



Interdisciplinary Trends in the Studies of *Diadema setosum*: A Bibliometric Analysis of the Period 1980-2025

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ABSTRACT

This study presents the first comprehensive bibliometric analysis of research conducted between 1980 and 2025 on the invasive long-spined sea urchin *Diadema setosum*. Using VOSviewer, 213 publications retrieved from the Web of Science Core Collection (TS= "*Diadema setosum*") were analyzed to assess publication trends, disciplinary scope, collaboration networks, citation impact, co-citation patterns and thematic clusters. The results reveal that the species is rapidly spreading in the Mediterranean and that there has been a sharp increase in publications since 2014, coinciding with a decline in 2022-2023 that corresponds to reported mass mortality events. The co-citation analysis consists of three intellectual clusters encompassing research on (i) marine ecology and echinoid phylogeography, (ii) invasion biology and Mediterranean monitoring, and (iii) disease ecology and mortality events. While marine and freshwater biology dominate the disciplinary profile, emerging environmental themes include ecotoxicology, microplastic exposure, pathogenic interactions, and biomaterial applications (e.g., chitin, chitosan, collagen), with low Total Link Strength (TLS) indicating limited integration. Japan, the USA and China are identified as the leading countries in research. Türkiye is placed within the top 10 in publication numbers but its citation visibility is reported as low because international collaboration is limited. An overall increase in publications has been observed after 2010 and studies related to the expansion of the species into the Mediterranean have contributed to this trend. Our findings indicate that research on *D. setosum* has traditionally been based on classical marine ecology and invasion frameworks, but is increasingly expanding into molecular ecology, disease dynamics and biotechnological applications. Supporting the sustainable use of the *D. setosum* species requires strengthening interdisciplinary approaches, encouraging multi-center collaborations, integrating open genomic and ecological data, understanding invasive dynamics, and assessing ecological risks.

INTRODUCTION

Diadema setosum (Leske, 1778) is an opportunistic detritivore/omnivore that plays an important role in controlling benthic algae cover as an ecologically dominant herbivorous species in reef ecosystems (Vafidis et al., 2021). Beyond its natural range in the Indo-Pacific and Red Sea, it was first recorded in Türkiye's Kaş Bay in 2006, thus entering the Mediterranean as an invasive species (Yokes & Galil, 2006). Increased sea water temperatures in recent years have accelerated the spread of *D. setosum*, with a sudden and rapid increase observed after 2018 (El-Sayed et al., 2020; Vafidis et al., 2021; Dimitriadis et al., 2023; Gökoğlu et al., 2023). This situation clearly demonstrates the effects of climate change-related marine biogeographic shifts on the distribution of living organisms. However, sudden and widespread deaths reported in the Aegean and Levant basins between 2022 and 2023 have resulted in the loss of more than 90% of sea urchin populations (Zirler et al., 2023a; Skouradakis et al., 2024). Clinical symptoms included spine shedding, mucosal integrity breaches and tissue necrosis and molecular analyses reported that these deaths were associated with *Vibrio* spp. bacteria (Zirler et al., 2023a; Dinçtürk et al., 2024; Skouradakis et al., 2024; Roth et al., 2024).

Although it has no economic or commercial importance in our country, it has been reported that *D. setosum* may pose a threat to public health, especially in tourist areas, due to the risk of physical contact caused by its spines (Zirler et al., 2023a). In addition, it has been reported that its abrasive effects on the substrate and the changes it causes in the habitat structure may negatively affect ecosystem services, particularly coastal-based economic activities such as diving tourism (Uthicke et al., 2009). Therefore, interdisciplinary research is of great importance for a comprehensive understanding of the ecological, economic and public health impacts of species such as *D. setosum*.

The quantitative and structural mapping of scientific research has become even more important, especially with the rapid increase in productivity over the past half-century. The paradigm shift described by Price as the "transition from small science to big

science" has made it necessary to measure and track information due to the increase in the number of publications, citations, and researchers (Price, 1963; Bornmann & Mutz, 2015). This momentum has become even more apparent with the expansion of large databases, the spread of the open access movement and the proliferation of interdisciplinary collaborations (Larivière et al., 2015; Piwowar et al., 2018).

In this process, bibliometric analyses have become not only a tool that provides rough performance metrics, but also an analytical framework that analyzes the intellectual structure, evolution, collaboration networks, and information flow of scientific fields (Aria & Cuccurullo, 2017; Donthu et al., 2021). In addition to classic indicators such as impact factor, total citation count, and h-index, network-based approaches such as co-authorship, co-citation, bibliographic matching and keyword co-occurrence are also used. Software such as VOSviewer (van Eck & Waltman, 2010), CiteSpace (Chen, 2006), and bibliometrix/Biblioshiny (Aria & Cuccurullo, 2017) provide decision-makers with powerful tools for visualizing the structural-topological characteristics of scientific fields.

Today, bibliometric analyses have become a widespread and effective method for analyzing the historical development, thematic orientations and scientific priorities of fields such as fisheries and marine biology. Aksnes & Browman (2016) evaluated publication trends in marine research over a 30-year period and showed that despite an increase in scientific output, interdisciplinary collaboration remained limited. Despite its spread as an invasive species in the Mediterranean, the scientific literature on *D. setosum* has been limited to heavy metal, distribution and descriptive ecological records (Grignard et al., 1996; Minn et al., 2004; Yokes & Galil, 2006; Nader & Indary, 2011; Cheang et al., 2015; Bronstein et al., 2016, 2017; Al Najjar et al., 2018; Şimşek et al., 2018; Nour et al., 2022; Uğurlu & Duysak, 2022; Gökoğlu et al., 2023; Vimono et al., 2023; Uğurlu, 2023). Bibliometric analyses show that studies on this species are quite limited both geographically and thematically; they focus on topics such as biomaterial potential, toxicological properties,

biopolymer production and eco-physiological adaptation and do not adequately represent the species (Bronstein et al., 2017).

These gaps in the literature have begun to be gradually filled in recent years with increasing interdisciplinary approaches. Uğurlu et al. (2023a) conducted morphological and mineralogical analyses of the crystal structures in *D. setosum* testa, revealing the potential of these materials for low-loss microwave devices. The same researchers produced chitosan and chitin from the spines and shells and suggested that the biomaterials they obtained be evaluated as environmentally friendly biopolymers (Uğurlu & Duysak, 2023). Different studies have found that different heavy metals accumulate in the tissues of this species, suggesting that *D. setosum* could be used as a potential bioindicator (Al Najjar et al., 2018; Uğurlu, 2023). Additionally, the collagen biomaterial isolated from the species was identified as Type 1 collagen (Uğurlu et al., 2023b).

Such studies reposition *D. setosum* not only as an invasive organism but also as a model marine organism for biotechnological, environmental and toxicological research. However, despite all these contributions, the fact that these studies are not sufficiently visible in international bibliometric databases highlights the need to increase the integration of Türkiye-based scientific production into global knowledge networks.

D. setosum is an invasive sea urchin species that was transported to the Mediterranean via the Lessepsian passage. It has become the focus of multidisciplinary research due to its dominant grazer effect on benthic ecosystems, biomaterial potential and toxicological significance. However, despite this growing interest, a systematic evaluation of the temporal, geographical and thematic characteristics of scientific publications on this species has not yet been conducted.

The main objective of this study is to present a comprehensive bibliometric analysis of the *D. setosum* literature using a dataset comprising a total of 213 academic studies published worldwide between 1980 and 2025, obtained from the Web of Science Core Collection (WoS) database using the search string

“TS=*Diadema setosum*.” The analysis includes publication trends by year, journals in which they were published, author and institutional productivity, country-based collaboration structures, keyword clusters, most cited publications and intellectual knowledge networks. In these analyses, both quantitative and visual-based information mapping was created using VOSviewer open-source bibliometric software. The objectives and outputs of this study can be summarized as follows:

- For the first time, a scientific productivity and collaboration analysis focusing solely on the *D. setosum* species and based on the Web of Science database has been conducted.
- It reveals the bibliometric counterparts of ecological, biomaterial, biopolymer and toxicological research themes in the literature related to the species.
- It evaluates the position of Türkiye-based publications within the global literature, their citation visibility and their position in international collaboration networks.
- It strategically identifies research gaps, emerging thematic clusters and future research potentials.
- In addition, this study aims to systematically reveal the global research trends and multidisciplinary dimensions of *D. setosum* using bibliometric methods, thereby providing a data-based foundation for the formulation of scientific policies related to the species.

MATERIAL AND METHODS

In this study, bibliometric data were obtained from the Web of Science (WoS) Core Collection database, which is interdisciplinary and highly reliable among scientific publications. The data set was obtained from the WoS platform due to its comprehensive search capabilities, widespread use for bibliometric analyses and high reliability. Data access was performed on July 26, 2025. The search was conducted using the query string “TS=*Diadema setosum*” and records matching all searchable fields, including title, abstract, author keywords and Keywords Plus®, were included in the search. The publication date range was 1980-2025, and no date restrictions were applied. All

document types were included to ensure a comprehensive evaluation of the literature. The search included the following WoS indexes:

- Science Citation Index Expanded (SCI-Expanded)
- Emerging Sources Citation Index (ESCI)
- Conference Proceedings Citation Index-Science (CPCI-S)
- Book Citation Index-Science (BKCI-S)
- Zoological Record (ZR)

After filtering, a total of 213 records were evaluated. The data set was exported in .txt format to include complete bibliographic metadata and citation information. Bibliometric mapping and network visualization were performed using VOSviewer software (version 1.6.19). The basic parameters used in the network analysis were as follows: i) a minimum of two documents were required for a co-author to be included in the co-authorship analysis and ii) a minimum of two occurrences were required for keyword matches. No manual editing, correction, or classification was performed, and all analyses were conducted using the original data obtained from the WoS platform.

A co-citation analysis was used to identify influential studies that shape the conceptual framework of this field. This method maps publications that are frequently cited together, revealing the intellectual foundations of the research field. The bibliometric indicator Total Link Strength (TLS) was used to measure the cumulative strength of co-citation links for each reference in the network. Additionally, the number of citations for each reference was recorded based on the analyzed dataset (WoS Core Collection, 1980–2025).

RESULTS

Number of Publications by Year

When examining the distribution of scientific publications related to *D. setosum* by year, it can be seen that a very limited number of studies were

produced between 1980 and 2010. During this period, the annual number of publications generally ranged from 1 to 4 and mostly exhibited a scattered production profile. However, a notable increase was observed in the period after 2011. In particular, the number of publications reached 9 in 2014 and 2015 and this increase became more pronounced in 2016, reaching 18 publications. It has been determined that 13 publications were produced in 2020, 10 in 2022, 15 in 2023 and 18 again in 2024. The fact that 7 publications have been recorded as of 2025 (up to the date of data collection) indicates that the number may increase further by the end of the year. These data reveal that scientific interest in the species has gained momentum over the past decade and has become more visible on the research agenda. The increase is thought to be related to multidimensional research topics such as the species' invasive spread in the Mediterranean, its environmental impacts and its biotechnological potential.

A significant increase in publications has been observed since 2010, with notable peaks in 2014 and 2024. These peaks are thought to be related to increased interest in the species' spread in the Mediterranean and ecological concerns reported during this period. In contrast, the decline observed in 2022 can be interpreted as a temporary shift of resources and scientific interest to other scientific fields following the Covid-19 pandemic.

Types of Publications

When scientific publications on *D. setosum* are classified by type, it is determined that the highest number is peer-reviewed "Article" (n=190). This is followed by publications of the "Proceedings Paper" type consisting of reports (n=13) and "Review Article" (n=3) (Figure 2). Additionally, the literature includes 2 Meeting Abstract and Short Note, 1 Editorial Material, 1 Correction and 1 Book Chapter (Figure 2). This distribution shows that the research topic has been examined largely through original research articles, but is also represented in a small number of publications of different types.

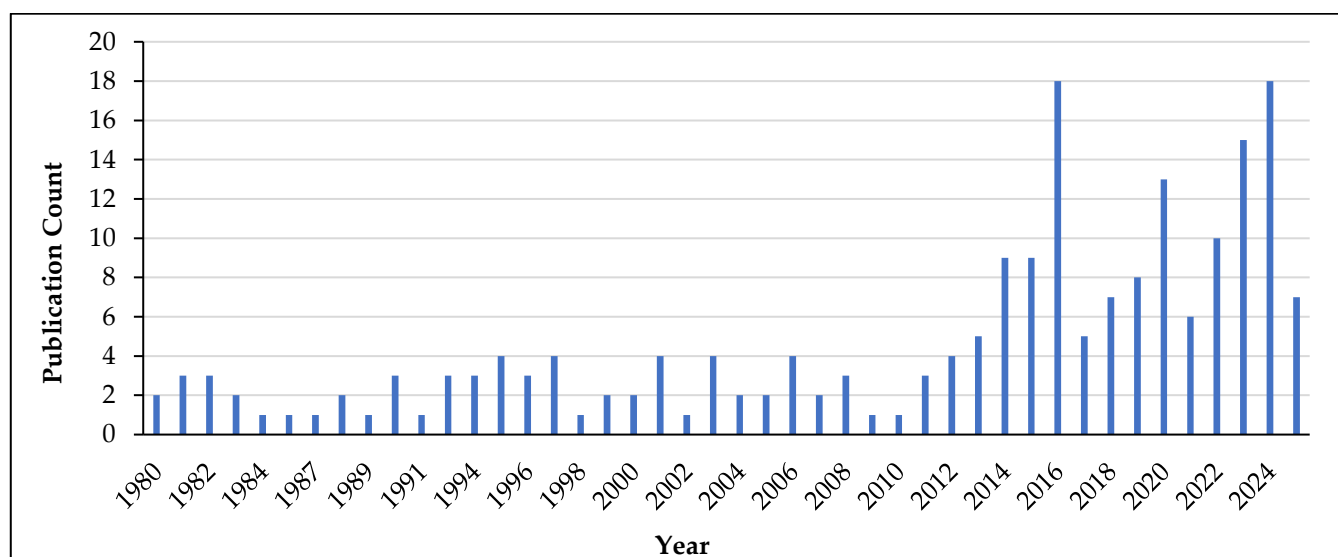


Figure 1. Distribution of publications on *Diadema setosum* retrieved from the Web of Science Core Collection (1980-2025). The trend line illustrates temporal shifts in research intensity, highlighting post-2018 acceleration associated with invasive expansion and mass mortality events (2022-2023). Data extracted using the query string “TS=*Diadema setosum*” (n=213).

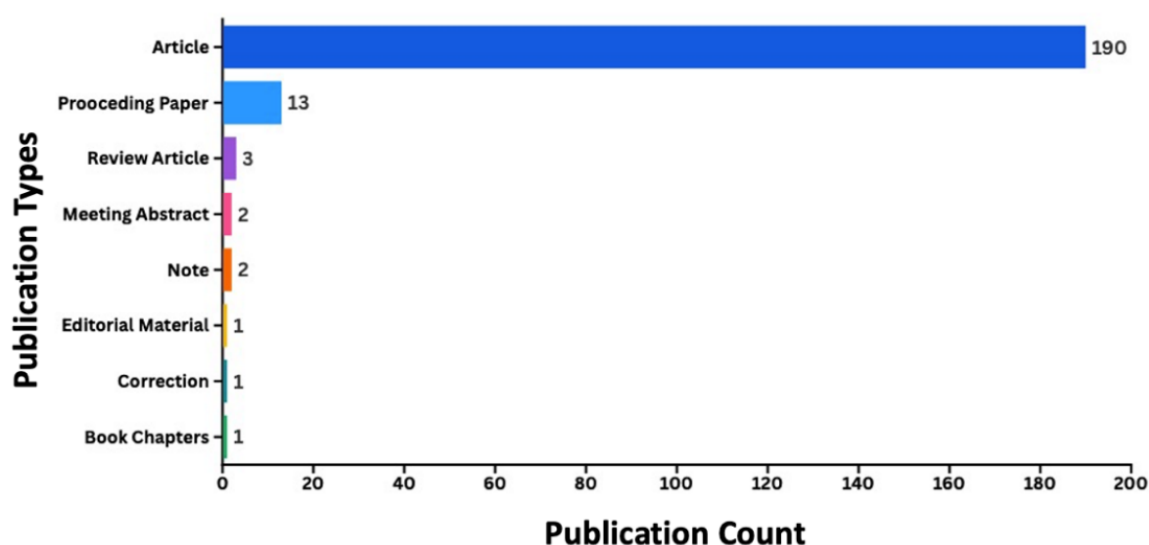


Figure 2. Distribution of publication types on *Diadema setosum* (n=213). Categories include all article types as indexed in Web of Science.

WoS Categories

When examining the distribution of scientific publications on *D. setosum* according to Web of Science (WoS) categories, it was determined that the majority of studies were concentrated in the Marine & Freshwater Biology (n=95) category. This category represents the main area of focus for research in terms of the species' basic ecological context. This is followed by the categories Oceanography (n=33), Ecology (n=34), Zoology (n=30), Fisheries (n=22) and Environmental Sciences (n=22). These categories indicate that the studies address the distribution of the

species in marine ecosystems, its ecological role and its environmental impacts.

In addition, a significant number of publications have been produced in fields such as Biochemistry & Molecular Biology (n=11), Biology (n=9), Geosciences Multidisciplinary and Multidisciplinary Sciences (each n=8). In fields such as Biodiversity Conservation, Food Science & Technology, and Toxicology (n=7), Chemistry, Medicinal, and Pharmacology & Pharmacy (n=6) and Reproductive Biology (n=5), a focus on more specific biological and applied topics has been observed (Figure 3).

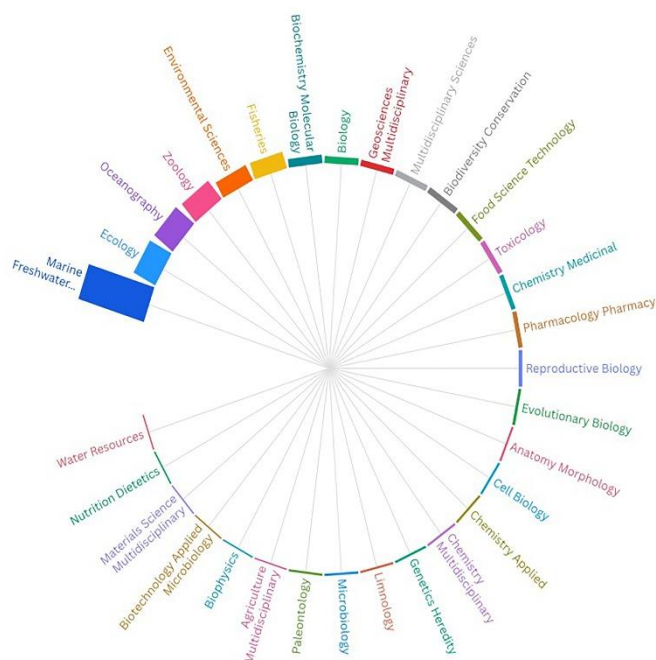


Figure 3. Distribution of *Diadema setosum* publications across the top 31 Web of Science categories. Categories were determined using WoS metadata tags, illustrating the dominance of “Marine & Freshwater Biology” and related ecological disciplines, while emerging representation in toxicology, biomaterials and molecular biology suggests interdisciplinary expansion.

Although they have a lower number of publications, research has also been found in categories such as Limnology, Anatomy & Morphology, Cell Biology, Applied Chemistry, Genetics & Heredity, Microbiology, and Paleontology (each with $n=3$). In addition, a wide variety of subfields with only one or two publications, such as Biophysics, Materials Science Multidisciplinary, Biotechnology Applied Microbiology, Materials Science Multidisciplinary, Nutrition Dietetics, Water Resources, demonstrate that *D. setosum* is also present in different scientific topics (Figure 3).

This broad disciplinary range shows that the species is not only of ecological interest but also of scientific interest in terms of its biochemical, toxicological, biotechnological and even engineering-based aspects, and that it is approached from a multidisciplinary perspective.

Institutions and Countries with the Highest Number of Publications

When publications on *D. setosum* were examined on an institutional basis, it was determined that Tel Aviv University ($n=16$) made the most significant contribution. This institution is followed by the Hellenic Centre for Marine Research ($n=11$), the Russian Academy of Sciences ($n=10$), Hong Kong Baptist University ($n=9$), the Smithsonian Institution, University of Putra Malaysia and the University of Hong Kong (each with $n=7$) (Figure 4). The higher education institutions that have published the most from Türkiye are Ege University, İskenderun Technical University, Muğla Sıtkı Koçman University and Akdeniz University (each with $n=4-5$) (Figure 4). This distribution shows that *D. setosum* research is being conducted by different research networks located in both Europe and Asia within a multi-centered structure.

In the country-level assessment, Japan was found to have made the most scientific contributions with 40 publications. Japan was followed by the United States ($n=27$), the People’s Republic of China ($n=18$), Greece, Indonesia and Israel (each with $n=17$). The number of publications originating from Türkiye is 15, which places Türkiye in the top 10. In terms of literature contributions related to the species, the contributions of France and Italy ($n=14$), Malaysia ($n=12$), Russia ($n=11$) and the United Kingdom ($n=10$) are also noteworthy. These literature distributions and numbers indicate that *D. setosum* has become a subject of research both in its natural distribution areas and in regions where it is invasive and that it exhibits a wide geographical distribution in the international literature.

Although Türkiye-based institutions publish a high number of articles, their international visibility remains low due to the fact that most research is published in local journals and international collaborations are limited. This situation shows that researchers in Türkiye need to publish their work in journals with higher impact factors and strengthen international collaborations.

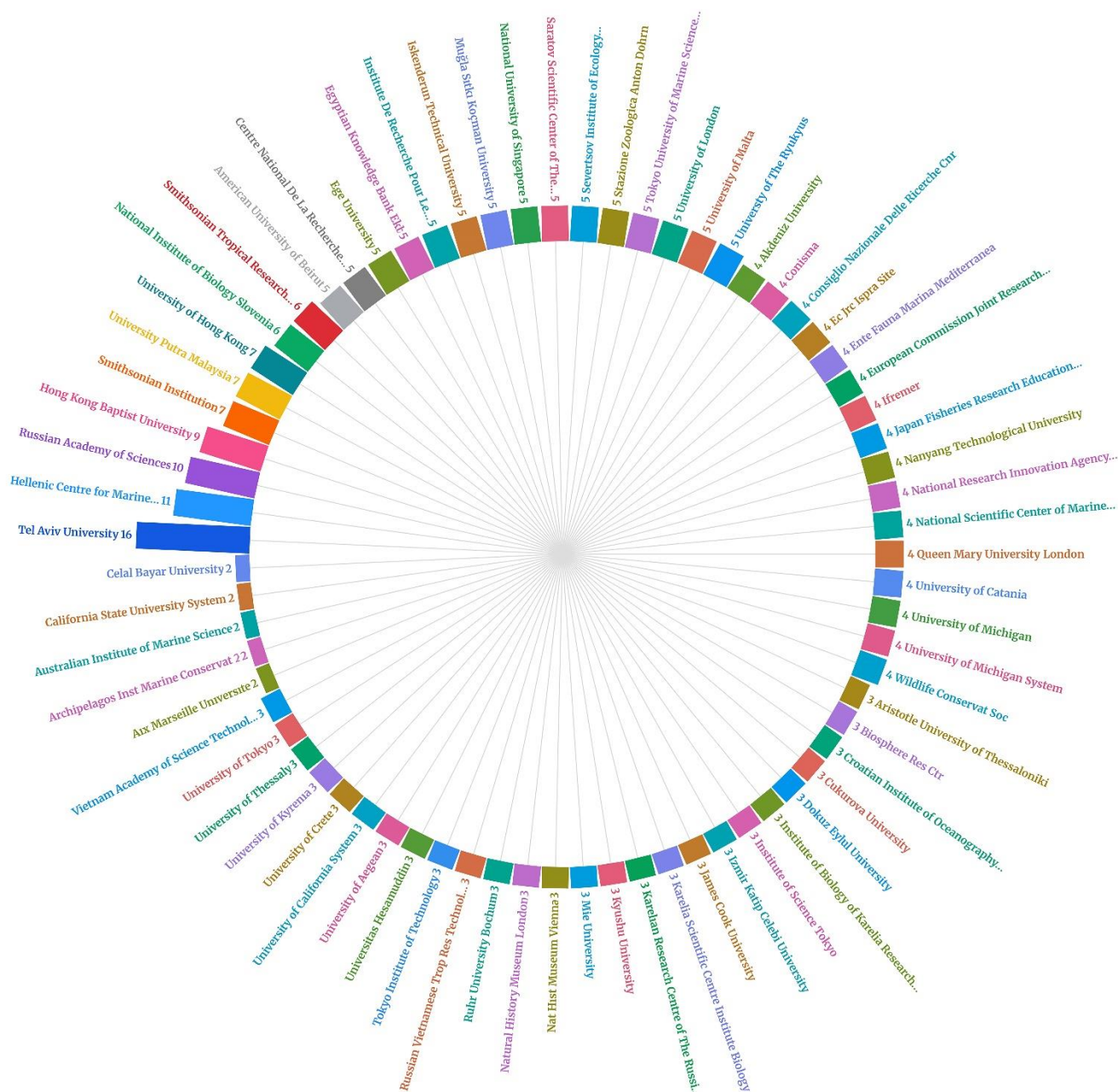


Figure 4. Leading institutional contributors to *Diadema setosum* research (n=213). Node size corresponds to the number of publications per institution and color intensity reflects co-authorship link strength as visualized.

Publication Titles

When examining the journals in which scientific studies on *D. setosum* have been published, it was determined that the highest number of studies were published in the *Journal of Experimental Marine Biology and Ecology* (n=10). This journal is followed by *Marine Biology* and *Mediterranean Marine Science* (n=8 each). Six studies were published in *Marine Pollution Bulletin* and *Zoological Science*, while five studies were published in *Coral Reefs* and *Thalassas* (Figure 5).

Among the journals hosting four scientific studies, *Invertebrate Reproduction Development* and *Marine Ecology Progress Series* stand out; while *Comparative Biochemistry and Physiology B*, *Invertebrate Biology*, *IOP Conference Series: Earth and Environmental Science*, *Journal of Environmental Biology*, *Marine Ecology Progress Series* and *Regional Studies in Marine Science* each feature three studies (Figure 5).

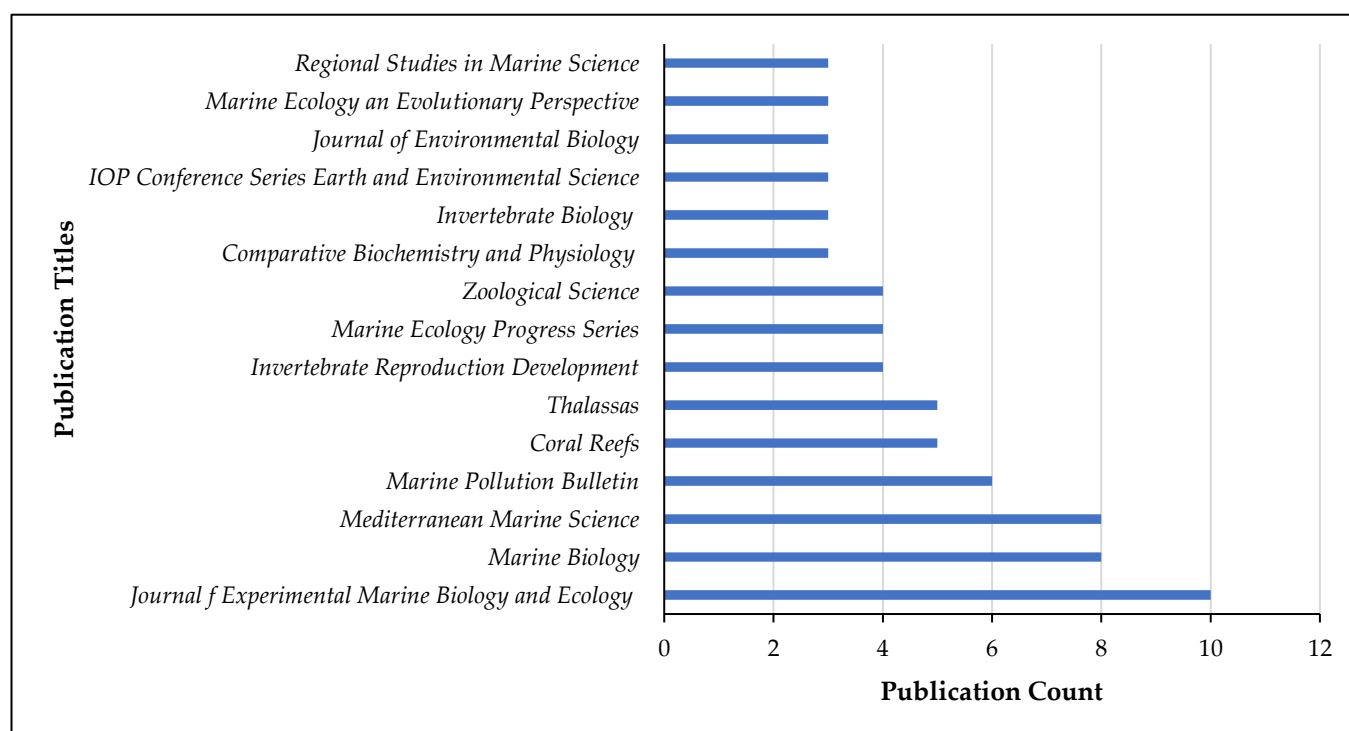


Figure 5. Main journals (top 15) publishing *Diadema setosum* research. The selection of journals is based on publication frequency in WoS-indexed records and shows the concentration in marine biology publications (e.g., *Journal of Experimental Marine Biology and Ecology*, *Marine Biology*) and the gradual inclusion of multidisciplinary outlets.

In the remaining numerous journals, only one or two scientific studies were found. This distribution shows that research outputs on *D. setosum* are concentrated in a specific core group of marine and environmental biology journals, but due to the multidisciplinary nature of the subject, it is addressed in a wide range of publications. The diversity of journals highlights that the subject is addressed in various scientific fields such as ecology, toxicology, physiology, marine sciences and biochemistry.

Most Prolific Authors

When scientific publications on *D. setosum* are examined by author, Omri, B. (Israel) and Jian-Wen, Q. (Hong Kong) (each with 8 publications) are among the most prolific scientists. These researchers are followed by Yusoff, M. F., (Malaysia) Crocetta, F. (Italy) and Arshad, A. (Malaysia) with 7 publications. These researchers are followed by Gerovasileiou, V. (Greece), Motokawa, T. (Japan) and Abd Rahman, M. A. (Malaysia) with 6 publications each. In addition, it has been determined that authors such as Coppard, S. E. (London), Tiralongo Francesco (Italy), Loya, Y. (Israel), Yapıcı, S. (Türkiye), Corsini-Foka, M.

(Greece), Campbell, A. (London) and McClanahan, T. (Kenya) have contributed to the subject with 5 studies each. Among researchers based in Türkiye, Uğurlu, E. stands out in the international literature with four publications. Overall, this distribution shows that *D. setosum* research is being conducted by different research groups at both the geographical and interdisciplinary levels.

Citation Network of Publications

When examining the citation network for publications related to *D. setosum*, it is seen that Jian-Wen, Q. has the highest number of citations. The researcher's four studies have received a total of 116 citations. Lau, D. C. C., who received 88 citations for his two studies and Bronstein, O. who received 44 citations for his three studies, follow him. Kurashima, A., and Ishikawa, T. each received 30 citations for their three studies, while Kroh, A., received 27 citations for his two studies. Researchers such as Kurogi, H. (26), Kaneko, K. (21), Matsumoto, H. (21) and Osako, K., (21) have also received more than 20 citations (Figure 6).

Among the authors who received a more limited but still significant number of citations, Zirler, R., and Corsini-Foka, M., stand out with 22 citations from two publications. Among the researchers who made significant contributions to the local literature, Uğurlu, E.'s three publications received 10 citations, while Duysak, Ö.'s two publications received a total of 8 citations. The works of researchers named Alan, V. (7) and Öndeş, F. (7) have also found their place in the literature. This citation distribution shows that certain authors have created a high impact in a short period of time and that this field has taken shape around certain researchers from a bibliometric perspective (Figure 6).

Co-Citation Network: Intellectual Foundations of *D. setosum* Research

A co-citation analysis was conducted to identify the intellectual roots and fundamental literature supporting *D. setosum* research. The analysis revealed a network dominated by classical ecological and invasion biology studies, as well as molecular and biogeographic research and highlighted a shift from descriptive ecological studies toward integrative and multidisciplinary approaches (Figure 7).

Fundamental Studies in Marine Ecology and Evolutionary Biology

Lessios et al. (2001) (*Evolution*, 15 citations; TLS=240) emerged as the most influential reference, forming the intellectual basis for phylogeographic frameworks for echinoderms and studies of population structure in *D. setosum*. Pearse (1970) and Pawson (1983) provided early ecological perspectives on echinoderm distribution and reproductive biology that are frequently cited together in a historical context.

Invasion Biology and Mediterranean Expansion

Yokes & Galil (2006) (*Aquatic Invasions*, 13 citations; TLS=237) and Bronstein et al. (2017) (*Marine Ecology Progress Series*, 7 citations; TLS=159) are central nodes linking invasion biology to the species' Mediterranean colonization.

Mass Mortalities and Recent Ecological Changes

Recent co-citation clusters bring together studies documenting mass mortality events, such as Zirler et al. (2023a) and Skouradakis et al. (2024), demonstrating a shift in research focus from studies on the distribution of the *D. setosum* species to ecosystem disturbance and disease ecology.

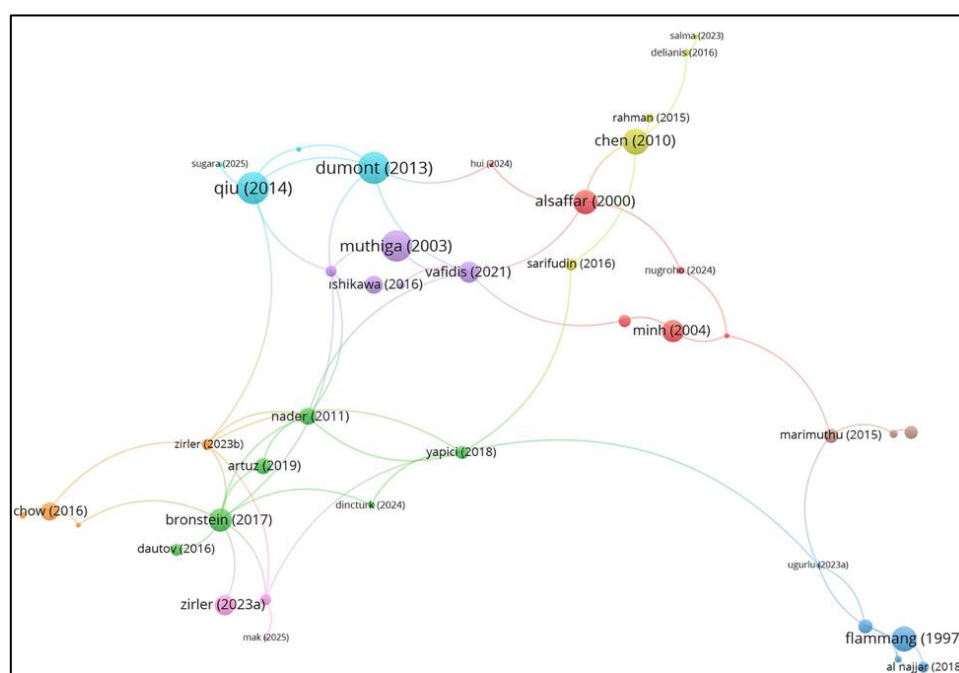


Figure 6. Citation network of *Diadema setosum* publications (1980-2025). Nodes represent individual publications (≥ 1 citation) and their size is proportional to the number of citations. Links indicate co-citation relationships and reveal the main highly cited studies at the center of the field (such as Bronstein et al., 2017; Roth et al., 2024).

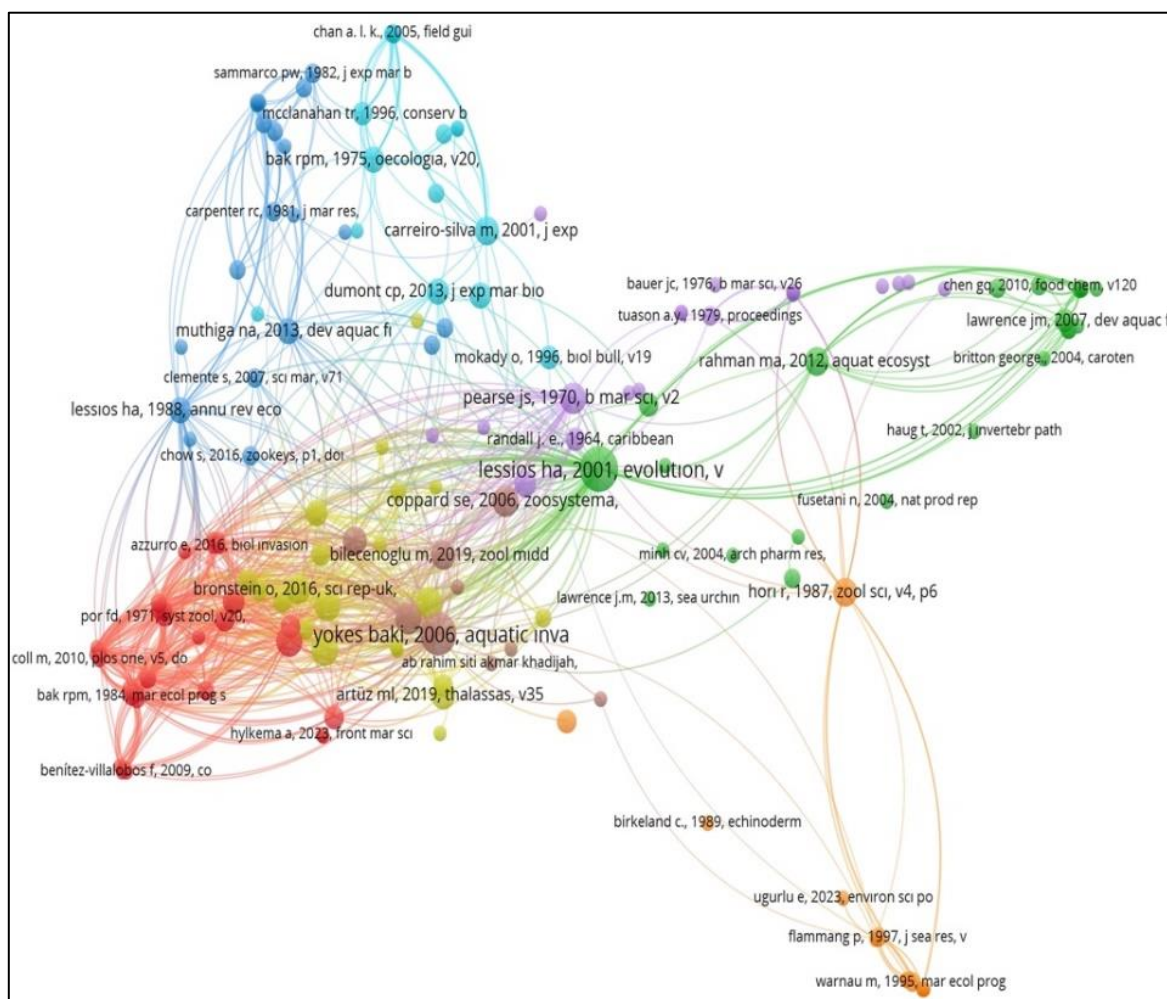


Figure 7. Co-citation network of cited references in *D. setosum* research (1980-2025)

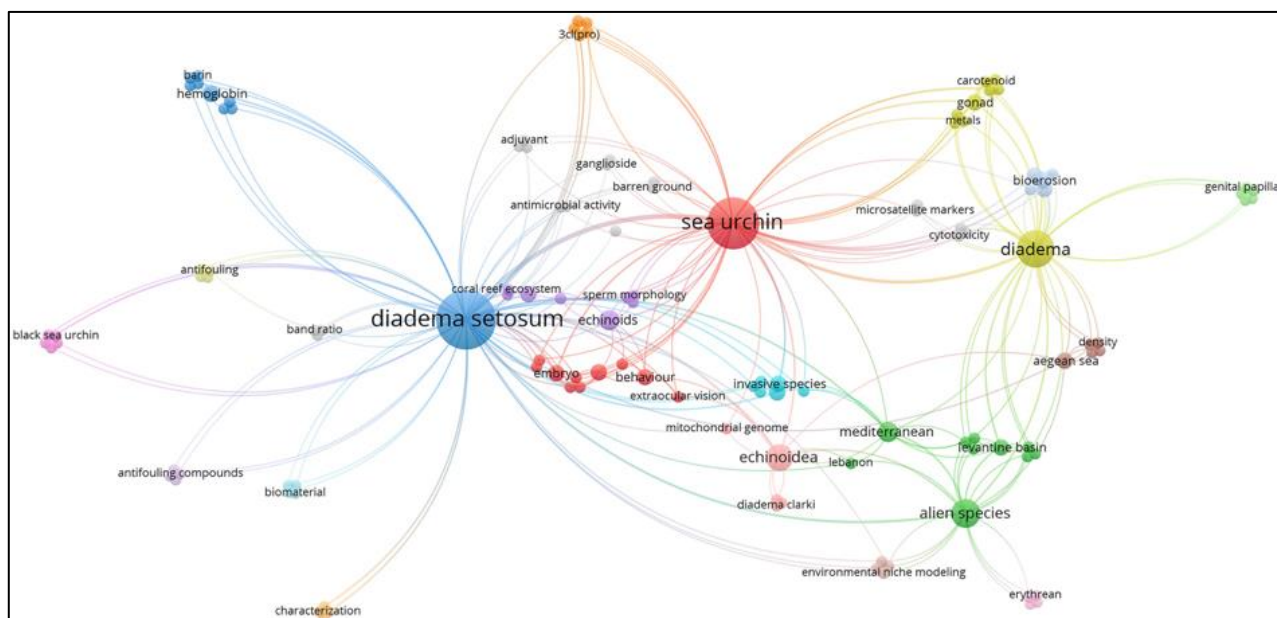


Figure 8. Keyword co-occurrence network for *D. setosum*. Node size reflects frequency, while color-coded clusters denote thematic groupings (such as invasion ecology, ecotoxicology, biomaterials). Total link strength quantifies keyword interconnectivity across publications.

Ecotoxicology and Biomaterials (Emerging Links)

Although less dense in terms of link strength, researchers such as Flammang et al. (1997) and Al Najjar et al. (2018) are included in environmental clusters linking toxicological monitoring to environmental risk assessments. Biomaterial-focused studies (Uğurlu & Duysak, 2023; Uğurlu et al., 2023b, 2023c) point to the early stages of interdisciplinary cross-connections, showing common citation links with engineering-focused journals.

However, the bibliometric density around ecotoxicology and biomaterial applications remains weak, reinforcing the need to include these themes in the core citation network through interdisciplinary collaboration.

Keywords Analysis

When examining the keywords used in scientific publications related to *D. setosum*, it was determined that the species name "*Diadema setosum*" was used 25 times, making it the most frequently used keyword. This keyword is followed by "sea urchin" (n=19) and "diadema" (n=10). Other prominent keywords include "alien species" (n=6), "echinoidea" (n=5), "Mediterranean" (n=3), 'echinoids' (n=3) and "bioerosion" (n=2) (Figure 8).

In addition, themes such as "coral," "platygra," "marine ecology," "invasive species," "behavior," "development," "embryo," "Levantine Basin," "Aegean Sea," "gonad," "heavy metals" and "hemoglobin" are also mentioned twice in the literature. When examining the total link strength of the keywords, it is observed that the terms "sea urchin" (38) and "*Diadema setosum*" (35) have the highest level of correspondence with other concepts (Figure 8). This distribution indicates that the taxonomic identity, biogeographic distribution and environmental impacts of the species are prominent themes in the literature. At the same time, the keywords point to multidisciplinary topics related to the species, such as toxicology ("heavy metals," "hemoglobin"), developmental biology ("embryo," 'development') and ecological impacts ("marine ecology," "bioerosion," "invasive species") (Figure 9).

DISCUSSION

Bibliometric analysis methods have been widely used to identify global research trends (Bornmann & Leydesdorff, 2014; Alvarado & Fabregat Malé, 2021; Ghani et al., 2022; Mao et al., 2023; Zamani et al., 2025). In particular, areas of research concentration, clustering methods and co-citation analysis techniques have been extensively applied in previous studies. The results of our analysis show that global research trends related to the *D. setosum* species exhibit significant parallels and discrepancies when compared to previous bibliometric studies. In studies specifically conducted on *D. setosum*, the exponential population increase after 2014, following the "invasion lag" period, occurred after the species' entry into the Mediterranean (Bronstein et al., 2016; Dautov et al., 2020; Mohd Ramzi et al., 2023; Zirler et al., 2023a, 2023b; Mak et al., 2025; Sugara et al., 2025; Tavoloni et al., 2025). These bibliometric results indicate a significant increase in the number of publications during this period. This aligns directly with the population explosion reported in the literature and the increased geopolitical ecological interest.

Within this global trend, the increase in reports on the widespread distribution of *D. setosum* along the Aegean and Eastern Mediterranean coasts after 2014 supports the rise in the number of publications in bibliometric graphs and suggests that it may have contributed to the overall increase in research outputs on regional geoeological events (Bronstein et al., 2016; Dautov et al., 2020; Mohd Ramzi et al., 2023; Zirler et al., 2023a, 2023b; Vimono et al., 2023; Mak et al., 2025; Sugara et al., 2025; Tavoloni et al., 2025). However, studies on *D. setosum* in the literature are still generally insufficient in terms of geographical distribution analyses and the weakness of international collaboration networks. For example, attention has been drawn to the lack of global-level inter-country collaboration maps. In analysis, despite the high number of Türkiye-based studies, the low number of citations indicates a lack of international visibility. In contrast, similar studies have shown that countries such as the US, China, and the UK are stronger in terms of both publication numbers and citations.

The sudden increases and decreases observed during the analysis are directly related to the “invasion lag” and subsequent rapid population spread dynamics frequently described in the literature. For *D. setosum*, the entry into an exponential spread phase in 2018, particularly in the Eastern Mediterranean, following a prolonged period of low case reports between 2006 and 2017, is defined in the literature as a “biological invasion burst” (Bronstein et al., 2017; Zirler et al., 2023b). Parallel to this situation, the sudden increase in publications observed in our study after 2018 reflects both the ecological spread of the species and the increase in scientific interest. Mass mortality events reported in the literature and the increase in the rate of invasive spread also support this situation (Zirler et al., 2023a; Roth et al., 2024; Skouradakis et al., 2024).

Furthermore, events such as the mass deaths reported in 2023-2025 support the idea that interest increased during this period (Zirler et al., 2023a; Roth et al., 2024; Skouradakis et al., 2024). In contrast, the

relative decline experienced in the 2020-2022 period reflects a temporary decline in scientific production due to disruption of fieldwork and international collaborations caused by the Covid-19 pandemic. The literature often refers to the shift of research areas and intensity to other areas after extraordinary events such as pandemics.

These patterns can be explained by the concepts of “citation bursts” and “topic bursts,” which have been observed not only in the case of *D. setosum* but also in general bibliometric analyses. This approach highlights sudden trend changes within time series and is explained and supported by algorithmic clustering techniques used by researchers such as Stephen Chan in the literature (Ghani et al., 2022; Mao et al., 2023; Zamani et al., 2025). Therefore, when comparing the analysis findings with similar patterns in the literature, the sudden increases and decreases identified can be interpreted as a combination of both ecological events and temporary pauses in the global academic system.

Table 1. Country-level performance metrics for *D. setosum* research (1980-2025). Indicators include number of documents, total citations and bibliometric link strength (calculated via VOSviewer). These metrics highlight regional dominance (such as Japan, USA) and emerging contributions from Eastern Mediterranean

Country	Documents	Citations	Total Link Strength	Country	Documents	Citations	Total Link Strength
Japan	9	95	2	Italy	1	5	4
China	7	124	5	Canada	1	0	3
Indonesia	7	15	1	England	1	0	3
Greece	5	68	11	USA	1	0	3
Türkiye*	5	9	4	Netherlands	1	17	2
Malaysia	5	22	1	Belgium	1	26	1
Turkey*	4	31	1	Scotland	1	5	1
Israel	2	22	6	South Korea	1	20	1
Austria	2	27	5	Thailand	1	0	1
Egypt	2	11	5	Vietnam	1	20	1
Russia	2	8	1	Jordan	1	5	0
Singapore	2	26	1	Kenya	1	41	0
India	2	16	1	Kuwait	1	24	0
Cyprus	1	5	4	Lebanon	1	13	0
Libya	1	5	4	Oman	1	13	0
Malta	1	5	4				

Note: *Studies conducted before 2021 are listed under Turkey, while those after 2021 appear under Türkiye, reflecting the name update.

The analysis findings show that studies on the *D. setosum* species in the global arena are largely conducted in a single center and that international project collaborations are limited. This situation suggests that countries in the Eastern Mediterranean, such as Türkiye, Lebanon, and Israel, are more isolated within the collaboration clusters mapped in the literature. There are studies in the literature that clearly demonstrate the concentration of authors and countries in global scientific network analysis through the analysis of collaboration groups (Bronstein et al., 2017; Vafidis et al., 2021).

Thematic Clustering and Scientific Foci Based on Bibliometric Analysis

Ecotoxicology

It has been determined that there are only a limited number of studies in the literature on metal accumulation in *D. setosum* tissues or shells (Minn et al., 2004; Huseini et al., 2021; Sawalman et al., 2021; Uğurlu, 2023; Tavoloni et al., 2025). However, some studies have focused on the mineral composition and chemical analysis of sea urchin gonads (Kaneko et al., 2009; Bronstein et al., 2017; Ghallab et al., 2024; Hong Kong Biodiversity Genomics Consortium, 2024). Additionally, collagen-based materials obtained from *D. setosum* shells have been used in metal removal studies. It has been demonstrated that Pb (II) ions can be rapidly, effectively, and stably removed from water using alginate-modified collagen beads (Uğurlu et al., 2023c). The number of studies that include analyses of toxic compound potential and environmental metal accumulation is quite low, and this area appears to be poorly represented bibliometrically. This indicates a gap in the field of ecotoxicology, and further research in this area is recommended for the future.

Habitat and Ecological Pressures (Habitat Loss)

Various studies have reported that *D. setosum* is naturally found in high densities in reef and rocky habitats, and in relatively low densities in seagrass and sandy substrates (Lessios et al., 2001; Öndeş et al., 2022; Ghallab et al., 2024). These habitat preferences are associated with environmental changes such as the degradation of natural habitats and increases in sea

water temperature during the species' invasive spread. Additionally, it has been reported that in areas where the species is found in high densities, it can cause biological erosion due to overgrazing, which may also lead to habitat loss (Muthiga & McClanahan, 2007, 2020; Moore et al., 2019). In this context, the relationship between habitat loss and *D. setosum*'s habitat preferences, as well as ecological and structural habitat changes, is showing an increasing trend in the literature.

Genetics, Phylogeny, Evolution and Population Structure

Genetic and phylogeographic analyses are emerging as an important area of development in *D. setosum* research. Periodically published studies based on the COI gene indicate that the two clades of the species are linked to their geographical distribution (Lessios et al., 2001; Vimono et al., 2023; Ghallab et al., 2024; Hong Kong Biodiversity Genomics Consortium, 2024; Shahid & Hassan, 2024). A comprehensive study conducted in 2023 clearly identified the source of the invasion and the direction of spread by showing that the *D. setosum* clade detected in the Mediterranean belongs to a single Red Sea clade (Bronstein et al., 2017; Shahid & Hassan, 2024). Such genetic data contribute to the understanding of evolutionary phylogeny and also establish scientific foundations for invasion biology.

Evaluation as a Biomaterial

The biomaterial potential of *D. setosum* has become increasingly visible in the literature in recent years due to growing interdisciplinary studies. The calcium carbonate (CaCO_3) found in the shell, spines, and Aristotle's Lantern structures of this species, particularly its low-loss dielectric properties and high crystalline structural order, make this organism noteworthy in the field of biomaterials science (Uğurlu & Duysak, 2023; Uğurlu et al., 2023b, 2023c; Uğurlu, 2023; Mansjur et al., 2025). Studies have revealed the microstructure of *D. setosum* shells using advanced analytical methods such as SEM, XRD, and FTIR (Uğurlu, 2023). These structures possess bioceramic and piezoelectric properties that could potentially be evaluated in fields such as bone tissue

engineering, biosensors, and microelectronic devices (Wu et al., 2022; Uğurlu et al., 2023b). Additionally, high-yield chitin and chitosan extraction has been achieved from *D. setosum* spines and shells. In an experimental study conducted by Uğurlu & Duysak (2023), chitosan obtained from the species was evaluated in the category of environmentally friendly biopolymers and reported to have been obtained with a deacetylation degree of over 85%.

In addition, Type I collagen isolated from this species has been proposed as a tissue support material and its potential for use in biomedical fields such as wound coverage and skeletal repair has been indicated (Uğurlu et al., 2023b). Based on this information, it has been demonstrated that *D. setosum* can be considered not only an invasive species but also a sustainable source of biomaterials.

CONCLUSION

This study provides a comprehensive overview of the research history of the *D. setosum* species by systematically analyzing the scientific literature published between 1980 and 2025 using bibliometric methods. Based on 213 academic studies obtained from the Web of Science database, the analysis mapped publication trends, prominent research themes, geographical distribution, author and institutional networks, and intellectual clusters in detail.

When publication numbers were examined by year, a significant increase was observed after 2014, despite the low number of articles published between 2006 and 2014. This period represents a turning point in global bibliometric activity. Genetics, invasion processes, and ecological impacts stand out among the research clusters. However, it has been determined that while the research is thematically focused on genetics and distribution, there is a serious lack of work in areas such as ecotoxicology, biomaterial applications and microplastic exposure.

When examined in terms of geographical distribution, the vast majority of publications are concentrated in Eastern Mediterranean countries, with studies based in Türkiye, Israel and Lebanon being particularly noteworthy. In contrast, it has been found that large-scale collaborative publications

based in the US, China or Europe is quite limited. This reveals an imbalance in geographical representation in the literature. When international collaborations are examined, it is observed that these studies are largely limited to the regional level and although countries such as Türkiye, which are located in the current distribution areas of the species, contribute to the research, the citation impact is low. This situation points to structural deficiencies in terms of both scientific visibility and integration into global knowledge networks.

FUTURE PERSPECTIVES

Based on the results of the bibliometric analysis conducted, the following future opportunities and areas of focus have been listed for *D. setosum* research.

Thematic Deepening and Diversification

The existing literature focuses mainly on distribution, genetic structure and ecological effects, while interdisciplinary studies such as ecotoxicological tests, microplastic transport, pathogenic infections and biomaterial production are lacking. Conducting studies focused on these areas will enhance the scientific value of the species and highlight the necessity of research on the sustainable use of *D. setosum* populations in nature.

Expanding International Collaborations

In regions where the species has become invasive, such as Türkiye, Israel, Greece and Lebanon, multi-center projects supported by molecular ecology, isotope analysis and metagenomic studies will contribute to ecosystem-based decision-making mechanisms and increase citation visibility.

Data Sharing and Open Science Applications

Sharing the obtained data on open-source data platforms (e.g., Echinobase, Dryad) will both strengthen the reproducibility of research and enable data-driven modeling.

Expansion of Biotechnological Applications

Advanced experimental studies such as the characterization of the functional properties of biomaterials such as chitin, chitosan, and collagen

obtained from *D. setosum* for antimicrobial and biomedical applications are important in terms of both academic and industrial collaborations.

Global Monitoring and Early Warning Systems

Considering the spread rate of the species, mortality patterns, and effects on the habitat, the integration of invasive organisms such as *D. setosum* into early warning systems and long-term monitoring studies are of great importance not only from a scientific perspective but also from a management perspective.

Compliance with Ethical Standards

Authors' Contributions

EU: Conceptualization, Writing – original draft, Investigation, Methodology, Formal Analysis

ÖD: Conceptualization, Writing – review & editing

All authors read and approved the final manuscript.

Conflict of Interest

The authors declare that there is no conflict of interest.

Ethical Approval

For this type of study, formal consent is not required.

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Data Availability

The study was conducted using articles accessed via Web of Science and then processed using VOSviewer software.

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