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Reversing the Blue Decline: Strategies and Practices of the Ocean Science Decade for Global Ocean Health Recovery

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Abstract As the health of the global oceans continues to decline, biodiversity is severely threatened, and human well-being is challenged. The United Nations Decade of Ocean Science for Sustainable Development (referred to as "the Ocean Decade") aims to reverse this trend through scientific research and technological innovation, providing a solid scientific foundation and practical pathways for the sustainable development of the oceans. This study focuses on the core goals and strategic priorities of the Ocean Decade, exploring in detail how scientific research and technological innovation can help understand and address the causes of ocean health decline, and how these efforts can promote the recovery and protection of marine ecosystems. By analyzing specific case studies, this research demonstrates successful projects implemented globally, such as the establishment of the Global Ocean Observing System and protection projects for key marine ecosystems, and how these projects offer viable solutions for the restoration of ocean health. This study aims to emphasize the central role of scientific research and technological innovation in addressing global ocean challenges and promoting sustainable development of the oceans. It is hoped that the discussions in this study will provide references and insights for future ocean science research and policy-making.

Keywords United nations decade of ocean science; Ocean health; Scientific research; Technological innovation; Sustainable development

Over the past few decades, the continued deterioration of the health of the global ocean has become a focus of international concern. The ocean, as the largest life support system on earth, is not only a treasure house of biological diversity, but also an important foundation for human social and economic activities. However, due to the impact of a series of human activities such as climate change, pollution, overfishing, etc., the global ocean is facing unprecedented pressure, and its health has declined sharply (Ryabinin et al., 2019). This decline not only threatens the survival of marine life and the richness of biodiversity, but also poses a direct threat to human well-being. For example, Tian et al. (2020) study conducted an ecological risk assessment of heavy metal pollution in the coastal areas of the Bohai Sea and Yellow Sea, pointing out the potential risks of these pollutants to the marine ecosystem, which will ultimately affect the sustainable use of fishery resources . The study by Liu et al. (2013) summarized the research progress of marine biodiversity in various sea areas and emphasized the environmental degradation (pollution, Coastal construction, etc.) threatens marine biodiversity, and the destruction of marine ecosystems directly affects the sustainability of fishery resources. Frequent marine pollution incidents have had a serious impact on the health and livelihood of coastal communities.

Against this background, the United Nations has launched a ten-year ocean science plan, the “United Nations Decade of Ocean Science” (2021-2030), which aims to provide support for the sustainable development of the ocean by strengthening scientific research and technological innovation. The plan emphasizes the core role of scientific research in solving ocean problems and aims to assemble global scientific forces to gain an in-depth understanding of the operating mechanism of marine ecosystems, diagnose the current status of ocean health, and propose practical and effective protection measures through interdisciplinary collaborative research. and recovery measures (Valdés, 2017). The goal of the Ocean Decade is not only for scientific research itself, but more importantly, to transform scientific research into practical policies and management actions, to provide scientific basis and technical support for global ocean governance, and to achieve long-term sustainable development of ocean health.

To this end, this study aims to explore how the Ocean Decade can reverse the declining trend of global ocean health through scientific research and technological innovation. Globally, marine scientific research and technological innovation are becoming the key to solving marine problems and promoting sustainable development of the ocean. Through an in-depth analysis of the core goals, strategic priorities, and specific cases during the implementation of the "Ocean Decade" plan, this study aims to reveal the actual role and potential of scientific research and technological innovation in ocean protection and restoration, and how these efforts contribute to It provides new ideas and solutions for the healthy restoration and long-term protection of marine ecosystems.

In addition, this study will also explore the challenges encountered in the implementation of the "Ocean Decade" plan, including issues in funding, coordination and cooperation, knowledge dissemination, etc., and how to overcome these through international cooperation, policy support, and public participation. challenge. Through a comprehensive analysis of the "Ocean Decade" plan, this study hopes to provide valuable reference and inspiration for future marine scientific research and policy formulation, emphasizing the role of scientific research and technological innovation in responding to global ocean challenges and promoting sustainable development of the ocean. Its core role not only provides the scientific community with research direction and motivation, but also provides the whole society with scientific basis and practical path to protect and restore ocean health.

1 Background and Causes of Ocean Health Decline

The decline of global ocean health is a complex issue that has attracted international attention. It is not only related to the stability of marine ecosystems and the protection of biodiversity, but also directly affects the economic development and public health of human society. When we deeply explored the background and causes of the decline in ocean health, we found that climate change, pollution, overfishing and other factors jointly act on the marine ecosystem, leading to a series of negative consequences.

1.1 The full impact of climate change

The impact of climate change on marine ecosystems is multifaceted. Poloczanska et al. (2016) reviewed recent responses of marine organisms to climate change in his study, ranging from tropical waters to polar oceans. The study covers changes in calcification rates, demography, abundance, distribution and species phenomena of marine organisms. Results showed general trends in species responses consistent with expectations from climate change, including shifts to poleward and deeper distributions, earlier spring phenology, decreased calcification, and increased abundance of warm-water species (Figure 1). At the same time, the rise in seawater temperatures has accelerated the melting of polar ice caps and raised sea levels, threatening the ecology and human living environment in coastal areas (Hoegh-Guldberg et al., 2019). In addition, climate change has increased the frequency and intensity of extreme ocean weather events, such as severe storms and hurricanes, which have had direct and indirect negative impacts on marine ecosystems and human activities.

1.2 The far-reaching harm of pollution to the ocean

Marine pollution is another important factor causing long-term harm to marine ecosystems. Plastic pollution has become a typical representative of marine pollution. Millions of tons of plastic waste enter the ocean every year, affecting the survival of marine life and affecting humans through the food chain. Häder et al. (2020) explored the impact of various pollutants generated by human activities, such as sewage, nutrients and terrestrial substances, crude oil, heavy metals and plastics, on the functions of marine and estuarine ecosystems (Figure 2). Pollutants affect ecosystem services and values by directly and indirectly interfering with ecosystem structure and function. Plastic pollution has had negative effects on growth, development, behavior, reproduction, and mortality, and more research is needed to reveal the effects caused by pollutants in detail (Thushari and Senevirathna, 2020). The above-mentioned studies show that marine pollution is a global problem that not only affects the health of marine ecosystems, but also has a significant impact on human health and the economy.

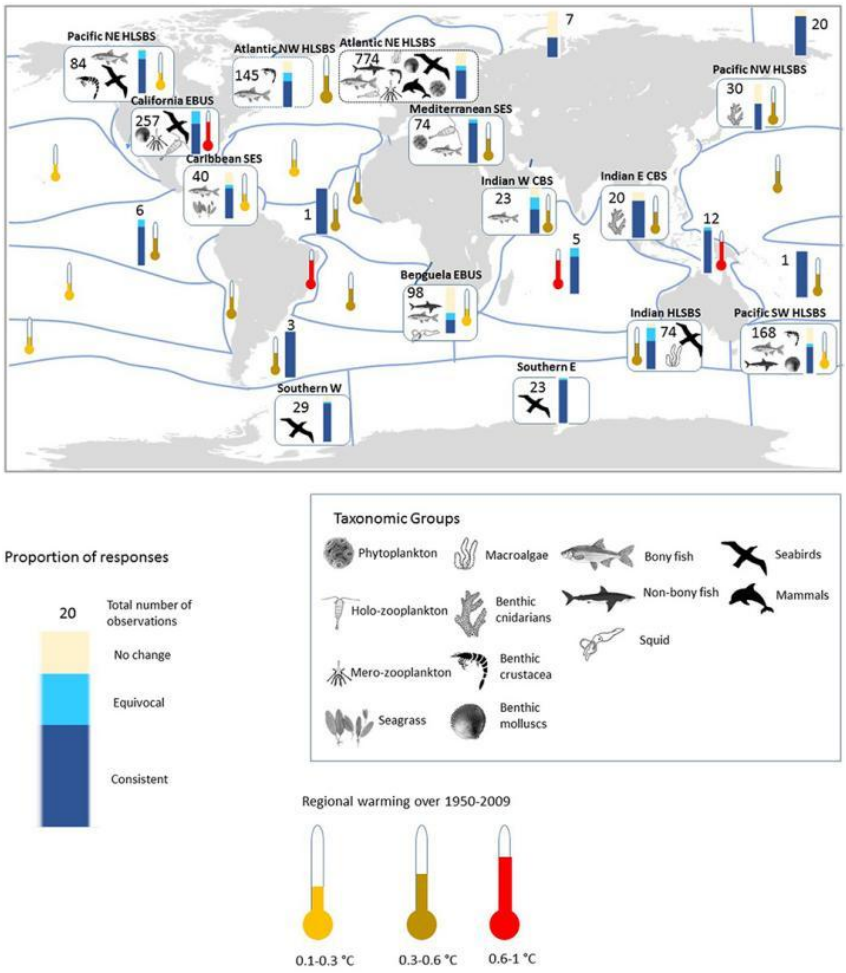

Figure 1 Global distribution of marine ecological impacts in various marine regions (Poloczanska et al., 2016)

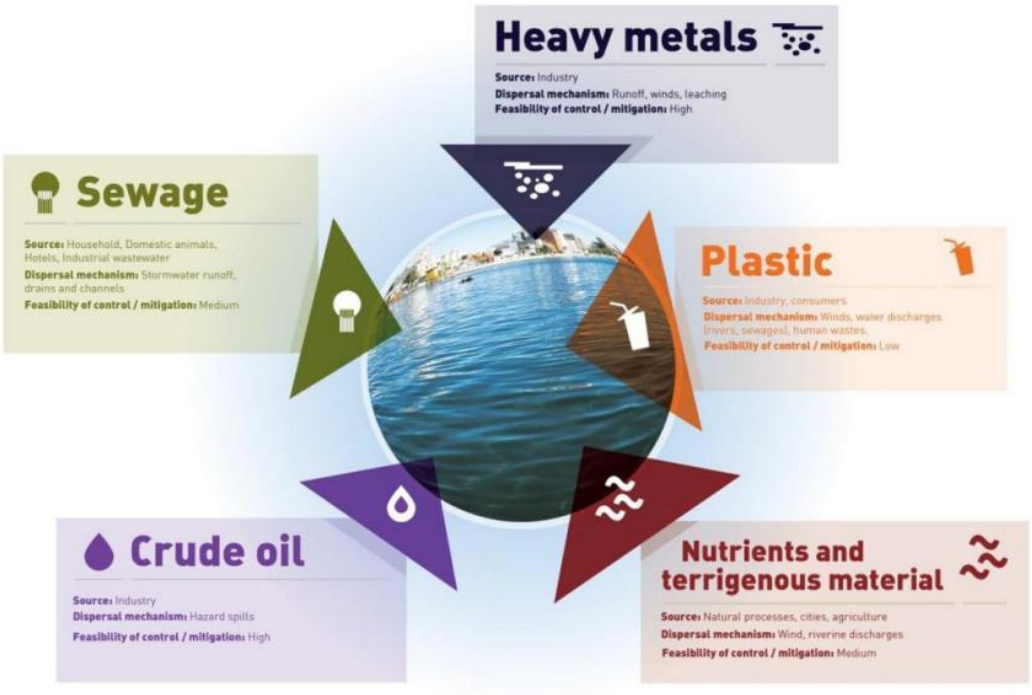

Figure 2 Pollutants produced by human activities

1.3 The ongoing problem of overfishing

As the global population grows and seafood consumption rises, overfishing has become one of the main threats to marine biodiversity. Research by Dulvy et al. (2021) shows that globally, about one-third of shark and ray species are facing extinction due to overfishing. This increase in fishing rates significantly increases global species extinction risks and requires immediate action to avoid further extinctions and protect food security and ecosystem functions. Global fishing production has reached its limit, and many species are overfished. There is an urgent need to change fishing patterns to reduce the pressure on overfished species (Zhou et al., 2015). The above-mentioned studies show that overfishing not only leads to a sharp decline in the number of specific fish species, but also destroys the structure and function of marine ecosystems, affecting the reproduction and survival of marine life. In addition, some destructive fishing techniques, such as bottom trawling, have caused serious damage to the seabed ecology, destroyed the habitats of marine life, and reduced the recovery capacity of the marine ecosystem.

1.4 Comprehensive influence of other factors

In addition to the above factors, seabed mining, offshore oil and gas development, noise pollution from shipping activities, and over-development of coastal areas also put pressure on marine ecosystems. These activities not only destroy the natural habitats of marine life, but also interfere with their normal living habits and migration routes, exacerbating the loss of biodiversity.

In the face of these challenges, global cooperation and action have become particularly important. Strengthening scientific research, promoting technological innovation, and formulating effective policies and management measures are the keys to reversing the decline of ocean health and achieving sustainable development of the ocean. Through international cooperation to strengthen the establishment and management of marine protected areas, limit pollutant emissions, implement sustainable fisheries management measures, and raise public awareness of the importance of marine protection, we can work together to protect this planet's precious blue assets.

2 Framework and Goals of The United Nations Decade of Ocean Science

Faced with the severe challenge of the continued decline in global ocean health, the Intergovernmental Oceanographic Commission (IOC) under UNESCO launched the "United Nations Decade of Ocean Science" (2021~2030), aiming to promote scientific research and technological innovation. Sustainable development of the ocean and contribute to the realization of the 2030 Sustainable Development Goals on water for life (SDG 14). This global initiative emphasizes the key role of scientific research and technological progress in protecting the marine environment and ensuring the sustainable use of marine resources.

2.1 Background of the launch of the Ocean Decade

The “Ocean Decade” is based on a deep understanding of the current deterioration trend of the marine environment and a high emphasis on the role of marine science in addressing global challenges. As mentioned in the study of Ryabinin et al. (2019), “The ocean we need for the future we want” is the slogan proposed by the UNESCO Oceanographic Commission (IOC) to the United Nations to consider a decade of ocean science. This initiative provides the oceanographic community with a unique opportunity to transform the way we work and make oceanography more relevant for the purpose of effectively supporting sustainable development. The Ocean Decade represents a true ecosystem modeling challenge that aims to protect people from ocean hazards and provide food and resources by identifying and removing pollution sources, mapping and protecting ocean ecosystems, understanding current and future ocean conditions, and protecting people from ocean hazards. and providing citizens with equitable access to data, information, and technology to achieve clean, healthy, and resilient oceans (Heymans et al., 2020). The global ocean is facing a series of problems such as climate change, pollution, and biodiversity loss. These problems not only threaten the health and stability of marine ecosystems, but also affect the sustainable development of the global economy and human well-being. Therefore , the United Nations proposed this ten-year action plan, hoping to promote marine scientific research and technological innovation by strengthening international cooperation, provide support for solving marine problems, protect marine ecosystems, and achieve sustainable use of marine resources (Caruso et al., 2022).

2.2 Core goals and strategic priorities

the "Ocean Decade" revolve around strengthening marine scientific research, promoting ocean health and sustainable management of marine resources. These goals include: improving understanding of marine ecosystems, enhancing ocean observation and data sharing capabilities, advancing the application of ocean science in policy development, and enhancing ocean science education and public awareness. To achieve these goals, the Ocean Decade sets several strategic priorities, including developing integrated ocean observing systems, supporting interdisciplinary ocean science research, promoting scientific and technological innovation, and strengthening international cooperation and partnerships (UNESCO, 2019).

2.3 The key role of scientific research and technological innovation

Scientific research and technological innovation play a vital role in achieving the goals of the Ocean Decade. Scientific research can provide an in-depth understanding of the complexity of ocean systems, help us understand the causes and mechanisms of ocean changes, predict future change trends, and provide scientific basis for formulating effective management and protection measures. Technological innovation, such as advanced ocean observation equipment, data analysis tools, and model prediction systems, is the key to improving ocean research capabilities and achieving sustainable resource management (Guan et al., 2023). In addition , scientific and technological innovation also promotes the application of marine science, enabling research results to be transformed into practical solutions to support policy formulation and implementation.

The United Nations Decade of Ocean Science is a global initiative that aims to address the challenges of declining ocean health and promote sustainable development of the ocean through scientific research and technological innovation. The successful implementation of the plan requires broad participation and cooperation from the international community, including governments, scientific research institutions, non-governmental organizations, the private sector and the public. By working together, we can improve our understanding of the ocean, protect marine ecosystems, achieve sustainable use of marine resources, and leave a healthier, more productive and resilient ocean for future generations (Lubchenco et al., 2015).

3 Contributions to Scientific Research and Technological Innovation

As global ocean health continues to face severe challenges, scientific research and technological innovation have become key forces in reversing this trend. Through in-depth scientific exploration and the application of cutting-edge technology, we can not only more accurately understand the operating mechanism of marine ecosystems, but also find more effective ways to protect and manage our marine resources.

3.1 Progress in scientific research

The study of marine biodiversity has always been an important part of the field of marine science. In recent years, scientists have discovered a large number of previously unknown marine life species through various research programs and exploration activities. These new discoveries not only enrich our understanding of marine biodiversity, but also provide important scientific information for the protection of marine ecosystems. in accordance with. At the same time, genomic research on marine organisms has revealed the mechanisms by which marine organisms adapt to extreme environments, providing a new perspective for humans to utilize marine biological resources and protect marine biodiversity (Laffoley et al., 2019).

Wunsch et al. (2020) pointed out that in the past fifty years, in the conceptual revolution of physical oceanography, the ocean has transformed from being regarded as a large-scale, extremely slowly changing fluid to a basically turbulent system , demonstrating the physical ocean The potential of combining marine acoustics and ocean acoustics technologies paves the way for the development of new and globally capable observing systems . Steen et al. (2020) compiled examples of analytical methods that have enabled transformational scientific progress in marine organic biogeochemistry since 2004 and predicted challenges and opportunities in the near future. In recent years, ocean engineering has made great progress, especially research related to geological environment and disasters (Guo et al., 2023). These advances have established bridges between different branches of marine science, promoted the development of interdisciplinary research, and provided scientific basis and technical support for the sustainable management of marine ecosystems.

3.2 Technological innovation and application

Technological innovation has greatly promoted the development of marine science, especially in ocean monitoring. With the advancement of remote sensing technology, automated buoy systems, and deep-sea detection technology, scientists are now able to monitor the physical, chemical, and biological parameters of the ocean in real time. The application of these technologies has greatly improved our observation capabilities and prediction accuracy of ocean changes. For example, Millar et al. (2021) discuss how innovations in mapping can help support the Ocean Decade. Leveraging innovations such as satellite positioning, satellite imaging technology, remote operations, autonomous vehicles and robotics, as well as analytics and cloud automation, we provide safer, more efficient, affordable and sustainable ocean survey and mapping solutions.

In terms of ocean management, technological innovation also plays a crucial role. The application of information technology and data analysis tools enables marine managers to process large amounts of marine data more effectively and achieve sustainable management of marine resources. For example, marine robotics plays a key role in performing increasingly complex and challenging maritime tasks (Zerik et al., 2018). The Research Team on Industrial Remotely Operated Vehicles (ROVs) has brought together an international group of ROV experts from academia and industry to identify key issues in ocean science that can be supported by increasing access to industrial ROVs and working with companies that use them (Macreadie et al., 2018).

Scientific research and technological innovation play an irreplaceable role in protecting ocean health and promoting sustainable development of the ocean. By continuing to deepen our scientific understanding of marine ecosystems and advancing technological innovation, we are expected to find effective ways to address ocean health challenges. In the future, strengthening interdisciplinary and cross-field cooperation and continuing to invest in marine scientific research and technology development will be crucial to achieving the goals of sustainable ocean development.

4 Practical Paths and Case Studies

Within the framework of the global initiative “United Nations Decade of Ocean Science”, countries and relevant organizations responded actively and launched a series of projects and practices aimed at protecting the marine environment, restoring ocean health, and promoting sustainable development of the ocean. These projects cover many aspects such as the establishment of a global ocean observation system, the protection of key marine ecosystems, and the application of scientific research and technological innovation in ocean management. The following are several typical cases that demonstrate how to promote the restoration and sustainable development of ocean health in practice through scientific research and technological innovation.

4.1 Specific project paths under the framework of the “Ocean Decade”

The Global Ocean Observing System (GOOS) is an international cooperation project aimed at integrating Earth observation systems to provide real-time and accurate data on changes in the global ocean environment. GOOS collects data on ocean temperature, salinity, sea level, sea ice cover, and biochemical parameters by deploying a series of ocean observation tools, such as buoys, satellites, and ship observation systems. These data are important for understanding the impact of global climate change, predicting extreme weather events, managing marine resources, and formulating marine protection policies (Moltmann et al., 2019). Through GOOS, scientists can better monitor ocean health and provide scientific basis for global ocean management.

In addition, Trakadas et al. (2019) proposed to strengthen the integration of archeology in marine sciences by creating a Marine Decade Heritage Network under the framework of the United Nations Decade of Ocean Science (2021~2030). Heymans et al. (2020) discuss how the Ocean Decade represents a true ecosystem modeling challenge, aiming to achieve a clean, healthy, resilient ocean through a series of specific goals, including identifying and removing pollution sources, mapping and protecting Marine ecosystems, understanding current and future ocean conditions, and more. Caruso et al. (2022) explored how the Ocean Decade can create a new foundation for ocean science and sustainable development, strengthen the sustainable management of oceans and coasts by strengthening the integration of science and policy interfaces, and bring benefits to future generations.

The article discusses the role of new technologies in ocean exploration and monitoring, as well as the key role of science communication in spreading ocean decadal information.

The above-mentioned research shows how the scientific community is achieving sustainable development goals through different projects and networks under the framework of the Ocean Decade. These projects address not only ecosystem conservation and management, but also the integration of cultural heritage, ecosystem modeling challenges, and the integration of science and policy. Together, these efforts move us toward a cleaner, healthier and more resilient ocean.

4.2 Case study: Technological innovation promotes ocean healthy restoration

Under the framework of the United Nations Decade of Ocean Science, projects and practices around the world demonstrate the important role of scientific research and technological innovation in promoting the recovery and sustainable development of ocean health. These cases not only highlight innovative approaches to solving ocean problems, but also emphasize the need for international cooperation. Below are two specific cases that illustrate in detail how these efforts are implemented in practice.

GOOS is a classic example of how international cooperation and technological innovation can be used to monitor ocean health and respond to global change. The system provides real-time ocean data to scientists, policymakers and the public by integrating ocean observation resources from around the world, including satellite remote sensing, buoys, ships and seafloor observation stations. The deep sea plays a key role in climate regulation, biodiversity storage and the provision of energy, mineral and biological resources. Long-term deep-ocean exploration and observation led to the initial conception of the Deep-Ocean Observing Strategy (DOOS), which aims to integrate deep-ocean observation activities on a global scale (Figure 3). Emerging technologies relevant to deep-sea sustainability and the blue economy include novel genomics methods, imaging technologies and ultra-deep hydrographic measurements. Progress can be facilitated through open science and discoverable, accessible, interoperable, reusable (FAIR) data principles, and agreement on data standards, practices, vocabularies, and registries (Moltmann et al., 2019). Emerging observation technologies for deep-sea observation, such as remotely operated unmanned vehicles (ROVs), autonomous underwater vehicles (AUVs), and genomic analysis, have brought revolutionary progress to deep-sea research.

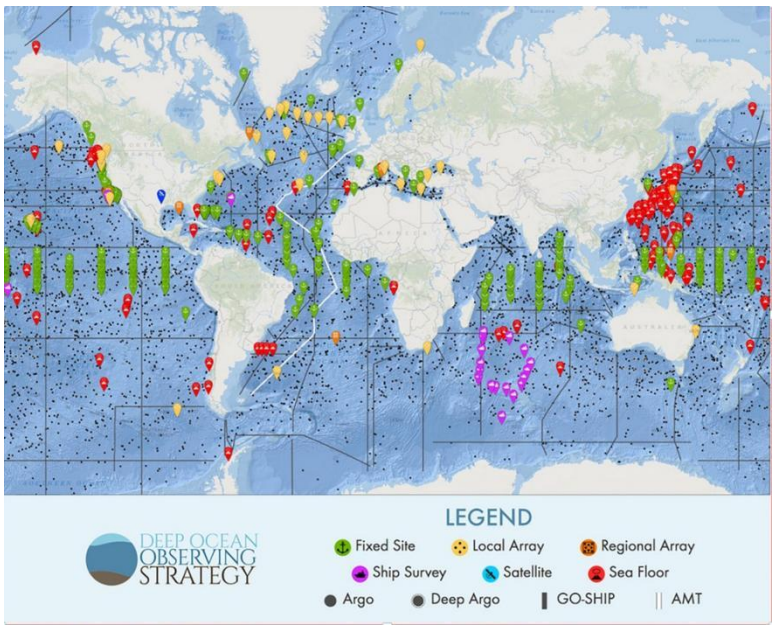

Figure 3 Inventory of sustained deep-ocean bserving (Moltmann et al., 2019)

The challenge of ocean acidification facing the U.S. West Coast shellfish industry is another striking example of how scientific research can help farmers adapt to environmental changes. In 2007, the U.S. West Coast shellfish

industry began to feel the effects of mass oyster larval die-offs, threatening vital economic activity in the region. Collaboration with Whiskey Creek Shellfish Hatchery showed that the aragonite saturation state of incoming seawater is highly correlated with larval survival (Barton et al., 2015). This work led the Pacific Coast Shellfish Growers Association (PCSGA) to begin monitoring the chemical status of shellfish hatcheries and coastal waters, establishing a collaborative monitoring network with university researchers and the U.S. Integrated Ocean Observing System in 2011 (Figure 4). Researchers use advanced monitoring technology to track changes in water quality in real time and develop mitigation strategies, such as adjusting the alkalinity of culture waters, to protect baby shellfish from acidified waters. This case not only mitigates the impact of ocean acidification on the aquaculture industry, but also provides valuable experience and technical support to other affected areas around the world.

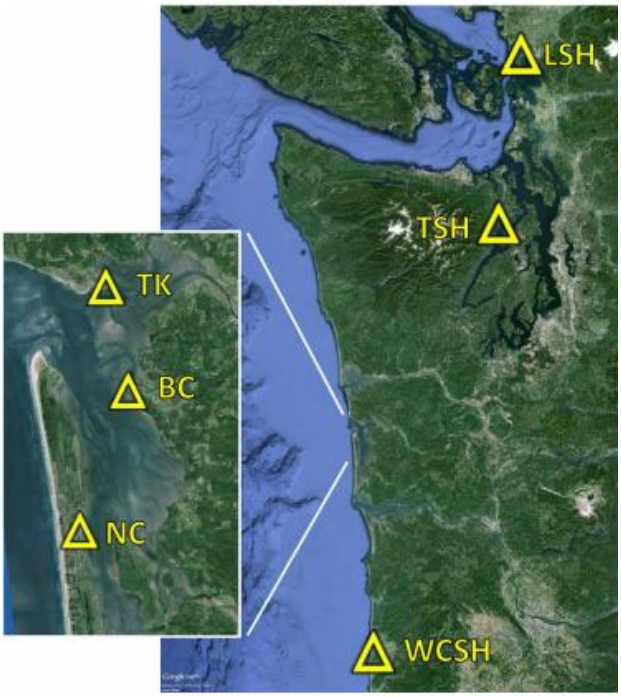

Figure 4 Monitoring sites established in 2011 by the Pacific Coast Shellfish Growers Association (PCSGA). (Barton et al., 2015)
Note: LSH: Lummi Shellfish Hatchery, Bellingham WA; TSH: Taylor Shellfish Hatchery, Dabob Bay, WA; WCSH: Whiskey Creek Shellfish Hatchery, Netarts Bay, OR. Inset of Willapa Bay; TK: Tokeland; BC: Bay Center (Ekone Oyster Co.); NC: Nahcotta (Jolly Roger Oyster Co.)

Through these cases, we see the practical application and huge potential of scientific research and technological innovation in solving marine environmental problems. The establishment and development of the global ocean observing system has improved our understanding of ocean changes and enabled us to more effectively monitor and respond to the challenges posed by global changes. At the same time, research on specific issues (such as the impact of ocean acidification on shellfish farming) demonstrates how scientific research can be directly applied to solve practical problems, helping related industries adapt to environmental changes and ensure sustainable development. These efforts not only provide effective tools for protecting marine ecosystems, but also lay a solid foundation for achieving the goal of sustainable ocean utilization. Driven by the United Nations Decade of Ocean Science , we look forward to the successful implementation of more such projects and practices in the future to jointly promote the restoration and development of global ocean health.

5 Conclusion and Future Prospects

With the implementation of the United Nations Decade of Ocean Science plan, global attention and response measures to the decline of ocean health have reached unprecedented heights. However, in the process of

promoting this ambitious plan, we face many challenges. At the same time, we also see the huge potential and contribution of scientific research and technological innovation in reversing the declining trend of ocean health.

5.1 Challenges during implementation

In the implementation process of the "Ocean Decade" plan, funding, coordination and cooperation and knowledge dissemination are the three main challenges. Insufficient funding has been a major obstacle limiting the implementation of marine scientific research and conservation projects. Effective ocean management and protection require a large amount of economic investment, including the purchase of scientific research equipment, the establishment and maintenance of monitoring systems, and the training of scientific researchers. Coordination and cooperation are also a major challenge. The ocean is a global shared resource that transcends national boundaries and requires joint efforts and cooperation from the international community to effectively manage and protect it. There are differences between different countries and regions in terms of economic development levels, scientific and technological capabilities, and maritime policies and laws. These differences increase the complexity of international cooperation. Knowledge dissemination and public awareness raising are equally important but full of challenges. How to effectively disseminate scientific research results and conservation knowledge to the public and improve the whole society's understanding and participation in marine protection is the key to achieving sustainable development of the ocean.

5.2 Contribution to scientific research and technological innovation

Despite the many challenges, the Ocean Decade has made a significant contribution to reversing the decline in ocean health through scientific research and technological innovation. Scientific research has deepened our understanding of the operating mechanisms of marine ecosystems and provided scientific basis for protecting and managing marine resources. Technological innovations, such as advanced ocean observation technology and data analysis tools, have greatly improved the efficiency and accuracy of ocean monitoring and provided strong support for ocean management. In addition, scientific and technological progress has also promoted the development of new solutions, such as biodegradable materials and clean energy technologies, opening up new ways to reduce marine pollution and combat climate change.

5.3 Conclusion and recommendations

"United Nations Decade of Ocean Science" plan provides a valuable platform for the restoration and sustainable development of global ocean health. Through scientific research and technological innovation, we can not only better understand and protect the ocean, but also provide effective strategies and solutions to deal with global environmental changes. Facing the future, continued scientific exploration and technological progress will continue to play a key role. Working with global partners, we are expected to achieve the ambitious goal of sustainable ocean development.

Looking forward, in order to overcome implementation challenges and achieve the goals of the Decade of Marine Science, the following suggestions are worth considering:

Increase financial investment: The international community should increase financial support for marine scientific research and technological innovation, especially to support capacity building in this field in developing countries.

Strengthen international cooperation: By strengthening international cooperation, share marine scientific research results and technological innovations, coordinate global ocean governance, and jointly respond to marine environmental issues.

Raise public awareness: Strengthen publicity and education on the importance of marine protection, increase public awareness, and promote society-wide support for marine health and sustainable development.

Promote the transformation of scientific research results: Establish an effective mechanism to accelerate the transformation of marine scientific research results into actual policies and management measures, and ensure that research investment can be transformed into actual benefits.

Continuous technological innovation: Encourage technological innovation, develop new tools and methods to address challenges in ocean monitoring and management, and improve the ability to sustainably utilize marine resources.

The "United Nations Decade of Ocean Science" plan provides a collaborative framework for the restoration and sustainable development of global ocean health, in which scientific research and technological innovation play an irreplaceable role. Facing the challenges in the implementation process, the international community needs to work together to jointly promote the continuous improvement of global ocean health and the sustainable development of marine resources through measures such as increasing investment, strengthening cooperation, raising public awareness, and promoting the transformation of scientific research results. In the future, with the advancement of science and technology and the deepening of international cooperation, we have reason to believe that the global ocean will usher in a healthier and more sustainable future.

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