Journal of Sea Research 198 (2024) 102487

Contents lists available at ScienceDirect

Journal of Sea Research

journal homepage: www.elsevier.com/locate/seares

Impact of high temperature heat waves on ocean carbon sinks: Based on literature analysis perspective

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ARTICLE INFO

Keywords:
Climate change
High temperature heat waves
Ocean carbon sinks
Carbon cycle

ABSTRACT

The Earth's oceans serve as vast heat storage reservoirs and the ocean currents, forming a heat transfer zone, act as a buffer for climate change. The oceans play a crucial role in the water cycle, carbon cycle, and nitrogen cycle, interacting with the atmosphere. However, the increasing occurrence of heatwaves in recent years has disrupted the stability of the oceans and affected their function as a global thermostat. This paper examines relevant literature from the Web of Science database spanning from 1996 to 2023. Our analysis reveals the evolving research hotspots regarding the impact of heatwaves on ocean carbon sinks, progressing from "carbon dioxide - carbon emissions - ocean - seawater - organic matter - marine sediment" over the past decades. Keyword frequency and centrality analysis indicate a deepening focus in this field of study. The research areas primarily revolve around climate change, carbon dioxide, ocean variability, the influence of high temperatures on the carbon cycle, the weakening of the ocean carbon sink function, and ocean temperature. This study summarizes research findings on the mechanisms by which high temperature heatwaves affect ocean carbon sinks, alterations in ocean carbon cycle patterns, their impacts on marine ecosystems, and factors influencing seawater temperature and heatwave occurrence. Finally, the paper discusses novel findings in this field and proposes countermeasures to enhance ocean sink capacity amidst the warming trend.

1. Introduction

The ocean is the largest active carbon reservoir on the planet, with a huge carbon sink potential(*Implementing A Carbon Neutral Strategy For Negative Ocean Emissions - China Knowledge [WWW Document]*, 2024
). It is estimated that about 7.8 carbon emissions (PgC/year) per year, about 2.3 PgC/year is absorbed by the ocean,1.5 PgC/year by land, and the remaining 4.0 PgC/year stays in the atmosphere(Stocker et al., 2013). Therefore, the ocean is an important site for the carbon fixation and storage processes. Seagrass beds, mangrove forests and salt marshes are considered to be three important coastal blue carbon ecosystems, while macroalgae, shellfish and even micro-organisms can also fix and store carbon efficiently.

Meanwhile, the ocean is a huge heat reservoir on the earth, the heat transmission belt formed by ocean currents plays a buffer role in climate change, and the ocean has played an important role in the water, carbon and nitrogen cycle with the atmosphere. However, new research published in *Nature* shows that climate change has changed the stability of the ocean, disrupting its role as a global thermostat and having a serious impact on Marine life.

In recent years, the trend of global warming has become more obvious, and the superimposed extreme heat waves have occurred frequently. A growing number of scientists are aware of the potential impact of global warming on ocean carbon sinks. A 2019 study, published in *the Proceedings of the National Academy of Sciences* (PNAS), showed that one out of five in the oceans would be extinct by the end of the century. A study published in September 2020 in *Natural Climate Change* noted that global ocean stratification has increased by 5.3% in the nearly 60 years from 1960 to 2018, and that ocean surface warming could cause more intense hurricanes. In February 2021, natural Geoscience research showed that the current Atlantic meridian flip circulation (AMOC) was the weakest in nearly a millennium, and that the weakening of this large heat-carrying ocean current affected weather across Europe and sea level in the United States. Heavy precipitation and the melting of the Greenland ice sheet increase fresh water in the ocean surface, disrupting the normal cycle of warm, high-salt sea surface water transported northward from the equator and low-salt deep water back to the south(Caesar et al., 2021); *Increasing Ocean Stratification Over The*

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https://doi.org/10.1016/j.seares.2024.102487
Received 29 September 2023; Received in revised form 2 February 2024; Accepted 20 February 2024
Available online 23 February 2024

Past Half-Century | Nature Climate Change [WWW Document], 2024; *Summertime Increases in Upper Ocean Stratification and Mixed Layer Depth - PMC [WWW Document],* 2024; Lotze et al., 2019). On October 22,2021, a new study published in *Communications Biology* by the university of British Columbia and Fisheries and Oceans Canada revealed that two years of Blob heat wave event may in the short term suppressed the "biological pump function of the Pacific". Biological pump, responsible for transporting carbon from the surface ocean to the deep sea, is an important mechanism to mitigate the impact of human activities on the earth's climate.

Global warming is not only warming the atmosphere, but also warming the ocean. In 2022, with the strongest high temperature lasting three months in the northern Hemisphere, the impact of ocean warming has once again attracted wide attention,especially its interaction with ocean carbon sink and its counterattack on climate change. In this study, we will review the relevant literature in the web of science database from 1996 to 2023, systematically analyze the hot spots, progress and trends of high temperature heat wave and Marine carbon sink, and explore the influence mechanism of high temperature weather on Marine carbon sink and its interaction with climate change.

2. Data and methodology

In this study, Citespace6.2.R6 Basic was selected for visual analysis of knowledge maps such as keyword clustering, keyword occurrence and time gram, and Python and Excel were selected as auxiliary mapping tools(Xiong and Zhao, 2020). Citespace is a visual analysis tool based on the JAVA platform, which can show the key literature, hotspot research and frontier direction in a certain scientific field. Firstly, make descriptive statistical analysis of the collected literature topics, authors, publication time, journals, countries of origin and research institutions; secondly, summarize and judge the research progress and trend in the field of Marine carbon sink, and show the development trend and trend of the research field in a certain period according to the principle of co-occurrence(Wang et al., 2018).

The source of the literature data for this study is the Web of Science core collection. The WOS core Collection is a collection of all authoritative and influential academic journals around the world, covering a wide range of disciplines, characterized by high quality, large quantity, large time span and complete literature. Data was retrieved by using the fields "TS=Warming and TS=Ocean Carbon Sinks" or "TS=High Weather and TS=Ocean Carbon Sinks" or "TS=Hot Weather and TS=Marine Environment" or "TS=High Temperature Weather and TS=Marine Life". In order to ensure the representativeness of the literature, newspapers and magazines, conference notices are excluded. The above search was conducted before January 2024. From the above operations, 773 English documents were obtained from 1996 to 2023.

3. Statistical analysis of the literature

3.1. Publication trends

According to Web of Science, a total of 773 articles were collected from 1996 to 2023 using keywords such as "Marine carbon sink" and "high temperature weather." Fig. 1 shows that the number of articles related to high temperature and climate rise in the field of Marine carbon sink has increased slowly over this period. Notably, the highest number of articles was published in 2021, with 84 articles, while the lowest was 6 articles per year. The number of articles exceeded 40 in one year starting from 2019.

It is important to note that the past five years (2015–2019) have been the five warmest years on record since complete meteorological observations began. In 2019, the global climate system warming accelerated, leading to early phenological periods, glacier melting, and sea level rise. Several historical records were broken, and climate extremes increased. In 2019, the global average temperature was approximately 1.1 °C higher than pre-industrial levels, making it the second warmest year on record.

Therefore, since 2019, scholars in the field of Marine carbon sinks have gradually started to focus on the impact of high temperatures and heatwaves on carbon sinks.

3.2. Regional distribution of publications

In order to explore the spatial and geographic distribution of the study, a survey was conducted on the distribution of paper researchers across different countries. In Citespace, the node type was set to "country" and the Top50, pathfinder, and pruning sliced networks algorithms were selected. Fig. 2 shows the national cooperative network of marine carbon sink research, where the size of the nodes indicates the number of published articles from different countries. Larger nodes indicate a higher number of published articles. It is worth pointing out here that the high centrality shows the importance of the nodes(Guo et al., 2021). Nodes with centrality greater than 0.3 (according to the

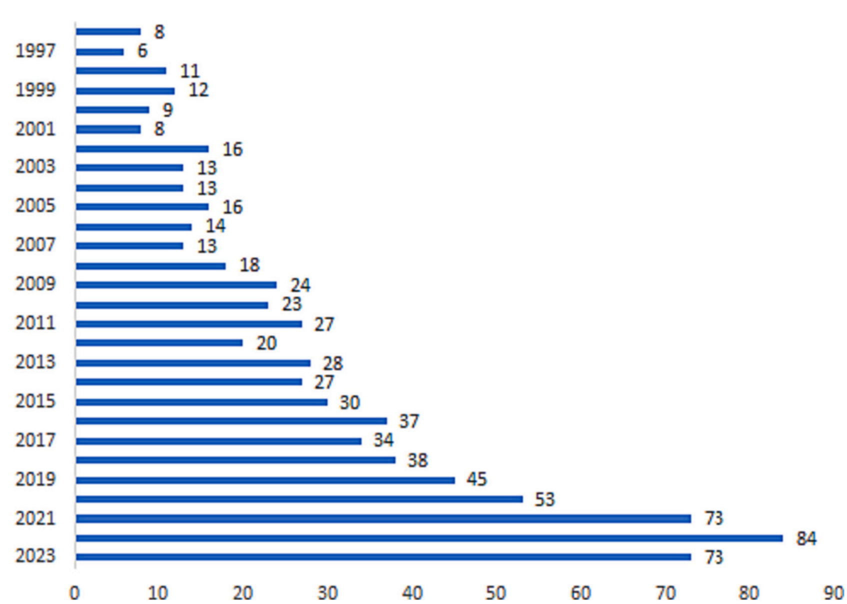

Fig. 1. 1996–2023 Statistics of annual research publications.

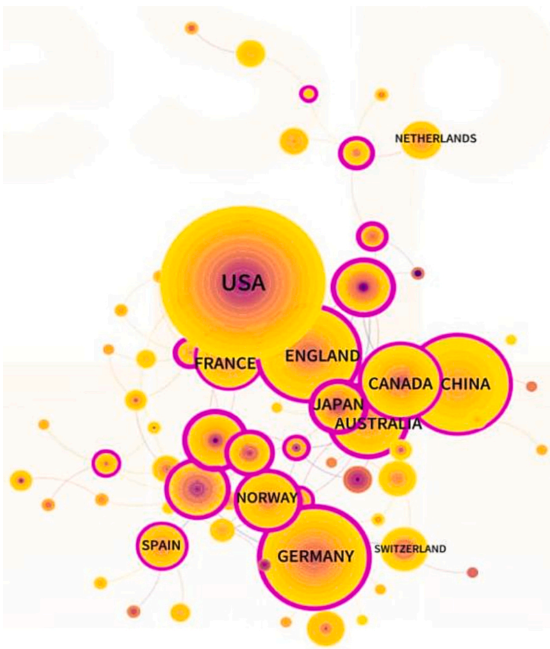

Fig. 2. National map of research contributions.

central status ranking) include Italy (0.56), Japan (0.43), Denmark (0.42), Australia (0.39), Germany (0.36), Israel (0.35), Belgium (0.34), and Poland (0.31). The centrality of Italy peaked at 0.3, indicating that the Italy maintains extensive cooperation with many countries, including Japan, Australia and Denmark. Fig. 2 demonstrates strong cooperative relationships between multiple countries. However, there is limited research literature on the impact of hot weather on carbon sink. According to the analysis of the WOS database sources, the United States has the highest number of published articles with a total of 287 out of 773. This is followed by more than 50 countries, including Germany, the United Kingdom, China, France, Canada, and Australia, accounting for approximately 18%, 16%, 16%, 13%, 10%, and 9% respectively. Other countries have relatively lower publication numbers, all less than 9% (Table 1).

Using Python to map the area distribution, as shown in Fig. 3 below. Europe has emerged as the leading region for high-temperature research, followed by North America, while few high-temperature carbon sink-related aspects have been documented in South America and Africa.

3.3. Author analysis of high yield

Through the author co-occurrence analysis, the core authors of a discipline or field and their cooperation strength and mutual citation relationship can be identified(Hu et al., 2013). In Citespace, node type was set to "author", and pathfinder and purning sliced networks

Table 1
shows the high contribution countries.

Ranking	Highly contributing countries	Number of posts	Centrality
1	USA	287	0.05
2	GERMANY	143	0.36
3	ENGLAND	127	0.22
4	CHINA	121	0.11
5	FRANCE	103	0.11
6	CANADA	75	0.14
7	AUSTRALIA	73	0.39
8	NORWAY	46	0.29
9	JAPAN	45	0.43
10	SWITZERLAND	39	0.08

algorithm were selected to analyze the published authors to obtain the author map. According to 773 papers contributed from 718 different authors, the cooperative network of authors involved in the carbon sink theme at high temperature was vividly drawn in Fig. 4, Table 2. Fig. 4 shows that many authors tend to work with a small group of collaborators, creating several major groups of authors. Most of the authors published less than 5 articles, only 3 people sent more than 5 articles related to high temperature literature, and BOPP L published the most articles with 9 articles. Through unremitting efforts, these authors have contributed to the promotion of Marine carbon sinks.

3.4. Classification of study content

Currently, the literature on the study of Marine carbon sinks in hot weather covers 10 classes in WOS, of which the top 5 are Geosciences Multidisciplinary, with 26%, Environmental Sciences, with 18%, Oceanography, with 14%, Meteorology Atmospheric Sciences, with 13%, and Ecology, with 8%.

3.5. Keyword analysis

The node with high mediation centrality and high frequency characteristics is the key literature in this field, representing the hot research topic in this period. According to the documented data, 548 keywords were involved in this study. Related Wpapers from 1996 to 2023 were exported to Citespace. In Citespace, node type was set to "keyword", and pathfinder and purning sliced networks algorithms were selected to analyze the published authors to obtain the keyword map, namely Fig. 5 (1). There are 242 nodes and 381 connections, and the network density is 0.0131, among which the keywords with higher occurrence times are shown as larger nodes in the figure. The analysis results in Fig. 5 (2) show that the frequencies of the top 12 hot spot keywords ranged from high to low: climate change (frequency = 134), variability (frequency = 83), ocean (frequency = 76), atmospheric co2 (frequency = 72), carbon dioxide (frequency = 62), temperature (frequency = 58), organic carbon (frequency = 58), carbon cycle (frequency = 57), co2 (frequency = 56), carbon (frequency = 51), southern ocean (frequency = 50), model (frequency = 38). From these hot keywords, we can see that the concerns of global writers are on climate change, carbon dioxide, ocean, variability, the impact of high temperature on the carbon cycle, the weakening of ocean carbon sink function and ocean temperature.

In addition, nodes with mediation centrality greater than or equal to 0.1 in the atlas generated by Citespace are defined as key nodes. The mediation centrality of a node refers to the number of all the shortest paths in the network passing through the node, which is a measure of the connection size of the nodes in the network in the overall network. The higher the mediation centrality of a node, the more it appears in the shortest path in the network, and the greater its influence and importance. Table 3 records the top 12 keywords in Table 3, and the key nodes are mainly carbon dioxide(Centrality =0.43), atmospheric co2 (centrality =0.32), carbon cycle (centrality =0.28), southern ocean (centrality =0.25), ocean (centrality =0.21).

3.6. Emergent words

Mutant keywords (hereinafter referred to as emergent words) indicate the transition of the keywords to be investigated in a short period of time, emphasizing the mutagenability(Wang et al., 2018). In Citespace, node type is set to "keyword", Top50, using pathfinder and purning sliced networks algorithm, select Timeline View in the control panel to obtain keyword mutational results based on the WOS core collection database shown in Fig. 6. Fig. 7 shows the top 6 most cited keywords, where keywords represents the node type, *year* represents the earliest time in the selected analysis year, *strength* represents the onset intensity, *begin* represents the onset time between 1996 and 2023, *end* represents the end time of the occurrence, and the right area with bold red indicates

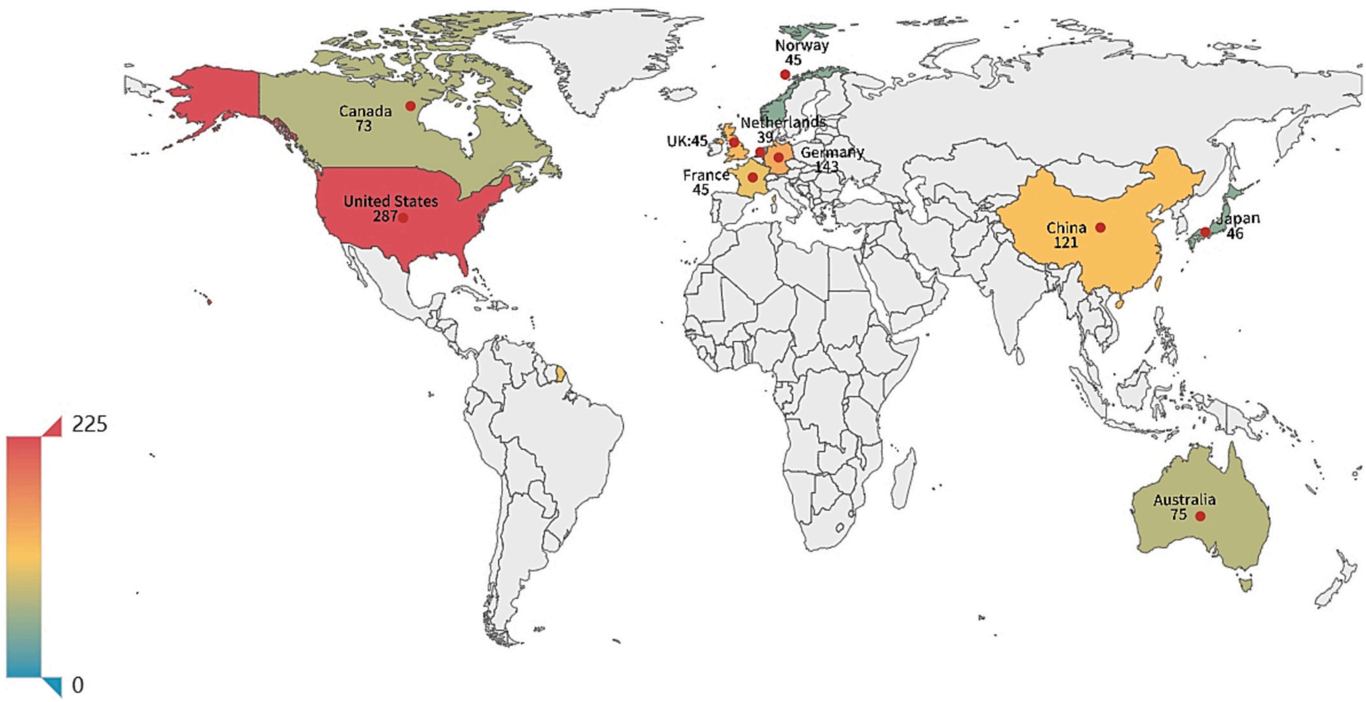

Fig. 3. Contribution of carbon sink research productivity in global hot weather.

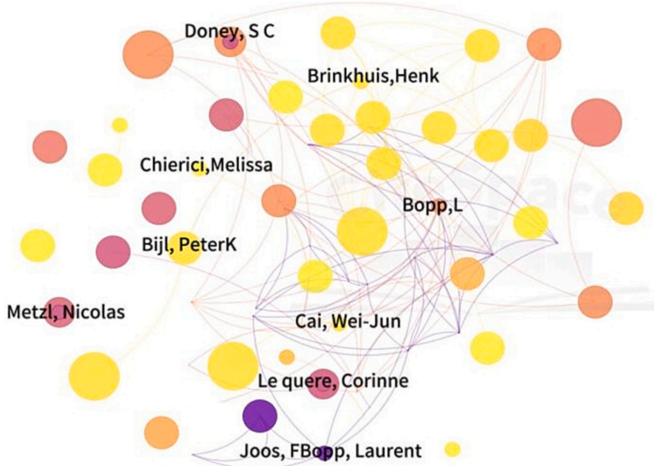

Fig. 4. Researcher statistics and mapping in this field in WOS.

Table 2
Author of the heat weather study in marine carbon sinks in WOS.

Ranking	High contribution writer	Number of posts
1	Bopp, L	7
2	Cai, Wei-Jun	5
3	Bopp, Laurent	5
4	Le quere, Corinne	4
5	Bijl, Peter K	4
6	Chierici, Melissa	4
7	Doney, S C	4
8	Metzl, Nicolas	4
9	Joos, F	4
10	Brinkhuis, Henk	4

the onset period. Through the analysis of these emerging words, it can be concluded that which node suddenly attracts attention and which node becomes the turning point in this research field, achieving the purpose of analyzing the time series changes in the field of Marine carbon sink (*Methodological Functions of the CiteSpace Knowledge Graph - China Knowledge [WWW Document],* 2024). According to the analysis of the results of the emerging words, in the past 20 years, the international research hotspot is "Carbon dioxide - carbon emissions - oceans - seawater - organic matter - marine sediments - wind ". The keyword frequency and centrality analysis shows that the research in this field is gradually developing in depth.

The Marine carbon sink is not only relevant to natural science disciplines such as marine carbon sequestration, but also encompasses a wide range of multidisciplinary fields including earth science, oceanography, environmental science, meteorology, atmospheric science, ecology, geochemistry, geophysics, marine freshwater biology, paleontology, geography, physics, and chemistry. To effectively analyze the sudden words research content, it is important to focus on the multidisciplinary combination of these fields. Additionally, attention should be given to new technologies, public participation, and functional maintenance in order to achieve sustainable development across various industries (Wang et al., 2018).

Note: The blue indicates the time interval, the red indicates the time period when the document is cited.

4. Study content and hot spots

4.1. Impact of climate change and heatwaves on ocean carbon sink function

According to the Intergovernmental Panel on Climate Change (IPCC), the oceans absorb about a quarter of the greenhouse gases and more than 90% of the heat generated by the greenhouse gases, playing a crucial role in alleviating the impact of climate change(*A Vision for FAIR Ocean Data Products | Communications Earth and Environment [WWW Document],* 2024). The forms of Marine carbon storage include inorganic, organic, granular, dissolved carbon and other forms.95% of the organic carbon in the ocean is dissolved organic carbon (DOC), and 95% of it is inert dissolved organic carbon (RDOC) which can not be used by organisms. The carbon storage of RDOC in the world's ocean is about 650 billion tons, and the carbon storage cycle is about 5000 years,

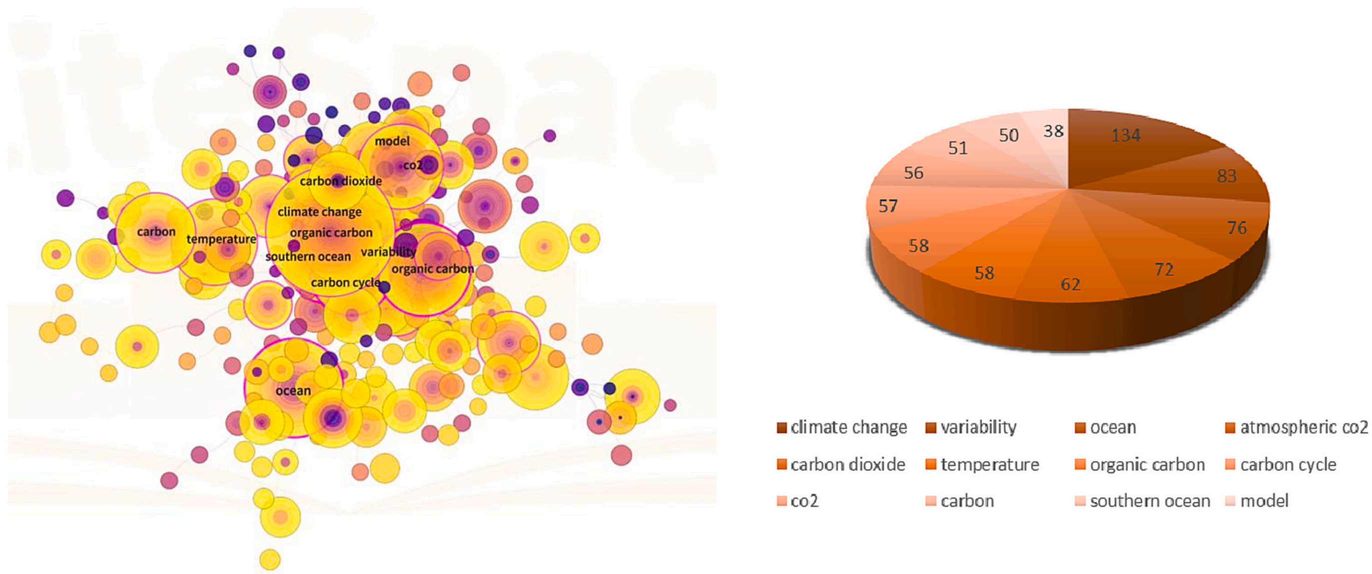

Fig. 5. Keyword statistics and mapping of relevant studies in the WOS database.

Table 3
Keywords in order by frequency and centrality in this field from 1996 to 2023.

Ranking	Keyword	Frequency	Ranking	Keyword	Centrality
1	Climate change	134	1	Carbon dioxide	0.43
2	Variability	83	2	Atmospheric co2	0.32
3	Ocean	76	3	Carbon cycle	0.28
4	Atmospheric co2	72	4	Southern ocean	0.25
5	Carbon dioxide	62	5	Ocean	0.21
6	Temperature	58	6	Climate change	0.19
7	Organic carbon	58	7	Arctic ocean	0.19
8	Carbon cycle	57	8	Seawater	0.18
9	Co2	56	9	Carbon	0.16
10	Carbon	51	10	Anthropogenic co2	0.16
11	Southern ocean	50	11	North pacific	0.15
12	Model	38	12	Dynamics	0.14

together with atmospheric CO_2.The same amount of carbon, and its quantity changes can also reflect on global climate change. However, high temperature climate changes the stability of the ocean, destroys its role as a global thermostat, and causes serious effects on Marine life, and the influence mechanism of Marine carbon sink is shown in Fig. 7.

The researchers utilized a method to distinguish surface water from deep seawater in order to analyze global ocean temperature and salinity observations from 1970 to 2018. Their findings revealed that climate change has significantly disrupted the ocean mixing process. Surface water tends to be warmer, with temperatures decreasing as depth increases. Climate change exacerbates the temperature difference between surface and deep water. Global warming leads to the melting of glaciers, which releases freshwater into the ocean. This freshwater reduces the salinity of the upper seawater and decreases its density. By comparing seawater density over the years, the researchers observed that the barrier separating surface and deep ocean is strengthening at an accelerated rate. The temperature and density disparities between ocean layers are increasing, similar to a layer of oil floating on the surface. This reduction in mixing efficiency hinders the exchange of oxygen, heat, and carbon between the surface water and the lower ocean, thereby interfering with the heat storage and carbon sink functions of seawater.

4.2. Changes in the marine carbon cycle pattern

Major vulnerabilities to the future behavior of carbon-climate systems in the ocean include the effects of ocean warming, enhanced vertical stratification, enhancement of Southern Ocean western winds and polar contraction, and shifts in biological pumps and ecosystem functioning (Doney et al., 2009). The results suggest recent decreases in CO2 uptake efficiency in the Southern Ocean, North Atlantic, and equatorial Pacific.

If the ocean absorbs human CO2 when its capacity becomes saturated, the global carbon cycle pattern will change significantly, and then threaten the basic conditions for human survival. The ocean mainly absorbs a large amount of CO2 due to warm salt circulation, biological activities, and chemical buffering of the upper seawater. The results show that the sea surface removes anthropogenic CO2 from the atmosphere through a chemical buffer mechanism, which has decreased by 16% over the past 50 years. Current high-intensity discharge of human CO2 results in the rapid consumption of seawater chemical buffer material and the absorption of artificial CO2 by the sea surface carbonate system. It is expected that by the end of the 21st century, the sea surface's ability to regulate atmospheric CO2 through the chemical buffer mechanism will further decrease by 55% to approach depletion.

Carbon conservation in marine sediments, coupled with that in large lakes, is the main mechanism for transferring carbon from the active surface carbon cycle to a slower geological carbon cycle. Conservation rates are low relative to the rate at which carbon moves between surface depots, causing largely ignored conservation terms when assessing anthropogenic forcing of the global carbon cycle. However, various anthropogenic drivers, including ocean warming, deoxygenation, acidification, human-induced changes in the delivery of sediments to the

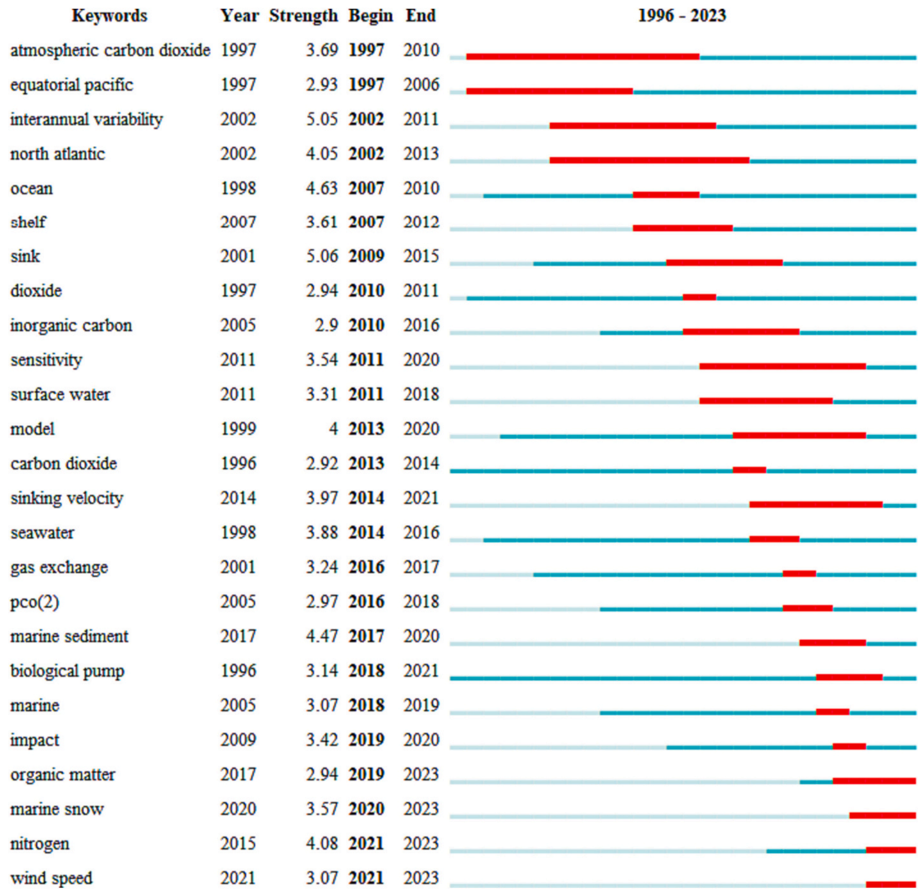

Fig. 6. Emergent words evolution of research in this field from 1996 to 2023.

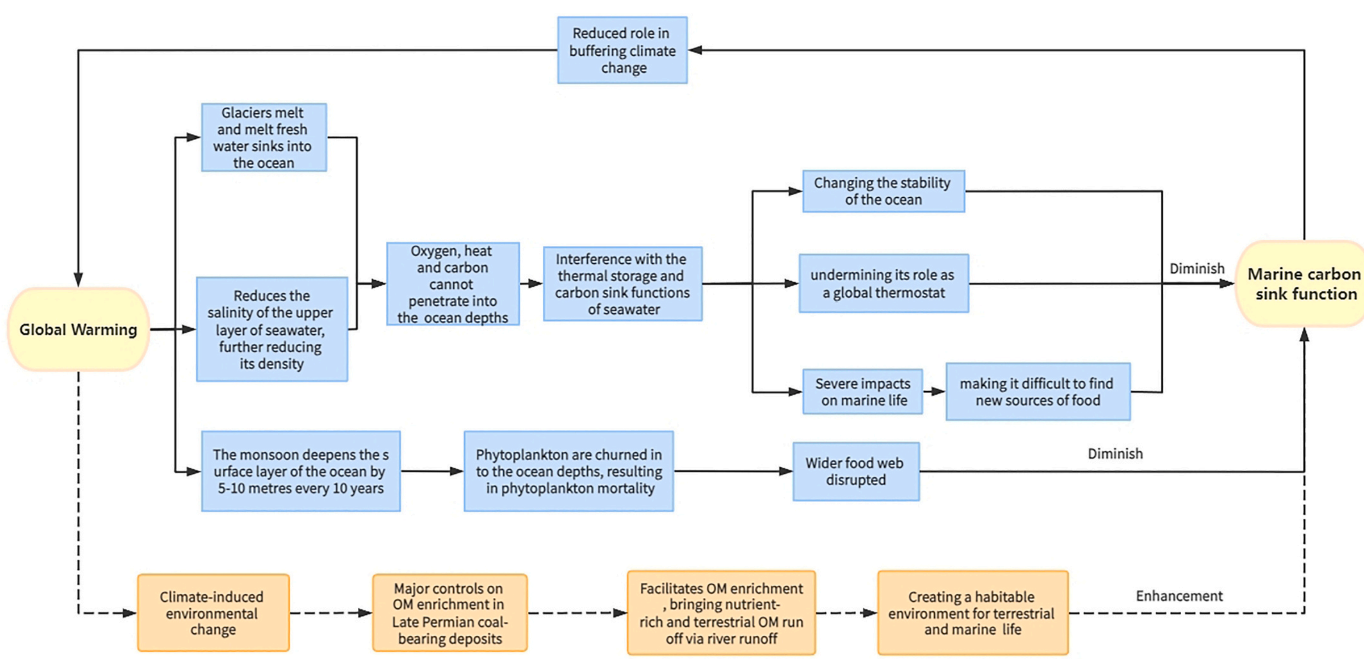

Fig. 7. Interinteraction and influence mechanism of global warming and ocean carbon sink.

ocean, and mixing of continental marginal sediments and irrigated areas, are reducing the already short period of carbon conservation. These drivers influence the cycle of carbonate and organic carbon in the ocean. The overall effect of anthropogenic forcing in modern oceans is to reduce carbon transport to sediments, increase sediment dissolution and remineralization, and subsequently reduce overall carbon preservation (*Anthropogenic Forcing of Carbonate and Organic Carbon Preservation in Marine Sediments | Annual Review of Marine Science [WWW Document],* 2024).

4.3. Impact of marine high temperature on marine ecosystems

Rising ocean temperatures can have a significant impact on global climate and marine life. On one hand, ocean warming can lead to increased evaporation, resulting in more precipitation and providing energy for stronger typhoons. On the other hand, rising ocean temperatures can affect factors such as salinity, pH, and dissolved oxygen content, which in turn can disrupt marine life, cause shifts in fish populations, damage coral reefs, and harm marine biodiversity.

In the past few decades, climate change-induced enhanced monsoons have caused the surface layer of the ocean to deepen by five to ten meters per decade. Many marine animals inhabit the surface ocean and rely on phytoplankton for survival. As the monsoons intensify, phytoplankton are pushed deeper into the ocean where there is insufficient light for their growth, resulting in their death and the disruption of food webs. Changes in ocean structure also reduce its ability to absorb heat and carbon dioxide, diminishing its role in buffering climate change.

According to Maya Gomes, an assistant professor of Earth and Planetary Science who studies ancient ocean geochemistry, rising temperatures can disrupt waterfalls and currents that are driven by the sinking of dense waters. This can slow down the ocean's circulation and its interaction with the atmosphere, leading to reduced oxygen levels. Reduced oxygen can cause widespread areas of oxygen-depleted "dead zones," particularly affecting marine life such as fish and those who rely on them. As nearly half of the world's food depends on the ocean, this poses challenges in finding alternative food sources.

Under global warming conditions, heatwaves have negative effects on primary producers in marine ecosystems. The impact of warming can be influenced by local factors such as light and nutrient availability. Research suggests that the effects of warming on species growth and carbon accumulation can be mitigated by reducing light intensity and enriching nutrients (*Water | Free Full-Text | Research Development, Current Hotspots, and Future Directions of Blue Carbon: A Bibliometric Analysis [WWW Document]*, 2024). Global warming is significantly reducing marine plankton and fishery resources, leading to imbalances in marine ecosystems. Maximizing marine fisheries resources can be achieved by improving marine plankton and reducing greenhouse gas concentrations and global warming (Mandal et al., 2022).

4.4. Factors affecting the occurrence of seawater temperature and heat waves

The average temperature of seawater is 7 °C, and researchers often use the heat content to reflect the temperature of the ocean. For a long time in the past, human measurement of the ocean relied on ship measuring instruments to measure the temperature, which consumed manpower and material resources and limited the measurement of the sea area. With the development of technology, the automatic measuring machine can measure the temperature up and down to a depth of about 2000 m. Some sea areas where special physical phenomena often occur are also the key areas for scientists to make ocean observations and measure seawater temperature, such as a very strong ocean current, Kuroshio, east of Japan.

Human activity is an important factor in causing the rise in ocean temperatures. Industrial activities continue to use fossil fuels such as coal, oil and natural gas, and fossil fuels emit greenhouse gases such as carbon dioxide, methane and nitrogen oxide. Greenhouse gases in the atmosphere absorb heat, increasing net heat in the entire Earth system, warming the oceans. Greenhouse gases in the atmosphere have increased from about 300 ppm before the industrial Revolution to 415 ppm today, and they are still increasing, bringing the ocean temperature to a long-term upward trend.

Even in the absence of human activity, ocean temperature changes periodically due to natural factors. Suns's ups and downs can also affect changes in ocean temperature. Global ocean temperatures can also produce seasonal cycles due to differences in ocean area between the northern and southern hemispheres. Year-to-year changes in ocean temperature are also influenced by special climates such as El Nino and La Nina. El Nino, for example, warms the Middle East and the Pacific Ocean, thus warming surface and ocean temperatures around the world. El Nino and La Nina also lead to periodic changes in global ocean temperature. In addition, volcanic eruptions produce lots of ash, which pours into the stratosphere to block out the sun, causing periodic changes in ocean temperature.

5. Conclusion and discussion

5.1. Conclusion

Based on Citespace knowledge graph, this paper analyzes the knowledge graph structure of Marine carbon sink research since WOS 20 years, identifies the core authors of carbon sink research, literature contributing countries, key words, sudden words and disciplines involved in the research, so as to clearly grasp the research status in the field of Marine carbon sink. At present, the research on the impact of the heat wave on Marine carbon sink mainly focuses on the ocean warming, the impact of high temperature on Marine life, and the mitigation of the negative impact on Marine life and the weakening of carbon sink function.

(1) According to the analysis of the papers related to high temperature in the Marine carbon sink core journal 1996–2023, it is found that the research on the influence of high temperature in the Marine carbon sink has accelerated growth since 2015, because 2015–2019 was the five warmest years since the complete meteorological observation record. In 2019, the global climate system warming accelerated, phenological period advance, glacier melting, and sea level rise… many historical records were refreshed, and the climate extremes was enhanced.

(2) The country with the highest number of articles is the United States, accounting for approximately 37% of the total. This is followed by Germany, the United Kingdom, France, China, Australia, and Canada, all of which are coastal countries, with more than 50 articles each. The main authors dedicated to the study of marine carbon sinks are partially concentrated but generally dispersed, and there is a weak mutual citation relationship among research teams.The identified and analyzed keywords include "climate change","carbon dioxide","variability","carbon cycle","oceanic carbon cycle", "oceanic carbon sink", "ocean temperature","high temperature", and "variability". These keywords appear frequently in the research. Over the past 20 years, the international research hotspots have shifted from "carbon dioxide - carbon emissions - oceans - seawater - organic matter - marine sediments - wind" in chronological order, reflecting changes in research priorities.

(3) The impacts of climate change on ocean carbon sinks are multifaceted, including changes in ocean temperature, ocean acidification, and impacts on marine organisms and ecosystems. This view is strongly supported by numerous studies, including the research conducted by Harley et al. (2016) and published in Global Change Biology. Their paper highlights the substantial influence of changes in ocean temperature on the growth of phytoplankton, which in turn has a profound impact on the ocean's ability to sequester carbon.Meanwhile, the issue of ocean acidification has also received a lot of attention, such as Feely et al. (2016) review article in Chemical Reviews detailing the impacts of ocean acidification on marine life and the carbon cycle.

(4) Research in recent years has found that climate change is already altering the stability of the oceans, undermining their role as a

global thermostat and having serious impacts on marine life. This is reflected in the IPCC (Intergovernmental Panel on Climate Change) 2019 special report, Climate Change and the Oceans and Cryosphere, which describes in detail the impacts of climate change on marine ecosystems and functions. In addition, Global climate change is adversely impacting the mariculture industry by disrupting the metabolic processes of cultured shellfish and algal organisms. This disruption alters the net accumulation and quality of substances in their bodies, ultimately affecting their carbon fixation, storage, and carbon sink functions. This idea is supported by a specific case study in Gao et al. (2019) published in Aquaculture Environment Interactions. To address carbon change and vulnerability in the ocean, a sustained carbon observing system for the surface ocean, improved global spatial coverage and internationally coordinated data synthesis activities are needed (Doney et al., 2009).

(5) The interaction mechanism between the ocean carbon sink and high temperature can be summarized as follows: Global warming leads to the melting of glaciers, resulting in the influx of freshwater into the ocean. This freshwater reduces the salinity of the upper seawater, leading to a decrease in its density. Consequently, oxygen, heat, and carbon struggle to penetrate deep into the ocean, thereby interfering with the seawater's ability to store heat and act as a carbon sink. Additionally, the intensification of monsoons stirs up phytoplankton in the ocean, limiting light availability for their growth and ultimately causing their death. This disruption in the food web leads to the destruction of broader ecosystems. Despite the ocean's crucial role in absorbing approximately a quarter of greenhouse gases and over 90% of greenhouse gas heat, changes in its structure diminish its capacity to buffer climate change by absorbing heat and carbon dioxide.

(6) If the current trend of rapid global warming persists in the next 50 years, it poses a significant threat to marine ecosystems, especially fisheries resources. To address this issue, the system of impulsive differential equations (IDEs) can be introduced as a modeling approach. By comparing the results obtained from ordinary differential equations (ODEs) and IDEs, a more accurate representation of the dynamics of marine ecosystems can be achieved. This modeling framework can be further extended to optimize control methods by incorporating effective control strategies. The aim is to maximize the utilization of marine fishery resources by enhancing marine plankton, reducing greenhouse gas concentrations, and mitigating global warming (Mandal et al., 2022).

5.2. Discussion

Climate change can have significant impacts on the stability of the oceans, disrupting their role in maintaining temperature and carbon sinks. It can also have serious effects on marine plankton. However, some studies suggest that warming temperatures can create a habitable environment for both land and marine life. Warm and moist conditions, along with inputs of freshwater and terrestrial plants, have been identified as the main factors controlling organic matter (OM) accumulation during late Permian coal deposition. A global/regional climate-driven model of OM accumulation in a transitional environment has been summarized. The authors believe that a warming climate can create a habitable environment for both land and marine life by bringing in abundant nutrients and terrestrial OM through freshwater inputs, leading to high OM accumulation (Zeng et al., 2022).

To cope with the impact of climate change on the marine carbon sink, the ecological value of the marine carbon sink can be enhanced by improving the carbon sequestration capacity, particularly in the fishery carbon sink. This can be achieved by building demonstration marine pastures based on fishery aquaculture, expanding the total area of the fishery carbon sink, and increasing carbon storage per unit area through innovation in fishery aquaculture technology and carbon sequestration technology. Additionally, efforts should be made to improve the protection capacity of the coastal marine ecological environment to prevent the destruction of natural marine carbon sinks such as corals, marine algae, and mangroves (Cheng and Chen, 2021).

This paper provides valuable information for research in this field, including identifying research hotspots, core authors, contributing countries, and disciplines involved. This information can guide the development of subsequent research. Previous literature indicates that high temperature weather is the latest hotspot, with a significant impact on ocean carbon neutrality. This is currently a key direction of carbon sink research. However, research in this area is still in its early stages and has not yet made substantial progress. There is limited intersection and collaboration with various disciplines, presenting significant development prospects. Therefore, further research and exploration by relevant researchers is warranted (Nie et al., 2018).

There are numerous potential research topics in this field that scholars should explore. One example is studying the carbon sequestration and sequestration potentials of different oceanic areas, which was initially investigated in the global carbon budget study by Le Quéré et al., published in Earth System Science Data (Le Quéré et al., 2018). Another hotspot of current research is the development of efficient carbon capture technologies to enhance the ocean's carbon sequestration capacity. For instance, Renforth et al. explored the potential of ocean alkaline mineralization for carbon capture in a paper published in Nature Geoscience (Renforth et al., 2019).Investigating ways to regulate the ocean's carbon pumping mechanism is another important direction for future research. This can help improve our understanding of the ocean carbon cycle process and identify new methods to enhance the ocean's carbon uptake and sequestration capacity. DeVries et al.'s paper published in *Nature Communications* highlights the significant role of marine microbial pumps in the carbon cycle (DeVries et al., 2017). Finally, exploring integrated programs that combine multiple approaches to leverage their respective strengths and bridge gaps is an important direction for future research. This concept is discussed in several review articles, such as Gattuso et al.'s paper in Ocean & Coastal Management, which proposes a framework for integrated strategies to address the impacts of climate change on the oceans (Gattuso et al., 2018).

CRediT authorship contribution statement

Hua Li: Conceptualization, Methodology, Supervision, Writing – original draft. **Jing Lu:** Data curation, Writing – original draft. **Helong Tong:** Resources, Writing – review & editing. **Yijun Liu:** Data curation.

Declaration of competing interest

We would like to submit the enclosed manuscript titled “Impact of High Temperature Heat Waves on Marine Carbon Sinks: Based on Literature Analysis Perspective” to your prestigious journal. There is no conflict of interest with this manuscript and the manuscript is approved by all authors for publication. I would like to declare on behalf of my co-authors that the work described was an original research that has not been published previously, and not under consideration for publication elsewhere, in whole or in part. All the authors listed have approved the enclosed manuscript.

Data availability

Data will be made available on request.

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