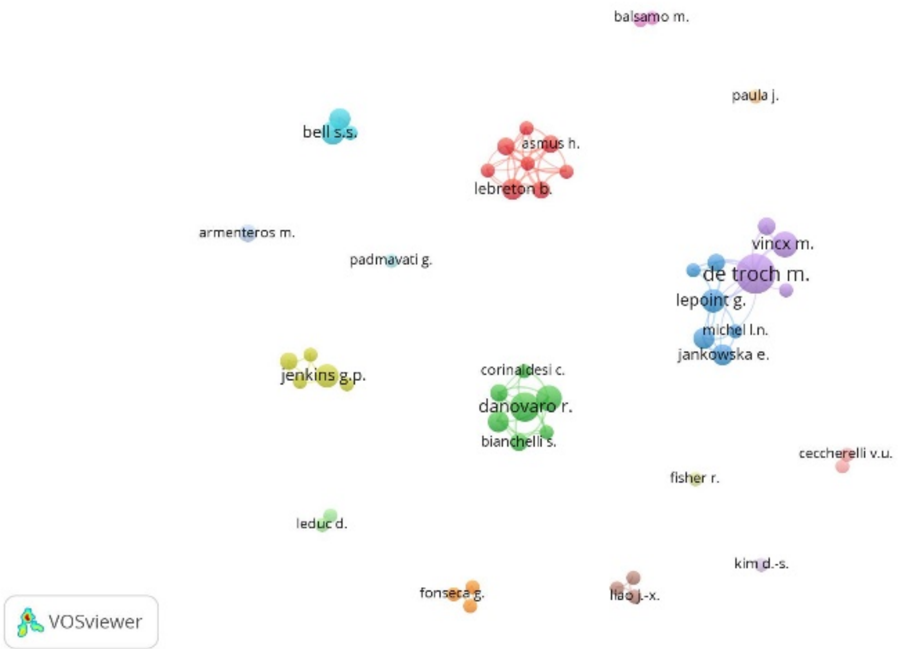

Figure 1. Network map of researchers co-authorship. Node size is based on the number of documents. Colours change according to clusters.

Table 2. List of the top 10 authors ranked by number of documents.

Author	Documents	Citations	Total link strength
De Troch M.	14	259	22
Danovaro R.	8	348	18

Gambi C.	6	173	16
Vincx M.	6	144	9
Bell S.S.	5	156	3
Jenkins G.P.	5	124	8
Lepoint G.	5	69	15
Walters K.	4	132	3
Pusceddu A.	4	114	12
Jankowska E.	4	59	9

The overlay visualization shows the average citations of the authors, with the size of circles depending on the number of documents (Figure 2). From this map, it is evident that the most productive author is not necessarily the most cited one. For example, De Troch, who owns the highest number of publications (14 documents), does not reach the highest citation number, owned by Danovaro (348 citations) with only 8 documents.

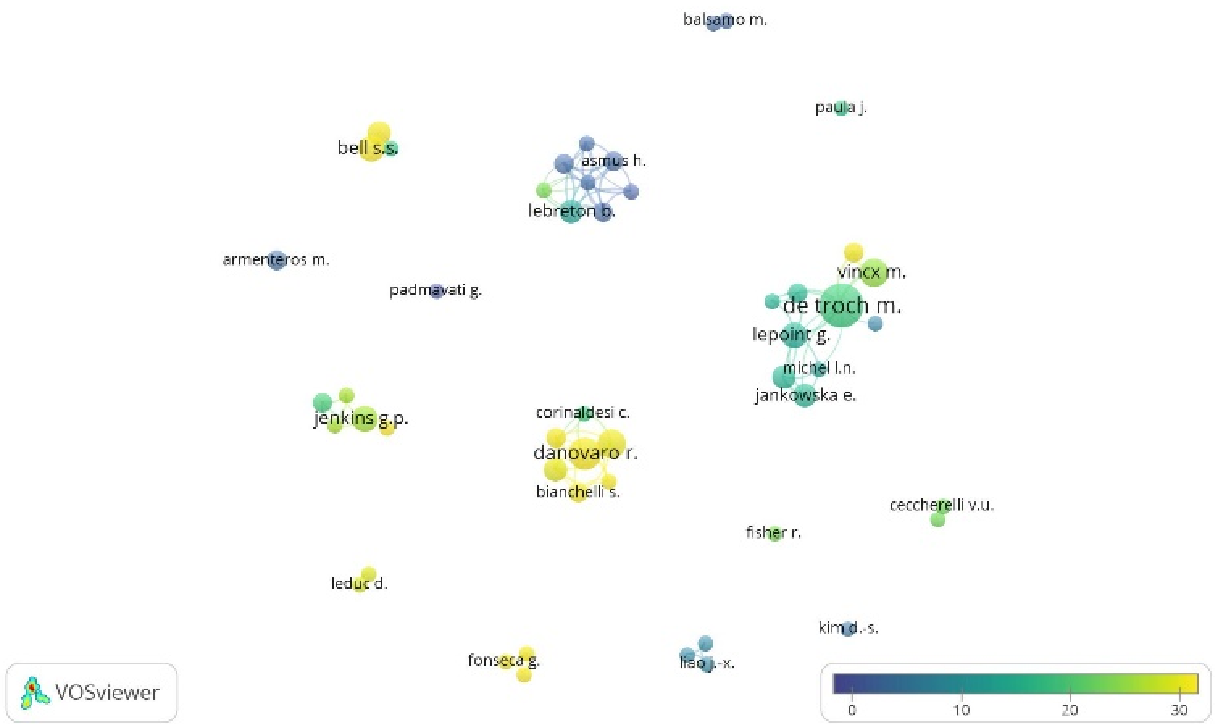

Figure 2. Overlay visualization of co-authorship researchers map. Node size is based on the number of documents. Colours change according to average citations per year.

3.1.2 Countries

Of the 41 countries, 15 met the minimum threshold of 3 documents per country. The 15 items are divided in 5 clusters, ordered by the number of documents, displayed in Figure 3. In the overlay visualization (Fig. 4), average citations are showed, circles size depends on number of documents. The first 10 countries, ranked by citations, are shown in Table 3. The analysis shows that Australia is the leader country in studies of meiofauna associated to seagrasses (15 documents and 568 citations), followed by Italy (15 documents and 422 citations), and United States (15 documents and 311 citations). These data are partially confirmed by the overlay visualization, where Australia and Germany show a high value of average citations per year, followed by Italy and France, while United States show lower values of average citations per year (Fig.4).

Figure 3. Network map of co-authorship countries. Node size is based on the number of documents. Colours change according to clusters.

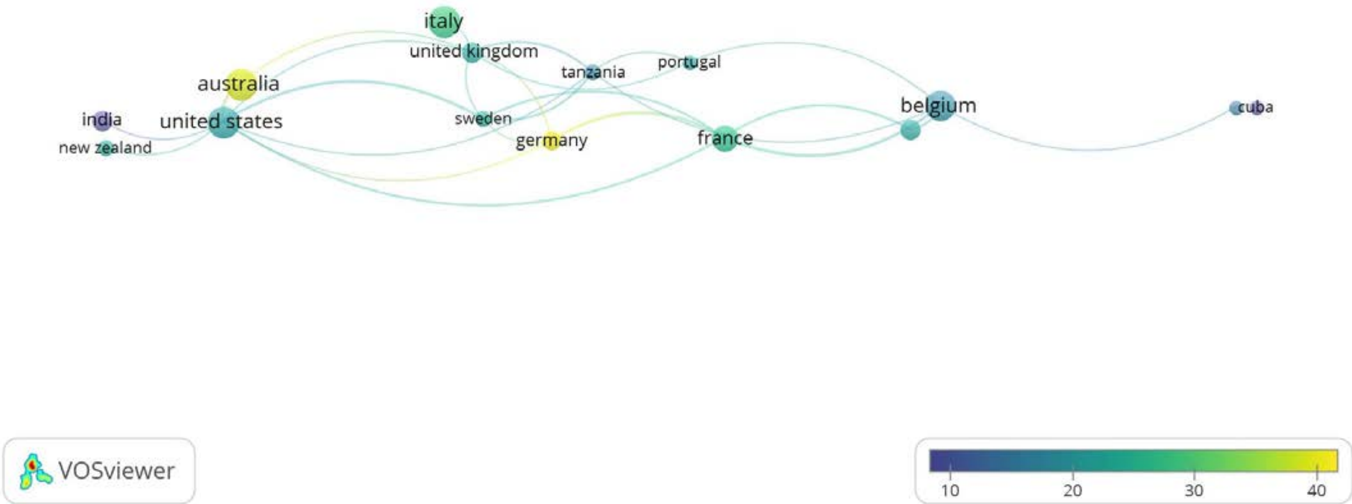

Figure 4. Overlay visualization (average citation per year) of network map of co-authorship countries. Node size is based on the number of documents. Colours change according to average citations per year.

Table 3. List of the top 10 countries ranked by citations.

Country	Documents	Citations	Total link strength
Australia	15	568	4
Italy	15	422	1
United States	15	311	13
France	10	265	12
Belgium	14	253	8
Germany	5	196	6
United Kingdom	6	135	8
Poland	6	134	4
Sweden	4	91	9
New Zealand	4	91	1

3.2 Co-occurrence analysis of keywords

The number of co-occurrences of two keywords is the number of publications in which both keywords occur together in the title, abstract or keyword list. All keywords occurring more than 3 times were included. Of the 818 results, 30 met the threshold and were grouped into 3 clusters (Fig. 5). A thesaurus file was created to avoid synonyms and to merge terms (i.e. singular and plural). The first 10 keywords ranked by occurrences are listed in Table 4. Following the four most common keywords (meiofauna, seagrass, nematode, and copepoda), “community structure” occurred 25 times. This suggest that the interest in understanding and describing this aspect of meiofauna associated to seagrasses, is still significant.

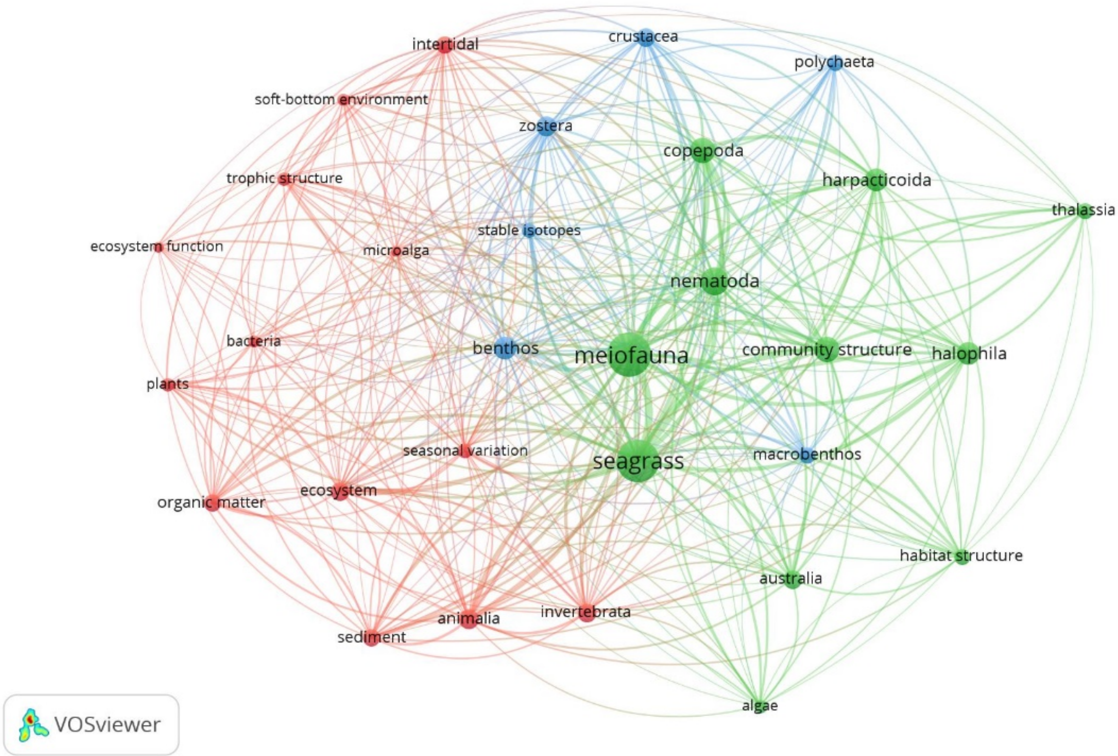

Figure 5. Network map of keywords co-occurrence. Node size is based on the occurrence. Colours change according to clusters.

Table 4. List of the top 10 keywords ranked by occurrences.

Keyword	Occurrences	Total link strength
Meiofauna	78	397
Seagrass	75	395
Nematoda	31	201
Copepoda	27	184
Community structure	25	156
Benthos	22	128
Halophila	22	128
Harpacticoida	20	120
Animalia	16	120
Zostera	16	95

In the overlay visualization (Fig. 6), keywords are shown by average citations per year, weighted by their occurrences, so even though the term “meiofauna” is the most frequent, it is not the most cited one. The keywords “organic matter”, “bacteria” and “sediment”, even if with a low number of occurrences, reach high average citation values (27, 27 and 30, respectively), highlighting the correlation between meiofauna and these components of the benthic environment. On the contrary, the keyword “trophic structure” and “ecosystem function” are displayed with low occurrences and low average citation values (less than 15), probably due to the relatively recent interest of scientific community in understanding the role of meiofauna in the trophic structure of benthic ecosystems.

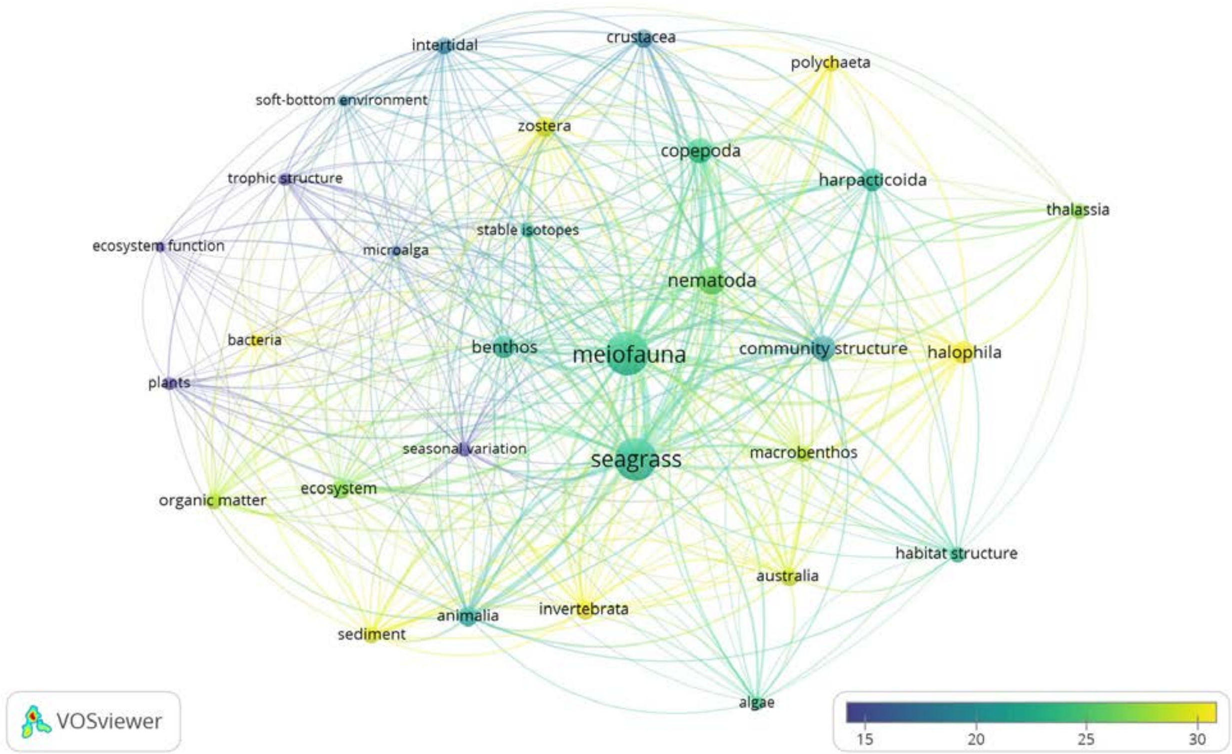

Figure 6. Overlay visualization of network map of keywords co-occurrence. Node size is based on the occurrence. Colours change according to average citations per year.

3.3 Citation analysis of journals

In the citation network analysis, two items are linked if at least one cites the other. The citation analysis of journals produced an overall number of 49 journals, among which 7 met the minimum threshold of 3 documents per journal with a minimum of 3 citations. The journals, ranked by number of documents, are shown in Table 5. The overlay visualization was chosen to better display average citations (Fig. 7). The journal “Estuarine, Coastal and Shelf Science” has the highest number of citations (345) and of documents (8). The results of this analysis show that there is a limited number of specialized journals, with a very low number of documents (maximum 8).

Table 5. List of the journals ranked by number of documents.

Journals	Documents	Citations	Total link strength
Estuarine, Coastal and Shelf Science	8	345	19
Hydrobiologia	8	161	18
Journal of Experimental Marine Biology and Ecology	7	130	4
Journal of Marine Biology Association of United Kingdom	6	59	30
Marine Environmental Research	5	112	9
Marine Ecology Progress Series	4	124	13
Journal of Sea Research	3	93	17

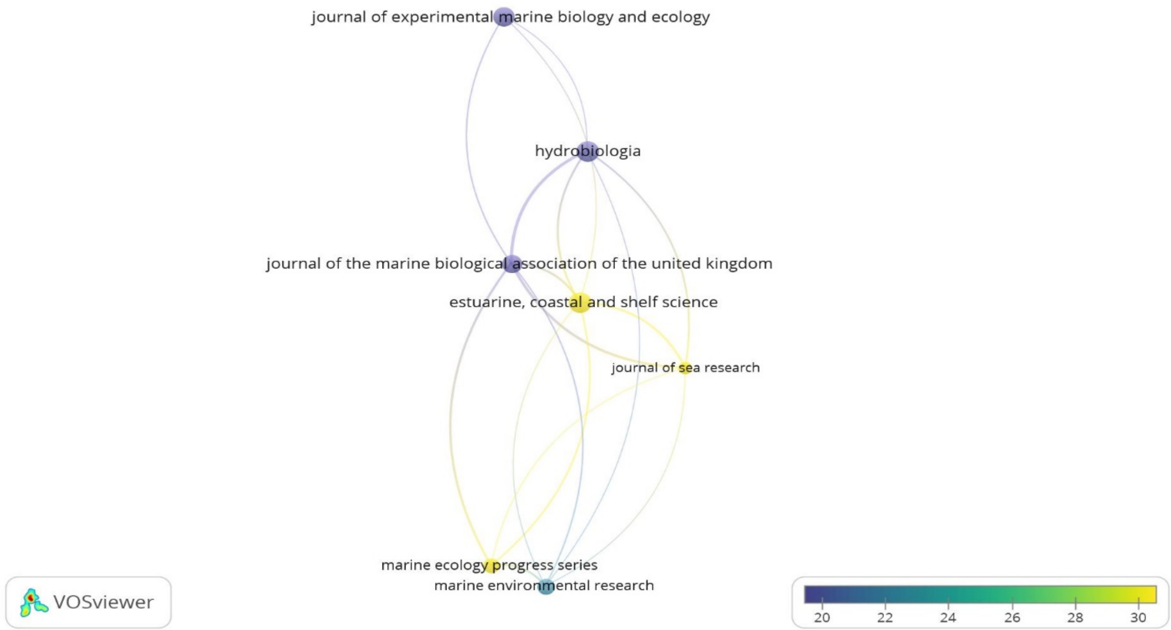

Figure 7. Overlay visualization of the journal citation map. Node size is based on the number of documents. Colours change according to average citations per year.

4. Conclusions

In the present study, the global scientific literature on meiofauna associated with seagrasses has been explored using the VOSviewer software. Through this bibliometric analysis it was possible to notice how scarce the global research about this topic is, and how it is limited to very few countries and authors. Despite the importance of seagrasses and the deep knowledge of other components of these ecosystems, both micro- and macro-benthos, the meiofaunal community inhabiting seagrass beds is starting to catch the attention of researchers around the world. Describing the community structure of the meiofauna inhabiting seagrasses seems to be a relevant topic in this field, but the lack of information is the major obstacle to the full knowledge of the role of meiofauna in seagrass ecosystems. It is desirable that, as suggested by the keywords' map, the increasing interest of the scientific community in meiofauna will be addressed to understand structure and functions of these communities related to seagrasses and all their implications. For example, it would be worthwhile investigating the relationship between macrofaunal and fish communities, since seagrass beds are globally recognized as nursery areas for a large variety of commercial fish species and meiofauna is a key but yet underestimated part of the trophic networks.

Further efforts are necessary for a better understanding of the relationships between meiofaunal communities and seagrass habitats, in order to include this overlooked component in environmental assessment studies and provide proper monitoring tools aimed at the protection and management of these marine ecosystems.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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