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The scientific literature on coralligenous habitat and fishing impacts

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Abstract

Among marine habitats, the coralligenous represents one of the most important biodiversity hotspots, also playing an important role in the carbon cycle. Coralligenous is a biogenic habitat of the circalittoral zone formed by calcareous structures built by crustose coralline algae and other assemblages of calcifying organisms. Due to its structural complexity, it is also considered one of the most vulnerable marine habitats, very sensitive to environmental changes, such as climate change, and to other anthropogenic impacts such as fishing activities. Trawling is the most harmful fishing method that is causing the degradation of large areas of coralligenous reef concretions. Small-scale and sport fishing can also cause damage to the most sensitive organisms of the coralligenous habitat that can be damaged or removed by fishing gear, both during the fishing activity and in the case of the involuntary abandonment of stranded or damaged fishing nets, also known as “ghost nets”. In this study, the global scientific literature on coralligenous habitat was explored, with a particular focus on human impacts and fishing activities. The analysis was carried out using the VOSviewer software, generating network maps based on literature data retrieved from the Scopus database. The results show that the scientific literature is mainly concentrated in Italy, proving the important contribution provided by the Italian research on the topic. The results also highlight a research gap in the application of environmental accounting methods to quantify and value natural capital and ecosystem services associated to the coralligenous habitat, and their loss due to human impacts.

Keywords: coralligenous; impacts; fishing; Mediterranean Sea; VOS viewer.

1. Introduction

The coralligenous habitat is one of the most important biocenosis of the Mediterranean Sea for its high structural complexity that promotes a huge floral and faunal abundance and diversity (Garrabou et al., 2002; Ferrigno et al., 2018; Ballesteros, 2006). For this reason, it represents the most important hotspot of biodiversity (Ferrigno et al., 2024), after *Posidonia oceanica* meadows (Boudouresque, 2004).

Many of the benthic species it hosts are endemic, sensitive, and protected, such as the red coral *Corallium rubrum* (Boudouresque, 2004; Ferrigno et al., 2020; Coll et al., 2010). Due to its high associated biodiversity, coralligenous habitat provides a wide range of important ecosystem services to humans (Tonin, 2018). In particular, they provide provisioning services through fishing, regulating services such as climate regulation through sequestration and storage of carbon, and cultural services due to the beauty of marine landscapes and diving tourism (Ballesteros, 2006; Buonocore et al., 2020a,b; Chimienti et al., 2017).

Due to its structural complexity developed in specific and stable environmental conditions, the coralligenous is among the most vulnerable marine habitats since any variation of these conditions can affect its organisms that cannot easily adapt to changes (Piazzi et al., 2012; Gatti et al., 2015b). Therefore, its stability is threatened both by global impacts such as climate change and local impacts such as fishing pressure (Piazzi et al., 2012; Bavestrello et al., 2014; Gambi et al., 2010; Bo et al., 2014; Rendina et al., 2019; Iborra et al., 2022). In fact, in the last decades, the increase of fishing activities is negatively affecting coastal benthic communities, reducing and degrading the structural heterogeneity of coralligenous assemblages (Gilman, 2015; Ferrigno et al., 2018a; Ferrigno et al., 2021; Rendina et al., 2020b; Piazzi et al., 2012; Gatti et al., 2015a; Betti et al., 2020). Bottom trawling is considered the most destructive fishing method causing the degradation of vast areas of coralligenous concretions (Boudouresque et al., 1990). This fishing technique generates a direct mechanical damage because it destroys the biostructure and an indirect damage because it adversely affects the macroalgal primary production as a result of increased water turbidity and sedimentation rates (Cerrano et al., 2001; Clark and Koslow, 2007; Althaus et al., 2009; Relini and Tunesi, 2009; Piazzi et al., 2012; Bavestrello et al., 2014; Bo et al., 2014; Ferrigno et al., 2024).

Even small-scale and sport fishing can cause serious damage to coralligenous organisms by damaging or removing them with fishing gears such as lines and gillnets (Bavestrello et al., 1997; Ferrigno et al., 2018). The loss of fishing gears, also known as “ghost nets”, in addition to damaging benthic and pelagic organisms, introduces xenobiotic compounds into the marine food web, generating toxic effects in marine animals and potential harm to human health (Rochman, 2015; Markic et al., 2018; Pauna et al., 2019). These direct impacts, together with those caused by climate change, lead to a deterioration in the functions of this marine habitat and the loss of associated ecosystem services (Althaus et al., 2009; Vihervaara et al., 2019; Buonocore et al., 2021; Liu et al., 2021a,b; Grande et al., 2023).

To date, the importance of coralligenous habitat is recognized internationally and numerous management and protection plans have been adopted to ensure its conservation in the framework of the Barcelona Convention (Tribot et al., 2016; UNEP, 2008, 2017). Coralligenous assemblages are monitored in the Mediterranean Natura 2000 network (La Mesa et al., 2019) and included in the broad category "reefs" of the EU Habitats Directive 92/43/EC (E.C., 1992). In addition, coralligenous was recently included among the habitats of particular interest under the Marine Strategy Framework Directive (MSFD), which assesses the "Good Environmental Status" (GES) of European marine waters (European Parliament, Council of the European Union 2008; European Commission 2010). It is also considered a useful indicator for the monitoring of the ecological status of coastal waters, according to the European Water Framework Directive (WFD, 60/2000/EC) because it represents a habitat very sensitive to environmental changes (Ferrigno et al., 2017,2020; Piazzi et al., 2022). For all these reasons, it is essential to monitor its ecological quality and health status to ensure its conservation (UNEP, 2019).

While many studies on the importance of the coralligenous habitat were published, a comprehensive overview of the literature on coralligenous habitat and anthropogenic impacts is still missing. To fill this gap, we performed a bibliometric network analysis to explore the global scientific literature on coralligenous habitat and human impacts, with a particular focus on fishing.

2. Material and Methods

2.1 Bibliometric Network Analysis

In this study, the VOSviewer software (version 1.6.20) (Van Eck and Waltman, 2018) was used to perform a bibliometric network analysis exploring the global scientific literature on the relationships between (i) "Coralligenous" and "Impacts", and (ii) "Coralligenous" and "Impacts" and "Fishing".

Bibliometric network analysis is a tool useful to quantitatively analyze trends and patterns of large amounts of data, integrating bibliometrics and social network analysis (El Alam et al., 2024). Bibliometrics uses different quantitative and statistical analysis to investigate knowledge structure and track the evolution of fields of science and related networks (Reuters, 2008; Zou et al., 2018). Social Network Analysis is a methodology that allows to investigate social relationships and has been applied in many fields of science to analyze social structures (Scott, 2007).

Bibliometric network analysis quantitatively explores the relationships between different variables such as countries, researchers, organizations, authors, and keywords related to the subject under investigation, also developing network maps and statistics (Chen et al., 2016; Geremia et al., 2024). This method allows the creation, visualization and interpretation of maps based on bibliometric network data, showing different clusters representing the classification of output results. The main technical terms used by the software are described in Table 1.

Table 1. Terminology used by VOSviewer software (Van Eck and Waltman, 2018).

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.

Different types of analysis can be generated by the VOSviewer software. In this study, the generated maps show the network of co-occurrence of keywords through a co-occurrence analysis (Table 2). The "total link strength" determines the size of items while the "link strength" determines the thickness of each connection (Table 1). The resolution parameter determines the number of clusters. The higher its value, the higher the level of detail and therefore the number of clusters. The user can arbitrarily set its value to display an accurate number of clusters (Van Eck and Waltman, 2018). In this study, a resolution of 5 was applied throughout the analysis.

Table 2. Different VOSviewer types of analysis (Van Eck and Waltman, 2018).

Analysis	
Co-authorship	In co-authorship networks, researchers, research institution, or countries are linked to each other based on the number of publications they have authored jointly.
Co-occurrence	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.
Citation	In citation networks, two items are linked if at least one cites the other.

2.2 Bibliographic research and data collection

Documents were collected on February 1st, 2024 from the web search engine Scopus. The search string used was composed by the terms: “Coralligenous” and “Impacts” and “Fishing” to explore the relationship among them.

The research on the relationships between “Coralligenous” and “Impacts” resulted in 87 documents published in a timeframe ranging from 2004 to 2024, while that on the relationship between “Coralligenous” and “Impacts” and “Fishing” resulted in 22 documents published in a timeframe ranging from 2008 to 2022.

The data were exported as .csv files and imported into the VOSviewer software.

3. Results and Discussion

3.1 Coralligenous and Impacts

The research on the Scopus database resulted in 87 documents published since the year 2004. The main keywords related to “Coralligenous” and “Impacts” are shown in Table 3, classified according to occurrence. The topics most related to the theme “Coralligenous” and “Impacts” are those characterized by a higher value of the occurrence. The network map in Figure 1 shows the co-occurrence of keywords based on the “link strength”. The analysis of the co-occurrence of keywords generated 940 results. Then, inserting a thesaurus file to avoid repetitions between singular and plural of the same word and applying a threshold of 5 occurrences, 61 keywords were generated and grouped in 5 clusters related to different disciplinary fields, among which zoology (red cluster), conservation (yellow cluster), monitoring (blue cluster), management (green cluster) and climate change (violet cluster). The larger the items and the smaller the distance between them, the greater is their correlation strength, as shown in the map (Figure 1).

The main keywords were “Mediterranean Sea”, “Ecosystems”, and “Biodiversity” (Table 3).

In addition, an analysis of the temporal distribution of keywords between the scientific publications related to “Coralligenous” and “Impacts” was also performed to identify main trends in the evolution of the scientific literature on the topic (Figure 2).

Table 3. Keywords most related to the themes “Coralligenous” and “Impacts”.

Keywords	**Occurrence**
Mediterranean Sea	61
Ecosystems	31
Biodiversity	26
Coralligenous habitats	26
Benthos	19
Coral reef	18
Climate change	16
Algae	15
Anthozoa	15
Coral	15

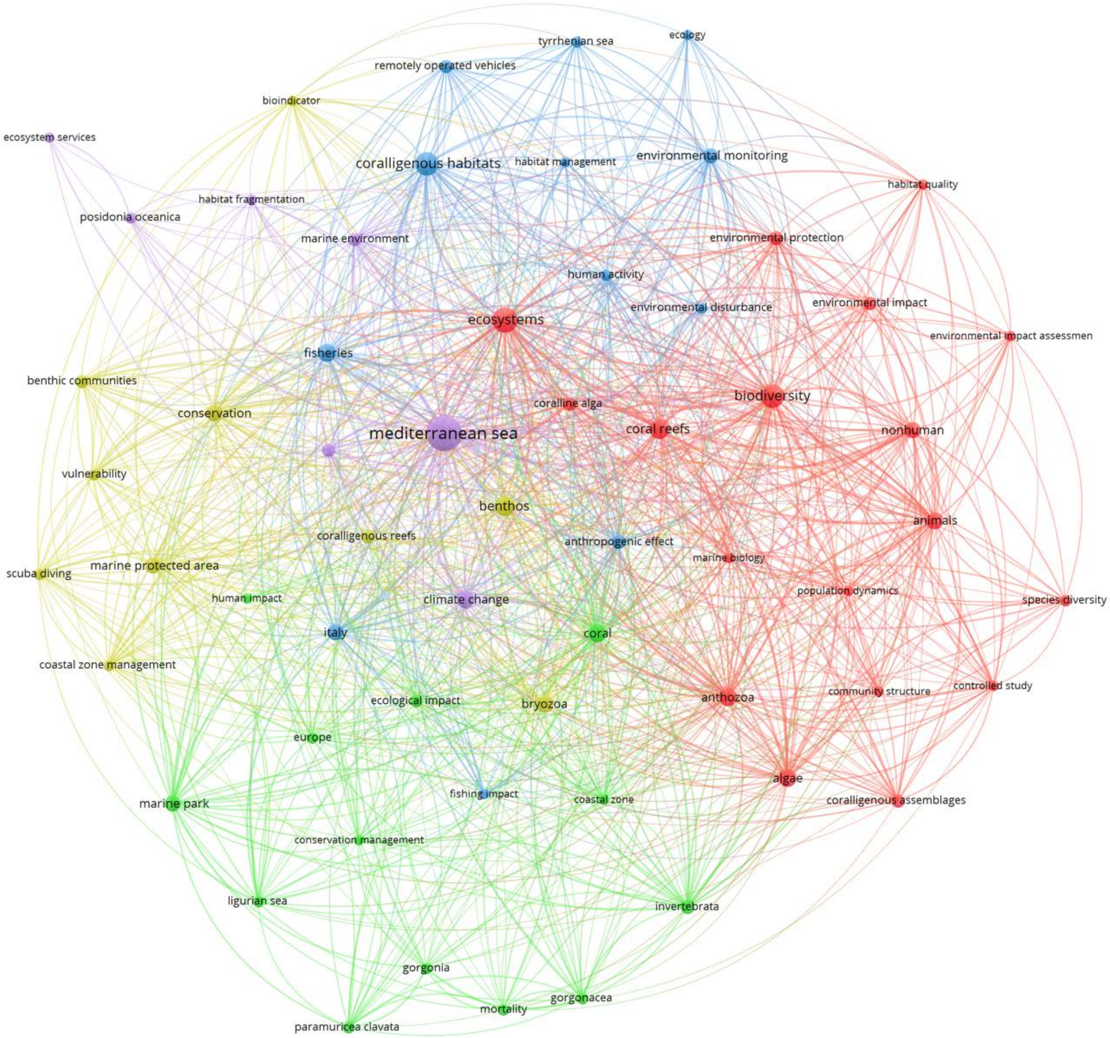

Figure 1. Co-occurrence map of keywords related to “Coralligenous” and “Impacts”.

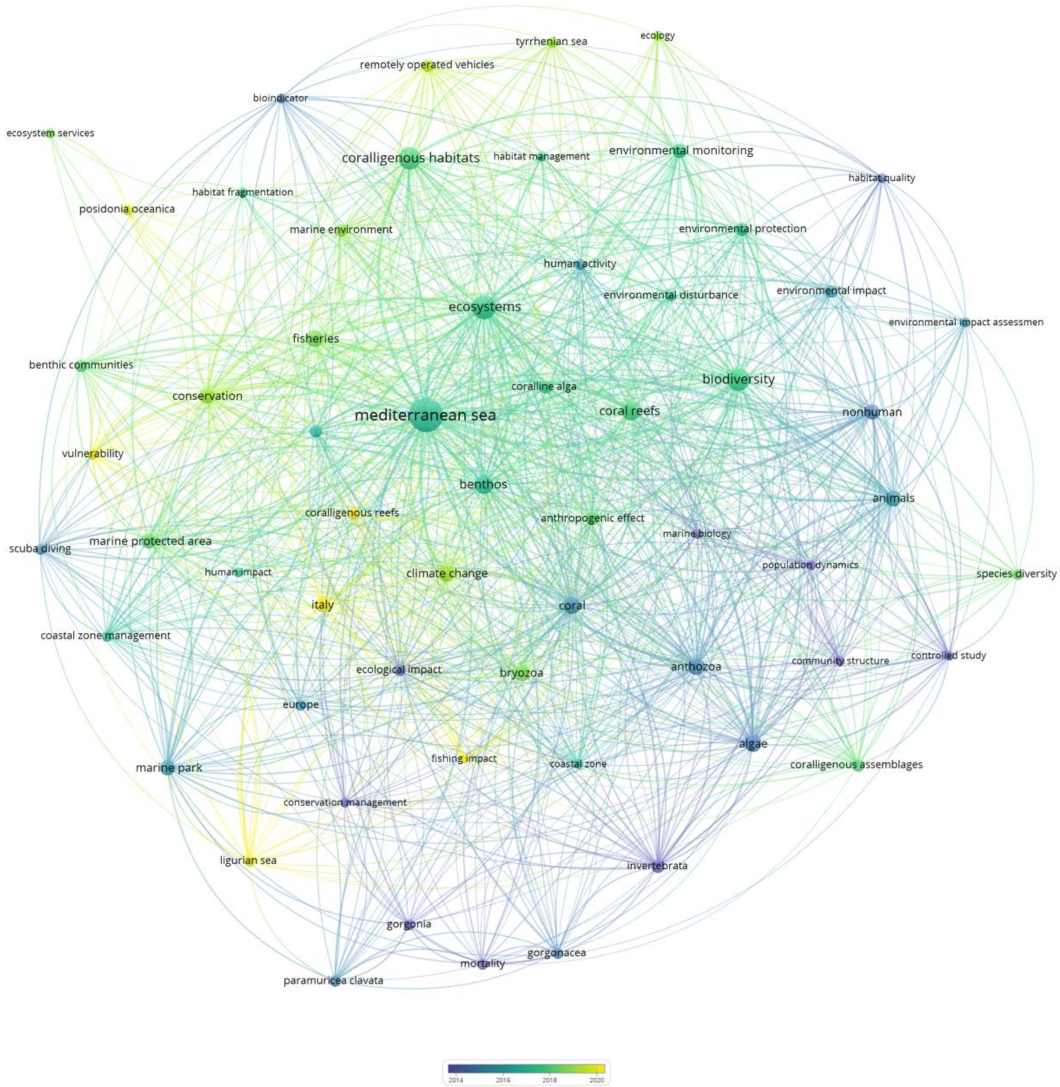

Figure 2. Temporal distribution analysis of keywords on “Coralligenous” and “Impacts”.

From the temporal distribution analysis, we observe that the most recent focus is on the themes of “Conservation”, “Climate Change” and “Fishing Impact” which underlines the recent increase in awareness on the importance of coralligenous habitats and the need to preserve them, especially from the anthropogenic impacts due to fishing activities. For this reason, in section 3.2 we expand the review of the literature by investigating more in depth the relationships between coralligenous and fishing impacts.

Table 4 shows the top five authors publishing on “Coralligenous” and “Impacts” ranked by total number of documents. Figure 3 shows the co-authorship network map based on the number of publications and it includes only authors with at least 3 publications. The total number of authors publishing on “Coralligenous” and “Impacts” was 385.

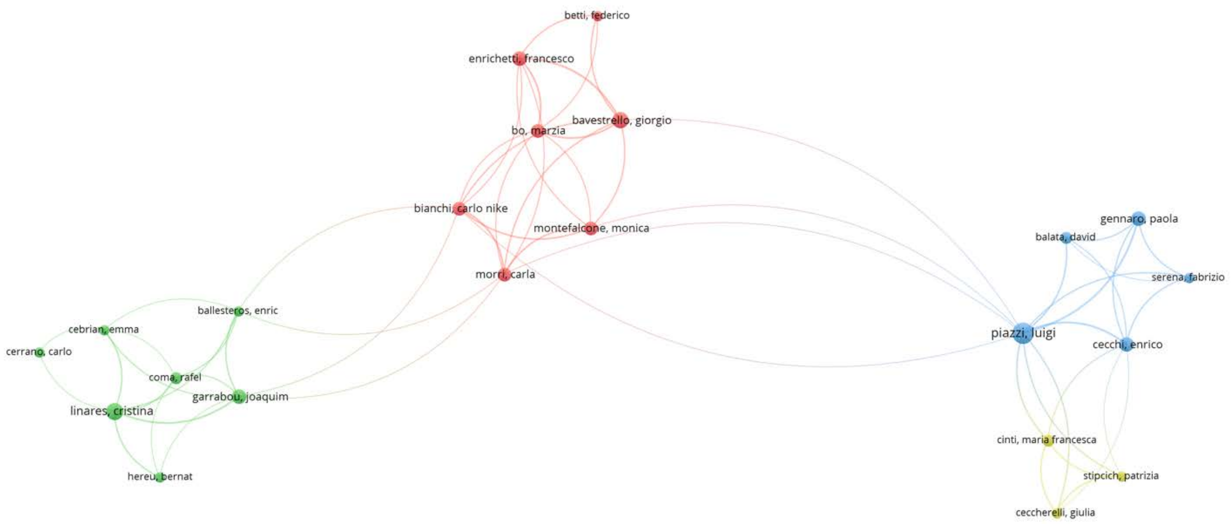

Figure 3. Co-authorship network map of Authors on “Coralligenous” and “Impacts”.

Table 4. Top 5 most productive authors related to the keywords “Coralligenous” and “Impacts”.

Author	Documents	Citations	Total link strength
Piazzi, Luigi	12	351	33
Linares, Cristina	8	416	17
Bavestrello, Giorgio	7	121	24
Cecchi, Enrico	6	186	18
Enrichetti, Francesco	6	78	20

3.2 Coralligenous and Fishing Impacts

To obtain a more selective knowledge of the scientific literature focused on the relationship between the “Coralligenous” and the impacts related to fishing activities, a further investigation was carried out using as research string the terms “Coralligenous” and “Impacts” and “Fishing”. The search on the Scopus database generated 22 documents from 2008 to 2022, more concentrated over the last decade, thus showing a growing recent interest on the topic (Figure 4).

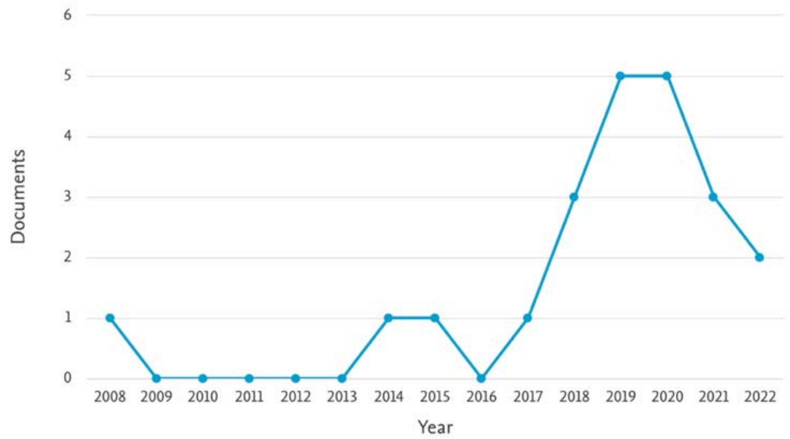

Figure 4. Temporal trend of publications on "Coralligenous" and "Impacts" and "Fishing".

In the network map of Figure 5 the thickness of each connection is based on the "link strength". The analysis of the co-occurrence of keywords generated 383 results. Inserting a thesaurus file to avoid repetitions between singular and plural of the same word and applying a threshold of 5 occurrences, 16 keywords were generated and grouped in 3 clusters related to different disciplinary fields, among which zoology (blue cluster), conservation (red cluster) and monitoring (green cluster).

Table 5 shows the first 10 keywords classified by "occurrence". Among the main keywords we find "Mediterranean Sea", "Ecosystems", and "Biodiversity", highlighting the focus on biodiversity conservation of coralligenous habitat on which the generation of ecosystem services flows depends. It is worth nothing that, although both in scientific and policy contexts there is a great interest for the biophysical and economic assessment of the ecosystem services loss due to human impacts, the topic "ecosystem accounting" does not appear among the main keywords. Likewise, timely research topics such as natural capital and the framework adopted by the United Nations for the assessment of ecosystem services (SEEA-EA) are not highlighted by the results, although they represent important tools for assessing the potential loss of ecosystem services caused by fishing impacts.

Figure 6 shows the temporal distribution of keywords related to "Coralligenous" and "Impacts" and "Fishing".

From the temporal distribution analysis, among the most recent keywords we find "Italy", "Conservation", "Environmental Monitoring", and "Remotely Operated Vehicles", which underline the recent focus on conserving and monitoring the Coralligenous habitat, and the important role played by the Italian research in this context.

The total number of authors publishing on “Coralligenous” and “Impacts” and “Fishing” was 89. Figure 7 shows the co-authorship network map based on publications number, including only authors with at least 2 publications. Table 6 shows the top five authors publishing on “Coralligenous” and “Impacts” and “Fishing” ranked by total number of documents.

Table 5. Keywords most related to the theme “Coralligenous” and “Impacts” and “Fishing”.

Keywords	Occurrence
Mediterranean Sea	16
Ecosystems	11
Fisheries	11
Biodiversity	9
Benthos	9
Remotely Operated Vehicles	9
Italy	7
Coral	6
Anthozoa	5
Animals	5

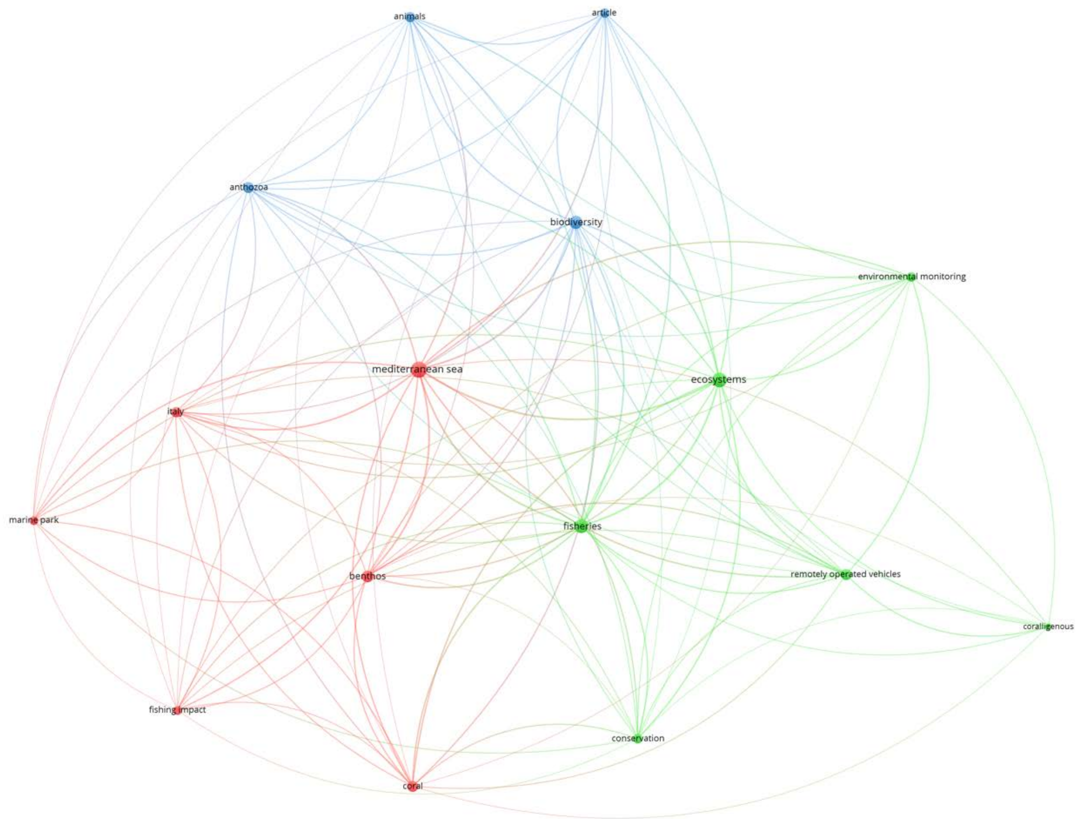

Figure 5. Co-occurrence map of keywords related to the themes “Coralligenous ” and “Impacts” and “Fishing”.

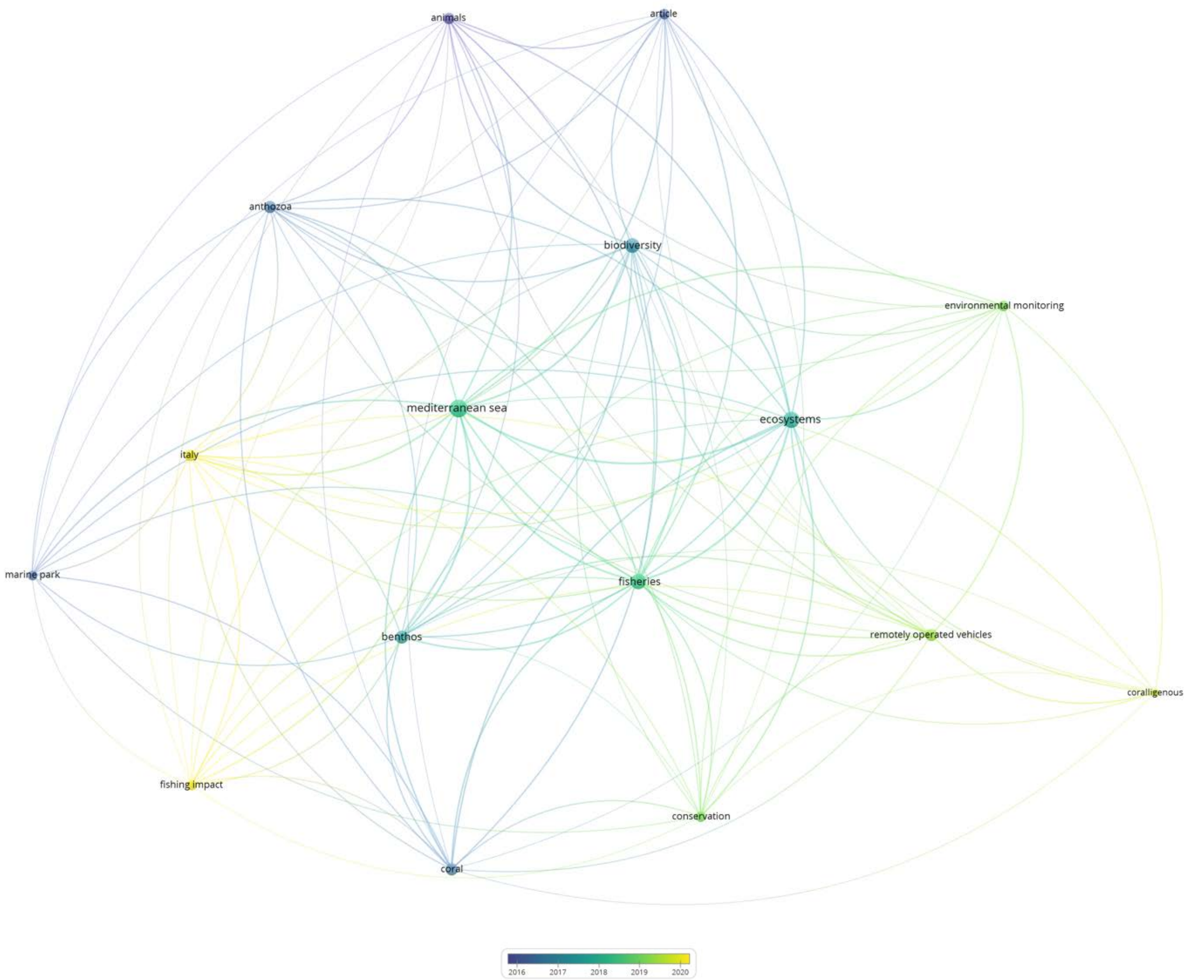

Figure 6. Temporal distribution analysis of keywords on “Coralligenous” and “Impacts” and “Fishing”.

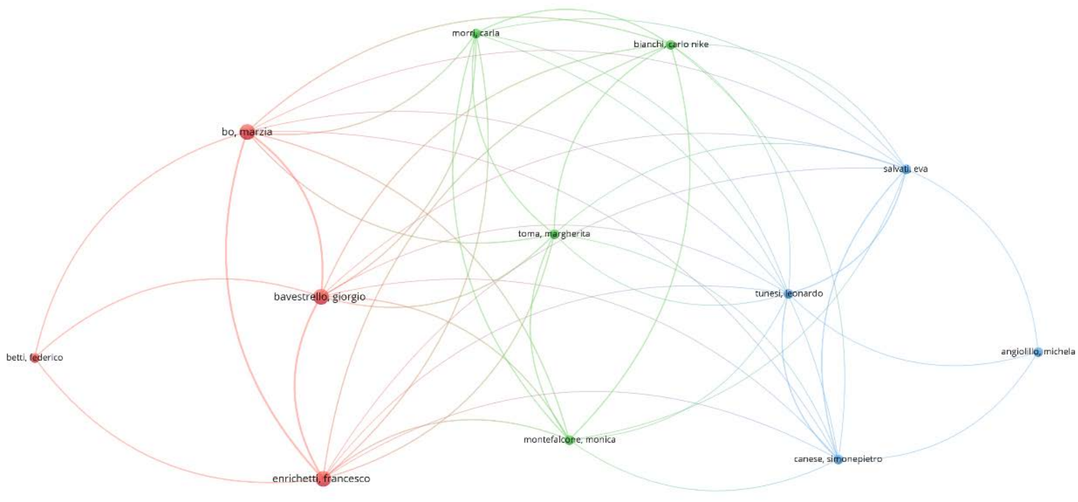

Figure 7. Co-authorship network map of authors on “Coralligenous” and “Impacts” and “Fishing”.

Table 6. Top 5 most productive authors related to the keywords “Coralligenous” and “Impacts” and “Fishing”.

Author	Documents	Citations	Total link strenght
Bavestrello, Giorgio	5	78	23
Bo, Marzia	5	78	23
Enrichetti, Francesco	5	78	23
Sandulli, Roberto	3	96	8
Angiolillo, Michela	2	107	3

4. Conclusions

In this study, the global scientific literature on coralligenous habitat was explored through a bibliometric network analysis focused on the relationships between coralligenous and impacts, with particular reference to fishing impacts.

The results show that the scientific literature on this topic is mainly concentrated in Italy, proving the important contribution provided by the Italian research on the topic. The results also highlight a research gap in the application of environmental accounting methods to quantify and value natural capital and ecosystem services associated to the coralligenous habitat, and their loss due to human impacts. To fill this gap, future studies could be focused on the integrated assessment of the biophysical and economic value of the coralligenous habitat applying standardized assessment frameworks such as the SEEA Ecosystem Accounting (SEEA EA) adopted by the United Nations Statistical Commission. This multicriteria approach to the assessment of the benefits provided by the coralligenous habitat to humans could support the development of effective monitoring and conservation programs while informing policy makers in charge for ensuring the sustainable management of marine habitats.

References

Althaus F., Williams A., Schlacher T. A., Kloser R. J., Green M. A., Barker B. A., ... & Schlacher-Hoenlinger M. A., 2009, Impacts of bottom trawling on deep-coral ecosystems of seamounts are long-lasting. *Marine Ecology Progress Series*, *397*, 279-294.

Ballesteros E., 2006, Mediterranean coralligenous assemblages: a synthesis of present knowledge. *Oceanography and marine biology: an annual review*, *44*, 123-195.

Bavestrello G., Cerrano C., Zanzi D., CattaneoVietti R., 1997, Damage by fishing activities in the Gorgonian coral *Paramuricea clavata* in the Ligurian Sea. Aquatic Conservation Marine Freshwater Ecosystem 7 (3), 253-262.

Bavestrello G., Bo M., Canese S., Sandulli R., Cattaneo-Vietti R., 2014, The red coral populations of the gulfs of Naples and Salerno: human impact and deep mass mortalities. *Italian Journal of Zoology*, *81*(4), 552-563.

Betti F., Bavestrello G., Bo M., Ravanetti G., Enrichetti F., Coppari M., ... & Cattaneo-Vietti R., 2020, Evidences of fishing impact on the coastal gorgonian forests inside the Portofino MPA (NW Mediterranean Sea). *Ocean & Coastal Management*, *187*, 105105.

Bo M., Bava S., Canese S., Angiolillo M., Cattaneo-Vietti R., Bavestrello G., 2014, Fishing impact on deep Mediterranean rocky habitats as revealed by ROV investigation. *Biological Conservation*, *171*, 167-176.

Boudouresque, C. F., 2004, Marine biodiversity in the Mediterranean: status of species, populations and communities. *Travaux scientifiques du Parc national de Port-Cros*, *20*, 97-146.

Boudouresque C. F., Ribera M. A., 1994, Les introductions d'espèces végétales et animales en milieu marin–conséquences écologiques et économiques et problèmes législatifs. In *First international workshop on Caulerpa taxifolia* (pp. 29-102). Marseille: GIS Posidonie.

Buonocore E., Picone F., Russo G. F., Franzese P. P., 2018, The scientific research on natural capital: a bibliometric network analysis. Journal of Environmental Accounting and Management 6: 381–391.

Buonocore E., Donnarumma L., Appolloni L., Miccio A., Russo G. F., Franzese P. P., 2020a, Marine natural capital and ecosystem services: An environmental accounting model. Ecological Modelling 424: 109029.

Buonocore, E., Appolloni, L., Russo, G. F., Franzese, P. P., 2020b, Assessing natural capital value in marine ecosystems through an environmental accounting model: A case study in Southern Italy. Ecological Modelling 419: 108958.

Buonocore E., Grande U., Franzese P.P., Russo G.F., 2021, Trends and evolution in the concept of marine ecosystem services: an overview. Water, 13(15), 2060.

Cerrano C., Bavestrello G., Bianchi C. N., Calcinai B., Cattaneo-Vietti R., Morri C., Sarà, M., 2001, The role of sponge bioerosion in Mediterranean coralligenous accretion. In *Mediterranean Ecosystems: Structures and Processes* (pp. 235-240). Milano: Springer Milan.

Chen D., Liu Z., Luo Z., Webber M., Chen J., 2016, Bibliometric and visualized analysis of emergy research. *Ecological Engineering*, *90*, 285-293.

Chimienti G., Stithou M., Dalle Mura I., Mastrototaro F., D'Onghia G., Tursi A., ... & Fraschetti S., 2017, An explorative assessment of the importance of Mediterranean Coralligenous habitat to local economy: The case of recreational diving. Journal of Environmental Accounting and Management, *5*(4), 315-325.

Clark M. R., Koslow J. A., 2007, Impacts of fisheries on seamounts. In Pitcher T. J., Morato T., Hart P. J. B., Clark M. R., Haggan N. and Santos R. S. (eds) Seamounts: ecology, fisheries and conservation. Oxford: Blackwell Publishing: 413–441

Coll M., Piroddi C., Steenbeek J., Kaschner K., Ben Rais Lasram, F., Aguzzi, J., ... & Voultsiadou, E., 2010, The biodiversity of the Mediterranean Sea: estimates, patterns, and threats. *PloS one*, *5*(8), e11842.

Cordeiro C. M., 2019, A corpus-based approach to understanding market access in fisheries and aquaculture international business research: A systematic literature review. *Aquaculture and Fisheries*, *4*(6), 219-230.

Council of the European Communities, 1992, Council Directive 92/43/EEC on the conservation of natural habitats and of wild fauna and flora.

El Alam R., Grande U., Buonocore E., Paletto A., Franzese P. P., 2024, The Scientific Research on Environmental Accounting: A Bibliometric Network Analysis, Ecological Questions, 35(1): 1–17.

E.C., 1992, Council Directive 92/43/EEC (Habitat Directive) of 21 May 1992 on the conservation of natural habitats and of wild fauna and flora. As amended by the Accession Act of Austria, Finland and Sweden. Official Journal of the European Commission L 1, 1.1: 135.

E.C., 2008, Directive 2008/56/EC of the European Parliament and of the Council of 17 June 2008 Establishing a Framework for Community Action in the Field of Marine Environmental Policy (Marine Strategy Framework Directive, Bruxelles).

European Commission, 2008, Directive 2008/56/EC of the European Parliament and of the Council of 17 June 2008 establishing a framework for Community action in the field of marine policy (Marine Strategy Framework Directive). Official Journal of the European Union, L164, 19-40.

Ferrigno F., Appolloni L., Rendina F., Donnarumma L., Russo G. F., Sandulli R., 2020, Red coral (Corallium rubrum) populations and coralligenous characterization within "Regno di Nettuno MPA" (Tyrrhenian Sea, Italy). The European Zoological Journal 87(1): 203-213.

Ferrigno F., Russo G. F., Semprucci F., Sandulli R., 2018, Unveiling the state of some underexplored deep coralligenous banks in the Gulf of Naples (Mediterranean Sea, Italy). Regional Studies in Marine Science 22: 82–92.

Ferrigno, F., Rendina, F., Sandulli, R., & Russo, G., 2024, Coralligenous assemblages: research status and trends of a key Mediterranean biodiversity hotspot through bibliometric analysis. *Ecological Questions*, *35*(1), 1-32.

Gambi M. C., Barbieri F., Signorelli S., Saggiomo V., 2010, Mortality events along the Campania coast (Tyrrhenian Sea) in summers 2008 and 2009 and relation to thermal conditions. Biologia Marina Mediterranea 17: 126–127.

Garrabou, J., Ballesteros E., Zabala M., 2002, Structure and dynamics of north-western Mediterranean rocky benthic communities along a depth gradient. Estuarine, Coastal and Shelf Science, 55(3), 493-508.

Gatti G., Bianchi C. N., Morri C., Montefalcone M., Sartoretto S., 2015, Coralligenous reefs state along anthropized coasts: Application and validation of the COARSE index, based on a rapid visual assessment (RVA) approach. *Ecological Indicators*, *52*, 567-576.

Geremia E., Grande U., Muscari Tomajoli M. T., Petito A., Fasciolo G., Napolitano G., 2024, Feed production for sustainable aquaculture: A Bibliometric Network Analysis, Ecological Questions, 35(1): 1–17.

Grande U., Piernik A., Nienartowicz A., Buonocore, E., Franzese P.P., 2023, Measuring natural capital value and ecological complexity of lake ecosystems. Ecological Modelling, 482, 110401.

Iborra L., Leduc M., Fullgrabe L., Cuny P., Gobert, S., 2022, Temporal trends of two iconic Mediterranean gorgonians (Paramuricea clavata and Eunicella cavolini) in the climate change context. *Journal of Sea Research*, *186*, 102241.

Jankovský M., García-Jácome S. P., Dvořák J., Nyarko I., Hájek, M., 2021, Innovations in forest bioeconomy: A bibliometric analysis. *Forests*, *12*(10), 1392.

La Mesa G., Paglialonga A., Tunesi L., 2019, Manuali per il monitoraggio di specie e habitat di interesse comunitario (Direttiva 92/43/CEE e Direttiva 09/147/CE) in Italia: ambiente marino. ISPRA, Serie Manuali e linee guida, 190/2019.

Liu C., Liu G., Yang Q., Luo T., He P., Franzese P.P., Lombardi G.V., 2021a, Emergy-based evaluation of world coastal ecosystem services. Water Research, 204, art. no. 117656.

Liu C., Liu G., Casazza M., Yan N., Xu L., Hao Y., Franzese P.P., Yang Z., 2021b, Current Status and Potential Assessment of China's Ocean Carbon Sinks. Environmental Science and Technology.

Markic A., Niemand C., Bridson J. H., Mazouni-Gaertner N., Gaertner J. C., Eriksen M., Bowen M., 2018, Double trouble in the South Pacific subtropical gyre: Increased plastic ingestion by fish in the oceanic accumulation zone. *Marine Pollution Bulletin*, *136*, 547-564.

Pauna V. H., Buonocore E., Renzi M., Russo G. F., Franzese P. P., 2019, The issue of microplastics in marine ecosystems: a bibliometric network analysis. Marine Pollution Bulletin 149: 110612.

Pauna V.H., Picone F., Le Guyader G., Buonocore E., Franzese P.P., 2018, The scientific research on ecosystem services: A bibliometric analysis, Ecological Questions, 29 (3): 53–62.

Piazzi L., Gennaro P., Balata D., 2012, Threats to macroalgal coralligenous assemblages in the Mediterranean Sea. *Marine pollution bulletin*, *64*(12), 2623-2629.

Picone F., Buonocore E., Chemello R., Russo G. F., Franzese P. P., 2021, Exploring the development of scientific research on marine protected areas: from conservation to global ocean sustainability. Ecological Informatics 61: 101200.

Relini G., Tunesi L., 2009, Le specie protette dal protocollo SPA/BIO (Convenzione di Barcellona) presenti in Italia. Schede descrittive per l'identificazione. Biologia Marina Mediterranea 16: 1–433.

Rendina F., Buonocore E., Cocozza di Montanara A., Russo G. F., 2022, The scientific research on rhodolith beds: A review through bibliometric network analysis. Ecological Informatics 70: 101738.

Rendina F., Ferrigno F., Appolloni L., Donnarumma L., Sandulli R., Fulvio G., 2020b, Anthropic pressure due to lost fishing gears and marine litter on different rhodolith beds off the Campania Coast (Tyrrhenian Sea, Italy). Ecological Questions 31(4): 41-51.

Rendina F., Kaleb S., Caragnano A., Ferrigno F., Appolloni L., Donnarumma L., et al., 2020a, Distribution and characterization of deep rhodolith beds off the Campania coast (SW Italy, Mediterranean Sea). Plants 9: 985.

Rendina F., Bouchet P. J., Appolloni L., Russo G. F., Sandulli R., Kolzenburg, R., ... & Ragazzola F., 2019, Physiological response of the coralline alga Corallina officinalis L. to both predicted long-term increases in temperature and short-term heatwave events. *Marine environmental research*, *150*, 104764.

Reuters T., 2008, Whitepaper Using Bibliometrics, Thomson Reuters, 12 pp.

Rochman C. M., 2015, The complex mixture, fate and toxicity of chemicals associated with plastic debris in the marine environment. *Marine anthropogenic litter*, 117-140.

Saggiomo L., Esattore B., Picone F., 2020, What are we talking about? Sika deer (*Cervus nippon*): a bibliometric network analysis. Ecol. Inform. 60, 101146.

Scott J., 2007, Summary for Policymakers. Intergovernmental Panel on Climate Change (Ed.), Climate Change 2013. The Physical Science Basis, Cambridge University Press, 1-30.

Skaf L., Buonocore E., Dumontet S., Capone R., Franzese P.P., 2020, Applying network analysis to explore the global scientific literature on food security. Ecol. Inform. 56, 101062.

Tonin S., 2018, Economic value of marine biodiversity improvement in coralligenous habitats. *Ecological indicators*, *85*, 1121-1132.

Tribot A.S., Mouquet N., Villeger S., Raymond M., Hoff F., Boissery P., Holon F., Deter J., 2016, Taxonomic and functional diversity increase the aesthetic value of coralligenous reefs. Scientific Reports 6: 34229

UNEP, 2008, Action Plan for the Conservation of the Coralligenous and Other Calcareous Bio-Concretions in the Mediterranean Sea. Tunis: Rac/Spa: 1–21.

UNEP, 2019, Monitoring protocols for IMAP Common Indicators related to biodiversity and non-indigenous species, which includes the guidelines for monitoring marine benthic habitats in the Mediterranean (WG.467/16). UNEP/MAP, Athens, GR.

Van Eck N. J., Waltman L., 2018, VOSviewer Manual 1.6.11. Manual, (version 1.6.9).

Vihervaara, P., Franzese, P.P., Buonocore, E., 2019, Information, energy, and eco-exergy as indicators of ecosystem complexity. Ecological Modelling, 395, pp. 23-27.

Zou X., Long Yue W., Le Vu H., 2018, Visualization and analysis of mapping knowledge domain of road safety studies, Accident Analysis & Prevention, 118: 131-145.