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Ethical governance and implementation paths for global marine science data sharing

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While global marine science data sharing plays a crucial role in advancing scientific research and knowledge dissemination, it also brings with it two major ethical conflicts: those between individual interests and the public interest and those between data privacy and data sharing, which are rooted in conflict of interest. In the context of globalization and rapid technological progress, current ethical governance frameworks are inadequate in regulating these conflicts. On the one hand, governance cannot meet the needs of rapidly evolving technologies; on the other hand, the complexity and diversity of stakeholders involved in governance make it more difficult. By introducing the theory of legal hierarchy and innovatively proposing the theory of ethical hierarchy, which classifies the ethical principles to be followed according to their importance and applicability, the priority and scope of application between different ethical principles can be clearly defined so that various stakeholders can make the right ethical choices. Using research methods such as literature review, case studies, and comparative analysis, we propose to construct an ethical governance framework that consists of a stakeholder consultation and communication network in terms of governance structure and clarifies the ethical responsibilities of each party in data sharing in terms of governance measures. This framework not only provides a platform for communication and cooperation among different stakeholders but also helps to balance the interests of different stakeholders and improve the level and extent of global marine science data sharing.

KEYWORDS

marine science data, data sharing, ethics, governance, ethical hierarchy

1 Introduction

Marine science data[1] are generally defined as original data and their derivatives that can be used in marine scientific research, management, and application activities and obtained through observation and monitoring, investigation, inspection and detection, testing and development, model calculation, statistical accounting and other methods (Pacific Society of China, 2022, 1). Data sharing refers to the act and process of providing data resources to users in accordance with unified management policies and rules (China Information Industry Association, 2022, 3). The aim is to ensure an orderly, efficient, and compliant data sharing process, addressing issues of data quality, security, privacy protection, intellectual property rights, and collaboration efficiency (Zeenea, 2024). The marine science data sharing process mainly involves data preparation work carried out by the marine science

data provider through the collection of marine science data by means of marine observation and marine monitoring and survey as well as the processing and collection of marine data by means of processing and analysis and providing data sharing services to marine science data publishers. The publisher of marine science data relies primarily on data service platforms and provides data sharing services for marine science data providers and recipients based on security management measures. The recipient of marine science data obtains data sharing services by receiving marine science data published by the data publisher (China Information Industry Association, 2022, 4).

At present, the relevant data analysis models are becoming more and more complex, and it is a key challenge for big data to deal with the diversity and complexity of marine model output. Due to different data formats, inaccurate data, and scientists' lack of understanding of the ethical reasons behind data sharing, many marine climate observations have not yet entered the data repository and are not widely available (European Marine Board, 2020). Sharing marine science data can break down barriers between regions, disciplines, and institutions, promote international scientific research cooperation and exchange by connecting researchers from around the world, and help jointly address global ocean governance and sustainable development challenges. Shared data on seabed topography, meteorology, biodiversity, and pollution provide a comprehensive and accurate information base and research materials for marine research, which not only avoids duplication of data collection and analysis but also helps to enhance the efficiency of scientific research and saves human, material, and financial resources. In addition, governments can formulate reasonable policies based on shared data, and businesses can develop new marine products and services, jointly promoting the prosperity and sustainable development of the marine economy. Therefore, when sharing marine science data, publishers or third-party organizations should pay attention not only to security management but also to the accuracy, timeliness, accessibility, and usability of the data[2] in order to ensure the quality

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1 Marine data is all-encompassing, including not only natural science data such as ocean geography, ocean water, ocean ecology, etc., but also data on social activities such as ocean shipping routes, ocean exploration, and marine scientific research. Marine natural science data mainly refers to the data obtained from observation or simulation of the marine natural environment, including information on the water quality and ecological environment of the ocean (e.g., chlorophyll concentration, suspended sediment content, colored soluble organic matter, etc.), information on the marine dynamic environment (seawater temperature, sea surface wind field, sea surface height, waves, currents, ocean gravity field, etc.), as well as marine biology, marine chemistry, seabed geology, marine biology, marine chemistry, seabed geology, sediment, underwater topography, sea ice, seawater pollution, and other marine environmental information. The main means of obtaining marine natural science data include actual observations, ocean remote sensing observations, and ocean numerical modeling. Therefore, ocean natural science big data can be divided into actual ocean measurement data, ocean remote sensing data, and ocean model data [see Hou et al. (2017)]. Marine big data: connotation, application and platform construction. Hou, X. Y., Hong, Y., Zhang, J. M., Zou, Y. R., Shi , X. Y., Ren, L. B., Cheng, X. et al. (2017). Marine big data: connotation, application and platform construction. *Ocean Bulletin*, 36(4), 362. Marine social activity data is the study of the interaction and mutual influence mechanism between human and marine ecology as well as integrated ocean management, ocean development, and sustainable development. Ocean data can also be classified as using ship-based observations, fixed-point observations, and mobile observations to obtain ocean factual data, satellite remote sensing data, and airborne remote sensing data [see Zhang et al. (2022)]. Reflections on Marine Data Security in China under New Situation. Zhang, X. Q., Xian, L. W., Lv, B. (2022). Thoughts on China's Marine Data Security under the New Situation. *Information Security and Communication Secrecy*, (07), 116-117. Marine science data in this paper mainly refers to marine natural science data and social activity data collected, stored, and used by means of information technology or measured or obtained by remote sensing.

2 Accuracy: through strict data quality inspection, to ensure the accuracy and reliability of the data, so as to avoid misleading conclusions. The accuracy of marine science data is essential for scientific innovation and policy-making. Timeliness: regularly update data to ensure users have real-time access to the latest developments and research results in marine science. Timely data updates will help researchers keep abreast of the latest scientific progress and trends. Accessibility: build a user-friendly data service platform to make data acquisition simple and convenient, and support a variety of data formats and transmission protocols. This helps to lower the threshold for data use and improve data utilization. Usability: continuously optimize the platform's functions and even provide data visualization tools to help users understand and use data more intuitively. By improving the availability of data, user satisfaction and trust can be enhanced.

and value of the data. Take China's newly released "Catalogues of Shared Ocean Data" and Ocean Cloud (China's national online service platform for marine data and information products) as examples. By building a one-stop service platform, it will provide comprehensive and reliable marine data services for marine departments, coastal areas, related enterprises and industries, education and scientific research, and the public as a whole. To some extent, this can promote international cooperation in the exchange of marine information and contribute positively to global cooperation in scientific research and knowledge sharing (Ministry of Natural Resources of the People's Republic of China, 2024).

Ethical governance refers to a set of processes, procedures, cultures, and values designed to ensure the highest standards of behavior (Winfield and Jirotka, 2018, 1-10). Ethical governance tools include internationally recognized ethical standards, international ethics committees, ethics review and evaluation mechanisms, etc. In ethical governance, there is a greater emphasis on "adaptive, people-oriented, inclusive, and sustainable policy formulation, recognizing that policy development is no longer limited to government but rather a process of multi-stakeholder joint efforts" (World Economic Forum, 2017). These multiple stakeholders include government, academic institutions, non-profit organizations, and the private sector. Ethical governance tends to focus on pre- and post-regulatory measures, which is significantly different from post-intervention methods of legal governance. Once ethical norms have judicial binding and universal enforcement power, they enter the scope of the law (Jia, 2022, 54-70).

Marine science data play a vital role in promoting global marine scientific research. However, in the process of data collection, release, and sharing, two important ethical conflicts arise: one is the tension between data owners' pursuit of personal interests and the public interest in scientific research progress brought about by data sharing and the other is the tension between the need for personal privacy protection and the goal of efficient data sharing (Meyer, 2018, 131-144). The root cause of these conflicts lies in the conflict of interest, which stems from the differences in values and interests of different stakeholders. In the context of globalization and rapid technological progress, current ethical governance frameworks are inadequate in regulating these conflicts. Therefore, the core issue of this study is in the context of global marine science data sharing—how to build a fair and effective ethical governance framework to balance the interests of all parties and ensure the authenticity, security, and fairness of the data? Therefore, the overall structure of this paper is as follows: first, analyze the current ethical conflicts in marine science data sharing, the fundamental reason lies in the conflict of interests; secondly, through the introduction of legal hierarchy theory, creatively put forward ethical hierarchy theory and divide the ethical principles that should be followed according to their importance and applicability so that all stakeholders can make ethical choices. Finally, build an ethical governance framework in the governance structure of stakeholders to form a consultation and communication network and governance measures to clarify the ethical responsibilities of all parties to data sharing. This study is expected to provide new ideas and methods for ethical governance of

global marine science data sharing as well as strong theoretical support and practical guidance.

2 The necessity of ethical governance for global marine science data sharing

The global sharing of marine science data plays a crucial role in promoting scientific research and the dissemination of knowledge. However, various ethical conflicts are emerging in this process, not only regarding the quality and security of data and intellectual property rights but also deeper issues such as research fairness and international cooperation. Currently, the global ethical governance framework is inadequate to address these challenges, which directly affects the smooth sharing of marine science data. Therefore, it is particularly important to establish a set of internationally recognized and credible ethical governance frameworks with a global perspective and a spirit of cooperation, which should go beyond the mandatory legal and regulatory frameworks of a single country. This will not only help solve the current ethical dilemma but also provide a solid ethical foundation for the sustainable sharing of marine science data.

2.1 Ethical conflicts arising from the process of data sharing

This section will provide an in-depth analysis of the two core ethical conflicts in the marine science data sharing process: the conflict between personal interest and public interest and the conflict between data privacy and data sharing. These two conflicts are of particular concern because they are universal throughout the world. They are becoming increasingly prominent with the rapid development of science and technology, which have a significant impact on the sustainability and effectiveness of marine science data sharing.

2.1.1 The conflict between personal interest and public interest

The conflict between personal interest and public interest has always been an unavoidable issue in the process of resource sharing and information flow (Søe and Mai, 2023, 17-18). In the context of marine science data sharing, this conflict is particularly prominent. The collection, collation, and analysis of data agglomerates a great deal of researchers' time, money, and human resources. Data owners naturally want to protect these fruits of labor and ensure that their interests are not harmed (Zhang et al., 2017, 7)—for example, researchers gain economic benefits or academic reputation by monopolizing data. However, the sharing of marine science data is of inestimable value to public interests such as global marine research, environmental protection, and addressing climate change. Such sharing can promote scientific research cooperation, accelerate knowledge innovation, and provide strong support for the sustainable use of marine resources and the protection of marine ecosystems.

However, it is worth noting that the problem of "pollution" in data collection has also emerged. Driven by interests, data owners may deal with data "unnecessarily" by means of falsification or tampering, and its motivation is often closely related to academic misconduct (Luo, 2015, 67-70). Such behavior not only undermines the rigor and impartiality of scientific research but also undermines public trust in scientific research. In addition, some researchers may rely too much on shared data and deliberately avoid some basic experimental designs and operations to avoid repeated experiments (Chen, 2021, 133). This may lead to a lack of independence and innovation in research and may also mask information in important but unshared data. The above-mentioned actions not only undermine the authenticity and reliability of data collection but also seriously affect scientific research based on such data and the public interest in marine protection.

Moreover, the problem of the "digital divide" in data utilization cannot be ignored (Chen, 2021, 132). Data owners may choose to keep the data proprietary to maintain their dominant position in scientific research. Some groups, such as scientific research institutions, large enterprises, or developed countries with advanced technology and adequate resources, can easily access, process, and analyze large amounts of marine science data. Because it has an advantage in the competition of scientific research, it promotes its scientific research progress and decision-making, while another part of the group, particularly those scientific research institutions, small enterprises or developing countries that are in a weak position in terms of technology, economy, and educational resources, faces problems such as difficulties in data acquisition and lack of data processing capacity. They may lose the opportunity to participate in high-level scientific research, resulting in a disadvantage in the use of data (Skaletsky et al., 2017, 31-32). Inequality in the use of data directly exacerbates inequality in scientific research opportunities: some groups are unable to access and use data resources equally; others make full use of data sharing for their own benefit, ignoring the contribution to the interests of society as a whole. This further hinders the progress of scientific research and the public interest in marine protection.

2.1.2 The conflict between data privacy and data sharing

In the information age, the conflict between data privacy and data sharing is becoming increasingly prominent, especially in the field of marine science data. Marine science data typically contain a large amount of sensitive information, such as precise geographic location, unique species distribution, and key environmental parameters, which are often closely related to national security, trade secrets, and personal privacy. As we pursue data sharing to promote scientific research, knowledge innovation, and international cooperation, we must face a serious challenge: how to ensure that sensitive information is not illegally obtained, abused, or disclosed in the sharing process.

The cybersecurity threat of data release cannot be ignored. In the special marine scene, the transmission, storage, mining, and sharing of data between the marine Internet of Things (IoT), the observation platform represented by the submarine observation network, and

between the marine Internet of Things or observation platform and shore-based, there are threats such as easy distortion[3], illegal access, disclosure of sensitive information, tampering of key data, etc (Zhang et al., 2022, 117). In particular, data transmission between the IoT and observation platforms, such as the submarine observation network, is more susceptible to the special marine environment, and it is relatively difficult to maintain and update related equipment. Once the equipment has a failure or security breach, it is difficult to repair and update in time, which increases the risk of data leakage and security. This may include confidential information, which usually refers to information that cannot be disclosed to the public due to national security (e.g., activities of military vessels, etc.), commercial interests, or other sensitive reasons. This information is usually protected by law, and illegal access or disclosure may be punishable by law (Chang et al., 2008, 134-138).

Marine science data may also contain sensitive information, such as personal information, location data (location of rare or endangered species), and other sensitive details that need to be strictly protected. Therefore, in the process of data sharing, a series of measures must be taken to ensure the maintenance of privacy and confidentiality from unauthorized access and use or improper disclosure. For marine science data involving personal privacy, some scholars believe that technical ambiguity and anonymization of data collected for the first time can protect personal privacy (Li, 2022, 366). However, in the process of subsequent data re-utilization and reorganization of various types of data, the above-mentioned protection measures may become ineffective, making previously hidden personal information liable to accidental disclosure.

In addition, ethical considerations in the data collection and use process are of vital importance. When collecting personal privacy

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3   Data distortion mainly refers to the deviation or inconsistency between the receiving end and the original data due to the influence of various factors during data transmission. Data distortion in marine science data is mainly affected by complex transmission environments, technical limitations, and human factors: 1. The marine environment is changeable and the transmission environment is complex. The marine environment is complex and changeable, including physical factors such as ocean currents, temperature, salinity, and pressure, as well as natural factors such as marine biological activities and seabed topography, which may interfere with data transmission. When transmitting data over long distances on the seabed, the signal may be attenuated due to seawater absorption, scattering and other reasons, resulting in gradual distortion of the data during transmission. 2. Transmission technology is limited. Although current submarine data transmission technology has made significant progress, it still has some limitations. For example, transmission speed, bandwidth, and stability may be subject to technical limitations, which may affect the accuracy and integrity of the data. At the data receiving end, if the data processing capabilities are insufficient or the algorithm is not accurate enough, it may also lead to deviations in the data analysis and recovery process. 3. Human factors such as operational errors or malicious behavior. In the process of data transmission, storage, mining, and sharing, if the relevant personnel operate improperly or negligently, data distortion may also be caused. During the data sharing and exchange process, there may be malicious data tampering, intentionally causing data distortion.

data, we must ensure that the explicit consent of the person being collected is obtained and that the relevant laws, regulations, and ethical norms are followed. If publishers or third-party organizations fail to strictly comply with privacy regulations and industry norms and misuse or illegally trade the collected data, it may also lead to more serious threats to disclosure and privacy violations (Lubarsky, 2017). This may bring some social pressure to individual scientists' scientific research activities, may cause widespread public concern, and may increase the risks and challenges in the scientific research process, leading to public doubts about scientific research (Chen, 2021, 131). Conversely, this concern and doubt can be used as an important force to promote the improvement of scientific research ethics and data protection.

To sum up, in the context of the global sharing of marine science data, two important ethical conflicts arise: one is the tension between the pursuit of the personal interests of data owners and the public interest in scientific research progress brought about by data sharing and the other is the opposition between the need for personal privacy protection and the goal of efficient data sharing. The root cause of these conflicts lies in the conflict of interest, which stems from the differences in values and interests of different stakeholders. In order to find a solution acceptable to all parties, we need to strengthen communication, consultation, and compromise in order to build a universal and applicable ethical environment for data sharing.

2.2 The current ethical governance is difficult to effectively regulate the above-mentioned ethical conflicts

However, it is difficult for the current ethical governance to effectively regulate the above-mentioned ethical conflicts. The main reasons are discussed below.

2.2.1 Governance cannot meet the rapidly developing technological needs

In the view of scientists, the innovative development of technology not only allows people to re-understand and transform the world but also continuously breaks through the ethical norms and standards formed in traditional society, triggering new social ethical issues (Han, 2021). The inherent nature of development determines that while technology removes some uncertainty, it also brings new uncertainties, which may lead to ethical conflicts that have not previously been considered—for example, the public generally believes that ocean data can be provided for use by domestic and foreign researchers, does not involve sensitive information, and does not require security protection. In fact, many marine data, such as longitude and latitude, marine geology, ocean currents, and other basic marine data near the coastlines of various countries, or marine data that have undergone certain aggregation and processing, may already be sensitive or even classified information. If it flows to hostile countries, it is very easy for hostile forces to use it (Zhang et al., 2022, 115-122).

In today's highly globalized scientific research environment, ethical norms play an important role in guiding the sharing of scientific research data. The main form of expression is the ethical norms of scientific data sharing, which provides researchers with ethical and behavioral standards that should be followed in the data sharing process. In the field of marine scientific research, the requirements of ethical norms are also implied in its data sharing service standards and related community standards (Leng et al., 2023, 2239-2249). However, at the same time, ethical standards for data sharing in the above-mentioned areas are lagging behind. The core source of this lagging phenomenon lies in the process of systematic construction and implementation of ethical governance itself, which is intertwined with many complex and deep-seated challenges. Ethical governance cannot rely solely on existing frameworks or means because, when faced with rapid changes in technology, they often appear powerless and cannot comprehensively and effectively respond to emerging ethical issues. First, the development of a comprehensive set of ethical management practices for the sharing of marine science data is not achieved overnight, requiring considerable time and cost. It includes not only the formulation of internationally recognized ethical norms but also governance institutions such as the establishment of international ethics committees and the improvement of ethical review and evaluation mechanisms. Therefore, it is particularly difficult to achieve the ethical governance goal of sharing marine science data in a short period of time. Secondly, the introduction of ethical norms cannot be achieved through unilateral efforts. It requires the joint participation and cooperation of all parties to jointly develop a recognized and credible ethical governance framework with a global vision and spirit of cooperation. Access to, processing, and accessibility of known data depends to a large extent on the independent efforts of individual countries. At the international level, however, there are few sustained efforts to coordinate and simplify the management of data repositories, harmonize data formats, and improve data accessibility (Verwega et al., 2021). The heterogeneity of data sources reflects differences in the interests of all parties and communication barriers, and it can be seen that it is difficult for all parties to reach a unified and effective synergy, resulting in difficulties in the practical implementation of ethical norms.

2.2.2 The stakeholders involved in governance are complex and multifaceted

Ethical conflicts in the sharing of marine science data do not exist in isolation and are linked to legal, social, and other issues, making it challenging to establish comprehensive norms that could encompass all ethical norms. Scholars have argued that governance includes traditional "management" and "regulation" as well as participatory bottom-up approaches involving stakeholders and the public (Han, 2021). As a result, it involves a variety of stakeholders, including scientists, ethicists, social organizations, stakeholders, the public, policy makers, government agencies, etc., and its related interests are complex and diverse. The current multi-stakeholder governance of marine science data sharing mainly includes international

governance led by a coalition of state actors, unilateral governance by sovereign states, bilateral governmental cooperation or multilateral governance by coastal state organizations and large interstate research institutions, and joint governance of the region by states, international organizations, and other actors within a region. The multi-stakeholder governance of marine science data sharing reflects differences in laws and regulations and policy planning for data sharing in different countries and organizations.

As different countries and organizations have different laws, regulations, and policy plans for data sharing, the ethical spirit behind them is naturally different. In terms of laws and regulations, compared to Europe and the United States and other countries or regions, Asian countries are still in the early stages of developing relevant legislation on marine science data sharing. Although in recent years Asian countries have gradually realized the importance of sharing scientific data and have gradually adopted legislation to grasp the right to speak of data resources and maintain national security, there is still a certain gap between the establishment of a legal system for sharing marine data and Western countries (Sun et al., 2022, 23-24). Combining policy and planning systems for the open sharing of marine science data in Asian countries such as Japan and South Korea, it was found that the degree of data sharing is single compared to the sharing patterns in Western countries. Their data sharing in marine science is still in its infancy, as a sound institutional mechanism in the field has not yet been established—for example, although the Japan Science and Technology Agency and the Integrated Maritime Policy Headquarters have developed policies and plans for the openness and reuse of data in the areas of science and technology and oceans, respectively, there is still a lack of a mechanism for cross-cutting policy coordination (Sun et al., 2022, 25). China, on the other hand, has enacted a "Personal Information Protection Law", and recently the Ministry of Natural Resources of the People's Republic of China organized the National Ocean Information Center to release "Catalogues of Shared Ocean Data" and the country's first national marine big data service platform (Ocean Cloud) in order to promote international cooperation in the exchange of ocean information data (Ministry of Natural Resources of the People's Republic of China, 2024).

It can be seen that the European Union, the United States, and China tend to establish a data sharing mechanism with open and transparent ethical principles in marine science data sharing, respect scientific research and the public's right to know, and attach importance to the protection of intellectual property rights. It embodies the concept of international cooperation and common development. Japan and South Korea prefer ethical data sharing mechanisms to ensure data accuracy, completeness, and reliability, with a focus on data quality and safety (Sun et al., 2022, 23-25). It should be noted that these ethical considerations are not absolute but are based on trends and characteristics of national or regional laws and regulations, policy planning, and practical practices in marine science data sharing. At the same time, these ethical minds will also change with the change of time and environment. Therefore, the establishment of a universal standard/guidance for the sharing of marine science data requires countries and

organizations to gradually reach consensus and cooperation through dialogue and consultation while respecting each other's interests and concerns, which may be challenging.

3 The ethical hierarchy of global marine science data sharing: Proposing theories

Against the background of the new era of global marine science data sharing, technological innovation has given developed countries the advantage of firmly grasping massive marine data resources through their cutting-edge ocean observation systems and data processing technologies. However, technological constraints and insufficient funding have made it difficult for some developing countries to fully integrate into this trend of data sharing and analysis, thereby undermining their competitiveness in marine scientific research. Especially in the construction of marine environment prediction models, if the training data of the algorithm focuses mainly on a specific area or type of marine environment, it is likely to be less reliable in predicting phenomena in other different environments.[4] This not only reflects

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4　It stems from technical limitations—that is, the model's generalization capacity is limited, and it cannot adapt to the complexity and diversity of all marine environments. Behind this technical limitation, there are deeper ethical conflicts. This conflict arises from the differences in values and interests of different stakeholders. Specifically:.

1. Differences in values: different stakeholders may have different values and expectations for the application of marine environment prediction models. For example, some stakeholders may be more concerned about the accuracy of the model in a specific region or type of environment while ignoring the applicability of the model in other areas. This difference in values can lead to bias in model building and selection, which, in turn, leads to ethical conflicts.

2. Differences in interest requirements: different stakeholders have different interest requirements in marine environment forecasting. For example, fishing and tourism countries have differences in their marine environmental forecasting. Fishing countries are primarily concerned with changing trends in marine resources (such as fish stocks) to guide their fishing activities and fisheries management. Tourist countries, on the other hand, are more concerned about the overall quality of the marine environment and landscape changes, as this directly affects tourist satisfaction and tourism revenue. If the training data of the prediction algorithm is mainly based on fishery survey data, it may place too much emphasis on the prediction of fishery resources and ignore environmental factors such as sea clarity and coral reef health that the tourism industry is concerned about. This mismatch of interest requirements can lead tourism countries to feel ignored, triggering ethical conflicts and obstacles to cooperation.

3. Fairness and justice: biases in marine environmental prediction models can lead to unfair resource allocation and unfair decision-making. If marine environment forecasts in some areas are more accurate, then these areas may have easier access to resource support and policy direction. This unfair phenomenon not only violates the principles of fairness and justice but also exacerbates conflicts between different stakeholders.

the limitations of the technical level but also reveals the deep ethical conflicts behind it, which are rooted in the differences in values and interests of different stakeholders. Given the above-mentioned conflicts of interest, there is an urgent need to reform ethical governance. To this end, we creatively propose the theory of ethical hierarchy in the field of the law of the sea. By defining a clear hierarchy of ethical principles, we hope that, in the face of ethical conflicts, various stakeholders can make ethical choices according to these levels. This is not only an adaptation to technological development but also a maintenance of the stability of global cooperation in marine scientific research, which contributes to a more just, transparent, and sustainable framework for ethical governance.

3.1 Introduction to the theory of legal hierarchy

Ethics, as a form of social norms, is also a system like law. As early as the 1980s, scholars in China initially explored this issue, believing that the ethical system is an open system influenced by social factors, economic conditions, cultural level, scientific level, cognitive level, social public opinion, local customs, geography, and accidental factors (Xie, 1985, 24-26). The ocean is a global ecosystem that provides habitat for many species, including humans. There is a need to ensure that the sharing of marine science data promotes environmental justice, biodiversity protection, and sustainable development. Therefore, the ethical principles of marine science data sharing can also be considered as a system. The essence of ethical conflict encountered in practice is the conflict between ethical values and principles within the ethical value system or between it and other ethical value systems. In the final analysis, this is a conflict of interest (Lu, 2019, 224-228). At this time, the ethical principles of marine science data sharing can use rank analysis to judge the ethical values and principles involved according to the specific uses and actual activities of data sharing and finally form a specific ethical hierarchy.

The theory of legal hierarchy (Stufenbaulehre) was first proposed by Adolf Julius Merkl, the representative of the Vienna Circle, later adopted by Hans Kelsen as one of his core ideas of pure law, and has been widely disseminated (Wang, 2022, 5-25). "Ladder structure" is the visual expression of the concept of legal hierarchy, referring to the way legal norms are organized into levels, with general principles and values at the top of the level and more specific rules and regulations at the bottom. This structure allows flexibility in interpreting and applying legal norms while also providing a framework for resolving conflicts between norms. Hans Kelsen emphasized the formal structure of the legal system and the importance of the constitution as a basic norm (Feng, 2022, 131-150). Hans LA Hart and Ronald Dworkin took a more detailed and flexible approach, emphasizing the role of values and principles in shaping the normative hierarchy (Zhang, 2014, 143-159).

Generally speaking, the so-called legal hierarchy is the system of determining the level of effectiveness of the upper and lower normative legal documents in a country's legal system—that is, when there is a conflict between legal documents, the system that prioritizes which one to apply. There are three presuppositions for the existence of the system: First, the ideal state of the legal order is internal harmony, which is the goal pursued by the legal system, so the internal legal order should be unified and orderly. Secondly, in the current legal system, due to legislative technology, legislative time, legislative subject matter, and other factors, there may be inconsistencies or conflicts in the content of different levels of legal norms. This kind of conflict is a normal phenomenon in the process of dynamic operation and continuous improvement of the legal system, and the conflict rules of hierarchy theory are established to solve this kind of conflict. When there is a conflict between different levels of legal norms that are legitimate and effective, hierarchy theory provides a rule for choosing which to apply preferentially— for example, in the current legal systems of different countries, the general hierarchy from high to low is constitution, law, regulation, and rule. Where there is a conflict between them, only superior law may be applied preferentially. However, if the provisions of the law themselves violate the content of the constitution and regulations are in line with the spirit of the constitution, regulations should first be implemented at this time. Third, the existence of "basic norms", the so-called basic norms, cannot derive their own effectiveness from a higher norm (Hu, 2006, 140-145). The "basic norms" have their own independence and fundamentals; it is the highest standard in the legal system, and other legal norms are based on and limited by it. In most legal systems, the constitution is such "basic norms". As the country's fundamental law, the constitution has the highest legal status, legal authority, and legal effect and is the basis for the formulation of other laws (Longley, 2019). Therefore, when other legal norms conflict with the constitution, priority must be given to the implementation of the constitution in order to maintain and protect the unity and authority of the legal system.

3.2 Propose ethical hierarchy theory

Through the interpretation of the spirit and purpose of the United Nations Convention on the Law of the Sea (UNCLOS), this paper discusses the possibility of ethical principles for sharing marine science data in practical marine scientific research and international cooperation. Inspired and pondered by the theory of legal hierarchy, it is assumed that legal norms can be arranged according to hierarchy, with higher norms having higher effectiveness than lower norms. It is recommended that, in the event of ethical conflicts or trade-offs in data sharing, the ethical hierarchy of data sharing prioritizes certain ethical principles or values. There are several ethical principles that can guide the sharing of marine science data, including but not limited to: (1) respect for autonomy: researchers should be able to control their own data and have the right to agree or disagree with its use [see article 240 (c) of the United Nations Convention on the Law of the Sea], (2) benefit to humanity: marine science data should be shared, with a focus on human welfare [see article 240 (a) of the United Nations Convention on the Law of the Sea], (3) non-malicious: efforts should be made to prevent potential harm such as marine disasters caused by the sharing of marine science data [see article 240 (d) of the United Nations Convention on the Law of the Sea],

(4) fairness: access to marine science data should be fair and not discriminate against any particular group or individual (see article 238, 243 and 244 of the United Nations Convention on the Law of the Sea), (5) responsibility: personnel involved in the sharing of marine science data should be responsible for ensuring that data are used in an appropriate and ethical manner [see article 240 (b) of the United Nations Convention on the Law of the Sea].

UNCLOS itself does not explicitly specify, nor does it imply, any priority in the above-mentioned principles. Therefore, based on the interpretation of UNCLOS and the limitation of the length of the article, the author does not attempt to place these principles in a hierarchy. In practice, all individuals and organizations involved in the sharing of marine science data, including scientists, institutions, and policy makers, do not necessarily follow these principles in the marine science research process because these basic principles are of equal importance in research and should be observed jointly (UNCLOS basic principles on marine scientific research), including "peaceful purpose", "for the benefit of all mankind", "principle of international cooperation", "principle of neutrality", etc.). However, in the specific context of marine science data sharing, when resolving ethical conflicts in sharing, we need to weigh and judge according to the specific situation.

We do need to weigh the value and importance of different principles when the aforementioned ethical conflicts common to marine science data sharing occur. The principle of respect for autonomy, as the cornerstone of the protection of personal privacy, undoubtedly occupies a central position. Specifically, institutions that host and manage marine science data, as well as scientists who collect and analyze such data, have a significant responsibility to ensure that informed consent is obtained from participants in the data collection process and should handle data sharing in a highly responsible and ethical manner. Here informed consent is not only a respect for the individual autonomy of participants but also the key to ensuring that data is used in accordance with ethical requirements. However, it is worth noting that the principle of respect for autonomy does not exist in isolation but functions within a more complex and diverse ethical framework. In the practice of data sharing, we also need to take into account many other principles, such as human well-being, non-malice, fairness, and responsibility. These principles may have different priorities and importance in different situations and require flexible and prudent trade-offs based on specific circumstances—for example, in emergencies that protect marine ecosystems from harm, the principle of humanity may require us to give priority to the public interest, even if it may, to some extent, violate personal privacy. This may mean that, in some cases, privacy boundaries need to be adjusted appropriately for greater environmental or public interest. However, such adjustments must be based on appropriate ethical considerations to ensure that individual rights are not unduly violated and that they are aimed at the wider welfare of society.

To sum up, the ethical hierarchy of marine science data sharing embodies three fundamental aspects. First, it arises from the existence of ethical conflicts inherent in the process—for example, scientific data collected from the ocean may contain sensitive or confidential information, such as the location of rare or endangered species or the activities of commercial or military vessels. This poses an ethical dilemma: how to safeguard such information while facilitating its dissemination for scientific research and conservation. Second, the ethical hierarchy prioritizes the application of ethical values and principles over the mere evaluation of the effectiveness of ethical practices. Third, this ethical hierarchy has a profound impact on the resolution of ethical conflicts, especially within a single context (e.g., the practices of a single researcher) or a specific data-sharing community (Lu, 2019, 224-228). However, its applicability extends beyond these boundaries, encompassing more complex scenarios involving ethical conflicts among diverse stakeholders (multiple researchers, institutions, or communities) and across various data-sharing activities.

Faced with this type of conflict, which involves more complex and diverse ethical issues, we need to consider the applicability of ethical hierarchy more carefully. By drawing lessons from the ethical hierarchy of genomics data sharing, it provides a useful perspective for us to understand and deal with ethical conflicts between different subjects and activities, which is conducive to the application of the ethical hierarchy of marine science data sharing. In this framework, privacy protection is always at the core, including the implementation of de-identification and coding/pseudonymization to ensure the security of the data sharing process (Thorogood and Chokoshvili, 2023, 353). While ensuring that privacy is fully protected, we should rely more on advanced technologies to ensure that the data sharing process meets ethical and legal requirements, thereby enhancing public trust in publicly shared genomics research (Kaye, 2012, 415-431). Given that the collection and use of genomic data often involves multiple interests, achieving equitable sharing has become an important consideration in the data sharing process. We need to ensure that the value generated by data is fairly distributed, taking fully into account the reasonable needs and expectations of all participants, to promote the sustainable development of genomics data sharing.

Suppose there is a multinational cooperation project involving research institutions, medical institutions, data providers, and patient groups in multiple countries. The project aims to accelerate research and treatment of rare genetic diseases by sharing genomic data. In this transnational cooperation project, all parties involved hope to benefit from data sharing, including research results, financial support, and reputation enhancement. In order to ensure the fair sharing of benefits, the project needs to develop a detailed set of benefits distribution mechanisms—for example, appropriate research results and financial support are allocated according to the contribution of participants in data collection, processing, and analysis. In addition, the project could establish an independent monitoring body to ensure fairness and transparency in the benefit distribution process. There may be cultural differences between research institutions and medical institutions in different countries, which may lead to ethical conflicts in the data sharing process. To address this issue, the project could establish a special ethics review committee composed of experts from different countries to jointly develop data-sharing agreements that meet the ethical standards of all parties. In the process of data sharing, data ownership is also a potential ethical

conflict (Malakar et al., 2024, 510). To solve this problem, the project may adopt the co-ownership model—that is, all participants share the data, but they must be used and analyzed in accordance with the terms of the agreement.

3.3 Take the principle of benefit to humanity as the bottom line ethics

In determining the ethical level of the sharing of marine science data, it is firstly necessary to clarify that individuals or organizations, including scientists, institutions, and policy makers, are subject to ethical conflicts. Secondly, the applicable ethical principles should be determined based on the specific purpose and actual activities of data sharing. In addition to these two primary approaches, there exists theoretically a fundamental level of ethics, which serves as a perpetual guiding principle. This fundamental ethics advocates the legitimacy of actions and conduct, rooted in basic human values. It represents the ultimate and non-negotiable criterion, taking precedence over all other ethical considerations within the hierarchy of ethical requirements (Liu and Yang, 2021, 81-86)—for example, in the field of AI ethics, programmers are required to follow ethical principles of "humanism," such as caring for human welfare and benefiting humanity, in almost every ethical guide or code when designing programs. This is simply because the development of AI technology (especially the application of ChatGPT) is beyond imagination, and its ethical guidelines are often not flexible enough to adjust to new social relationships, thus attempting to support the rapid development of technology through people-oriented basic ethics.

It is suggested that the principle of benefit to humanity should be regarded as a recognized and consistent bottom line ethical norm, and its status may be equivalent to the constitution as "basic norms". This principle can highlight the value closely linked to its effective allocation and achieve a geometric multiple increase in benefits to human society. From the perspective of information economics, data sharing can be transferred in multiple directions, and the same data can be analyzed and reused by the public without affecting its second and third utilization analysis, maximizing its value in the continuous value-added process. However, whether the principle of benefit to humanity can serve as the basic ethics for sharing marine science data urgently needs to be verified in practice. This formulation is theoretical innovation and requires sufficient empirical support. However, it cannot be denied that the cornerstone of marine science data sharing lies in sharing data to achieve win–win cooperation. The basic ethics revolve around the process of data sharing, which is actually the process of interaction between "people and people, people and society" using marine science data as a medium (Zhao, 2021, 35-37). Therefore, the principle of benefit to humanity of basic ethics (constant superior ethics) is also conducive to creating and changing the real structure of marine science data sharing to meet the needs of rapid technological development.

In summary, the five ethical principles outlined here—respect for autonomy, benefit to humanity, non-maliciousness, fairness,
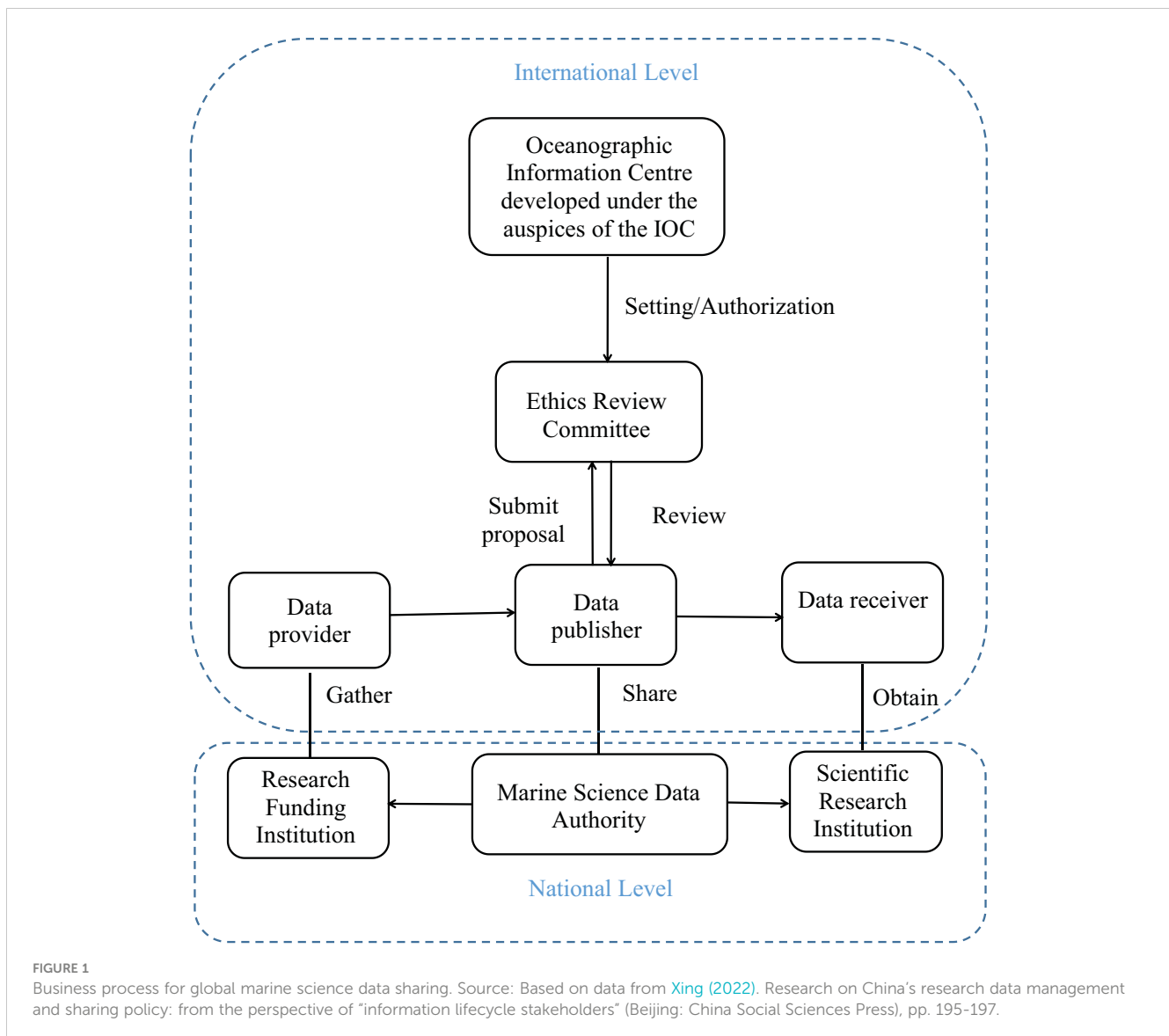
and responsibility—form a cohesive framework that guides the practice of marine science data sharing. Each principle serves as a cornerstone, underpinning the responsible and ethical use of data in the pursuit of scientific advancement and societal well-being. While we have not imposed a rigid hierarchy among these principles, their interdependence and mutual reinforcement are evident. Respect for autonomy ensures the autonomy of participants, benefit prioritizes human welfare as the ultimate goal, non-maliciousness mitigates potential risks, fairness ensures equitable access, and responsibility emphasizes accountability of all stakeholders. Together these principles provide a strong ethical foundation for the sustainable and beneficial sharing of marine science data, adapting to the rapid pace of technological development and societal change.

4 The implementation path of ethical governance for global marine science data sharing

Faced with possible ethical conflicts in the global sharing of marine science data, we must build a clear and inclusive implementation path. First of all, we must clarify and respect the rights and interests and demands of various stakeholders and form a consultation and communication network of stakeholders in the governance structure. Different countries and institutions can conclude network agreements on data sharing and conduct full discussions and consultations to ensure that the distribution of interests of all parties is balanced and respected. Secondly, we need to pay special attention to the ranking of ethical principles and clarify the ethical responsibilities of all parties in data sharing in terms of governance measures. All parties involved should follow ethical standards under the guidance of ethical hierarchy theory and abide by ethical principles consistent with the corresponding groups—for example, the original owners of marine science data, data centers, and journal platforms should ensure data quality and security, and data users should respect intellectual property rights.

4.1 Governance structure: A consultation and communication network composed of stakeholders

Stakeholder role theory states that different stakeholders formed around a particular social activity have their own different interests and demands, assume different responsibilities and obligations, and form a stakeholder that both cooperates and plays games with each other (Xing, 2022, 195). In order to ensure the maximum effectiveness of the governance mechanism and to identify the responsibilities, obligations, and interests of different stakeholders in the development of an ethical governance system for the sharing of marine science data, the Marine Information Center developed under the auspices of the Intergovernmental Oceanographic Commission (IOC) could serve as a multi-stakeholder international coordination committee (institution) on ethical governance. Not only does it help balance and coordinate the

FIGURE 1
Business process for global marine science data sharing. Source: Based on data from Xing (2022). Research on China's research data management and sharing policy: from the perspective of "information lifecycle stakeholders" (Beijing: China Social Sciences Press), pp. 195-197.

interests and demands of various stakeholders, forming a balanced and scientifically sound consultation and communication network, but it can also give them credibility.

The key words "scientific/research data" and "responsibility stakeholders" are used to search the world's leading academic databases and search engines. It can be seen that although different countries have different cultural backgrounds and practical situations, the relevant policies and research literature basically have consistent definitions of the parties responsible for the management and sharing of scientific data. At the national (internal) level, they mainly include scientific data regulatory agencies (such as government departments, specialized committees, etc.), research funding/management institutions, research institutions, research support and service institutions, research data centers, publishers of scientific researchers, etc (Xing, 2022, 195). Ethical governance of marine science data sharing cannot be separated from stakeholder participation. It is recommended that countries improve the relationship network at

the national level through "(research funding) institutions–data production–data platforms–data sharing–data usage–data supervision" and establish a joint consultation mechanism composed of research workers, research funding parties, platform builders, data users, and representatives of the public (Chen, 2021, 136).

On the one hand, the relationship network serves as a valuable link to international coordination mechanisms focused on marine science data sharing. It fosters the subjective initiative of various stakeholders in understanding the ethics of sharing, clarifying the interconnected relationships among them. Moreover, based on the operational procedures for international data sharing and the responsibilities of the institutions involved, it facilitates the establishment of an ethical governance structure for stakeholders that embodies both interdependence and strategic interplay (Xing, 2022, 197-199). On the other hand, if an ethics review committee can be added to existing international institutions to conduct ethical reviews of every act of marine science data sharing, i.e., the
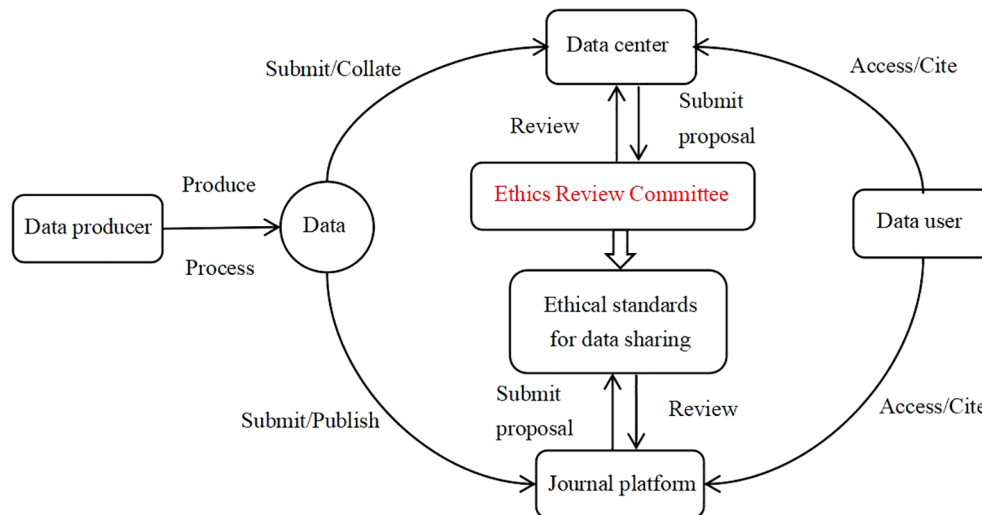
FIGURE 2
Ethical governance structure of stakeholders in global marine science data. Source: Based on data from Xing (2022). Research on China's research data management and sharing policy: from the perspective of "information lifecycle stakeholders", Ethical guidance (Beijing: China Social Sciences Press), pp. 197-199.

establishment or authorization of an ethics review committee (the Marine Information Center developed under the auspices of the Intergovernmental Oceanographic Commission), it will better play the role of ethical oversight of data sharing at the international level (Figure 1).

It is suggested that prior to the online publication or sharing of marine science data, the data center or journal platform (data publisher) be required to submit a comprehensive online publication or sharing application, including the format and any potential ethical considerations, to the Ethics Review Committee specifically established and authorized by the Marine Information Centre (MIC), which would be developed under the auspices of the Intergovernmental Oceanographic Commission (IOC). To facilitate ethical governance across the spectrum of international research sharing, where more stakeholders are involved, MIC would be poised to play a pivotal role in establishing and implementing ethical governance tools. These include, but are not limited to, internationally recognized shared ethical norms, international ethical governance coordination committees, robust ethical review mechanisms, etc. MIC's approach could not only streamline the process but also ensure that ethical considerations are embedded in every aspect of the sharing process. The Committee would review the compliance of the applicable data sharing scheme with online publication or sharing requirements and its ethical acceptability and make independent decisions. In addition, the Committee would issue ethical standards for data sharing, which could provide ethical guidance for production standards, submission/publication standards, and access/citation/authorization licensing standards (Figure 2).

In the process of sharing global marine science data, ethical standards for researchers must first and foremost require an open and transparent review process by the Ethics Review Committee to

ensure broad participation by all parties. Secondly, the content of the review should closely link the specific purpose and actual activities of data sharing. When intelligent agents with organizational decision-making or data production, processing, and sharing capabilities are considered active nodes, each active node should comply with the "equal cooperative relationship" elaborated by the community. In order to maximize the interests of all stakeholders in the governance structure, it is recommended to establish network protocols between active nodes and give autonomy to all parties, thus establishing collaborative partnerships among all parties involved in data sharing. Due to the unique nature of each dataset's various possible uses and potential risks, a separate network protocol must be established for each sharing, in which the potential benefits and risks of the sharing action must be identified (Lei and Bai, 2021, 7-11).

4.2 Governance measures: Clarify the ethical responsibilities of all stakeholders involved in data sharing

Lawrence Lessig pointed out in "Code and Other Laws of Cyberspace" that, in reality, there are at least structural, market, moral, and legal forces that play a regulatory role, with law being just one of them (Lessig, 1999, 90-95). Regulatory channels for online behavior include not only laws but also codes. Unlike the former, which primarily affect behavior outcomes through punishment, deterrence, and post-correction, codes provide "perfect control" that can not only affect behavior outcomes but also affect behavior choices and processes. When technology brings large-scale changes to industry and commerce, legal regulation, as one of the many regulatory means, should help society establish a transitional mechanism (Guo, 2020, 206). It can mitigate the impact of technological change and provide

space for all sectors of society to adapt and cushion rather than replace different standards of data ethics.

The United Nations General Assembly has proclaimed the United Nations Decade of Ocean Science for Sustainable Development (2021–2030), announced by the United Nations General Assembly to promote global marine scientific research (Thomson, 2021) to meet the common expectations of scientists, policy makers, industry, civil society, and the general public for the sustainability of the oceans, particularly for developing countries. In this process, the open sharing of marine science data is particularly critical. It is not only the basis for scientific research but also an important driving force for advancing marine science and achieving the sustainable development goals (Verwega et al., 2021, 1). This requires us to clarify the ethical responsibility of all stakeholders in data sharing in governance measures to ensure that data quality, security, and intellectual property rights are properly respected and protected from a legal perspective. At the same time, in the process of data sharing, respect for copyright and intellectual property rights should not be at the expense of personal privacy—for example, when quoting or cooperating, although the copyright of the data producer must be respected, it must also ensure that information containing personal privacy is not disclosed. Therefore, the original owners of marine science data should be responsible for ensuring the authenticity and integrity of the data and providing high-quality data support for scientific research; data centers and periodical platforms should assume responsibility for data management and services, ensure data accessibility and security, and provide convenient access to data for researchers. On the other hand, data users should respect the intellectual property rights of data, make rational use of data, and indicate data sources in research results, so as to promote the sharing and dissemination of knowledge, clarify the responsibilities and obligations of data users in the data sharing agreement, including respect for copyright, intellectual property rights, and personal privacy, and specify the scope, purpose, and limitations of data use.

Firstly, the original owner of marine science data, i.e., the producer or monitoring agency of marine science data, should ensure the authenticity and reliability of the data they submit rather than blindly enjoying the convenience of sharing data with others and benefiting from their data dividends and not disclosing the data they own (Chen, 2021, 135). Before sharing data, information that may contain personal privacy should be anonymized and desensitized to reduce the risk of privacy disclosure. Given that researchers are often influenced by the ethical norms of marine scientific research, such as their associations, societies, and research institutions, it is recommended that shared ethical awareness be incorporated into the professional ethics education system for researchers and that the ethical guiding purpose of ethical norms be implemented for their members. The cultivation of ethical awareness is strengthened, and researchers are enabled to develop autonomy in data sharing, a value system that balances risks and benefits is established, and ethical restraint mechanisms are established through industry self-discipline.[5] In order to promote the process of standardization of data formats, policy guidance and incentives should be strengthened. Policies can be developed to encourage research institutions and individuals to adopt unified data format standards, and priority support and funding can be given to the adoption of standardized data. At the same time, an incentive

mechanism can be established to recognize individuals and teams who have made outstanding contributions to the standardization of data formats.

Secondly, as important hubs for sharing marine science data, data centers and journal platforms should ensure that marine science data are not distorted or the quality damaged by non-technical factors, while ensuring ease of sharing, through the development of uniform global data formats or standard requirements covering all forms of marine science data, including text, images, video, and numerical models, making it "adaptable" and "compatible" with different regional or national laws and regulations in the sharing process so as to avoid cost consumption. We propose the establishment of a unified marine science data-sharing platform that functions as a central repository for storing and managing marine science data in a variety of formats. This platform will facilitate data retrieval, visualization, online processing, and recording of results. To ensure clarity and avoid confusion, we recognize that the development of such a platform should be distinguished from the establishment of a separate mechanism for managing access and ensuring intellectual property (IP) protection. We will therefore address access control and IP safeguards independently, ensuring that the focus of the data-sharing platform remains solely on facilitating data exchange and utilization within the marine scientific community. Through the data sharing platform, different research institutions and individuals can easily access and use this data (Open Data Charter (ODC), ODC Principles) and explore in depth how to integrate ethical principles into the initial design phase of data infrastructure, with the aim of equitably distributing the benefits of data sharing across society, thus addressing the digital divide and reducing social disparities (Liu and Han, 2024, 2). At the same time, we can learn from the international experience of global intellectual property protection and establish a minimum standard of intellectual property protection around the world. Relying on the signing of international treaties such as the Berne Convention and the Intellectual Property Agreement, the principle of "high not low" is adopted on issues such as the object of rights protection, methods of acquisition, content and limitations, and protection period. Each contracting party complies with the

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5 To improve ethical data sharing practices, the following recommendations are made:

1. Strengthening ethical awareness: This involves educating researchers on ethical principles and best practices related to data sharing to ensure that they are aware of the impact of their actions.

2. Enable researchers to develop autonomy in data sharing: Researchers should have the power to make informed decisions about when and how to share data while also being held accountable for the consequences of those decisions.

3. Establish a value system that balances risks and benefits: A clear framework should be developed to guide researchers in assessing the potential risks and benefits of data sharing to ensure that the overall impact is positive and socially responsible.

4. Establish ethical restraint mechanisms through industry self-discipline: The research community should work together to establish and enforce ethical standards through self-discipline mechanisms such as codes of conduct or ethics review committees.

"minimum protection standard" but may choose whether to exceed this minimum standard at its own discretion (Wang et al., 2021, 61).

Finally, data users should bear ethical responsibility for intentional distortion or unintentional misuse of data, but the three parties involved in data sharing are not the only ones mentioned above. In the above-mentioned sharing mechanism, a range of stakeholders have been involved, including data producers, research institutions, data centers, journal platforms, data users, and ethical review committees. If there is a need to further subdivide scientific research activities, there will also be funding committees and project leaders. If the research is funded by social institutions such as businesses, the range of stakeholders involved will be wider. In general, scientific data are treated as intellectual property, and their ownership is granted to recipients (Gordon and Betty Moore Foundation, 2020). However, there are also national regulations that state ownership of scientific data from publicly funded research institutions belongs to the state, and their derivative work or products belong to the discoverer or inventor (Wen, 2017, 91-101), although it has been explicitly requested that data users show respect for producers' copyright by citing or collaborating, without infringing the interests of data creators. However, specific operational monitoring methods still require further consultation and discussion among various stakeholders in this regard.

5 Conclusion

Against the background of globalization and the rapid development of technology, the two major ethical conflicts reflect the challenges of emerging technologies to ethical governance: one is the tension between the pursuit of the personal interests of data owners and the public interest of scientific research progress brought about by data sharing and the other is the tension between the need for personal privacy protection and the goal of efficient data sharing. The root cause of these conflicts lies in the conflict of interest, which stems from the differences in values and interests of different stakeholders. The current ethical governance framework appears to be inadequate in monitoring these conflicts. On the one hand, governance cannot meet the rapid development of technical needs; on the other hand, governance involves a variety of stakeholders, which makes governance more difficult.

At this time, we propose to creatively put forward the theory of ethical hierarchy by introducing the theory of legal hierarchy and taking the principle of benefit to humanity as the bottom line ethics, classifying ethical principles according to their importance and applicability, which aims to guide all stakeholders to follow ethical principles together so that they can make the right ethical choices. In terms of governance structure, stakeholders should build a consultation and communication network, and governance measures, the ethical responsibilities of all stakeholders involved in data sharing, should be clear. This not only protects their own interests but also ensures smooth progress in the sharing of global marine science data.

In terms of governance structure, it is recommended to establish a joint consultation mechanism composed of scientific researchers, research funders, platform builders, data users, and representatives of the public through the relationship network of (research funding) institutions–data production–data platforms–data sharing–data usage–

data supervision. A robust consultation and communication network, involving a variety of stakeholders, would be established to facilitate ethical data-sharing practices. At the heart of this network would be the Ethics Review Committee, authorized by the Marine Information Centre (MIC), which would provide a vital ethical oversight role. This Committee would ensure that all data sharing activities adhere to rigorous ethical standards, promoting transparency, accountability, and respect for the rights and interests of all parties involved in the marine science community. It is recommended to establish network protocols between various active nodes and give autonomy to all parties so that all parties involved in data sharing can establish collaborative partnerships. In terms of governance measures, it is recommended to clarify the ethical responsibilities of stakeholders involved in data sharing, which can facilitate accountability. However, some operational monitoring methods still require further consultation and discussion among stakeholders. All of the above are conducive to ensuring the effectiveness of ethical norms and achieving ethical governance for global marine science data sharing.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Author contributions

MZ: Conceptualization, Data curation, Methodology, Project administration, Validation, Visualization, Writing – original draft, Writing – review & editing. WZ: Conceptualization, Formal analysis, Funding acquisition, Investigation, Resources, Software, Writing – review & editing. CX: Conceptualization, Formal analysis, Methodology, Project administration, Supervision, Writing – review & editing.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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