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International Legal Framework for Tokenized Fisheries Management

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Abstract

This article describes the adoption of *tokenized fisheries management* as a novel strategy for improving fisheries governance, combating fisheries crime, and promoting sustainable fishing practices. This framework attempts to develop a transparent, efficient, and responsible system for managing fishing quotas, catch documents, and certificates by means of blockchain-based technology and tokenization. The framework addresses critical legal concerns, regulatory processes, and stakeholder participation that are required for successful implementation. The study looks at prior attempts to use technology for fisheries management as well as blockchain-based solutions used across various sectors. It examines existing legal frameworks and identifies legal gaps related to tokenization, as well as the limitations they impose on fisheries governance. Given that many national fisheries rules may not expressly accept digital tokens as genuine representations of fishing quotas or certificates, these may not be officially recognized. Consequently, it is critical to identify and analyse national and international fishery rules that may or may not expressly accept digital tokens in fisheries management. This paper also investigates the potential advantages and challenges of implementing such a system, as well as its role in protecting marine ecosystems. This study thoroughly examines the rules that govern this domain, explains the areas of legal application that remain challenging, and forecasts future developments.

Keywords: tokenization, fisheries management, precautionary principle, UNCLOS

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Marco jurídico internacional para la gestión pesquera tokenizada

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Resumen

Este artículo describe la adopción de la *gestión pesquera tokenizada* como una estrategia novedosa para mejorar la gobernanza pesquera, combatir la delincuencia en este dominio y promover prácticas de pesca sostenibles. Esta propuesta contempla un sistema transparente, eficiente y responsable para la gestión de cuotas de pesca, documentos de captura y certificados mediante el uso de tecnología basada en *blockchain* y *tokenización*. Se abordan las aprensiones legales más significativas en relación con los procesos normativos y la participación de las partes interesadas que se requieren para una implementación exitosa de esa propuesta. Para ello, se analizan intentos anteriores de utilizar tecnologías en la gestión pesquera, así como las soluciones basadas en *blockchain* utilizadas en la gestión de otros sectores. También se investiga los marcos legales existentes y las lagunas legales relacionadas con la *tokenización*, así como los límites que representan para la gobernanza pesquera. Dado que muchas normas nacionales sobre la pesca pueden no aceptar expresamente los tokens digitales como representaciones genuinas de cuotas o certificados de pesca, es posible que estos no se reconozcan oficialmente. Por consiguiente, es fundamental identificar y analizar las reglas pesqueras nacionales e internacionales que pueden o no aceptar expresamente tokens digitales en la gestión pesquera. Además, el artículo investiga las posibles ventajas y problemas de adoptar un sistema de este tipo, así como su papel en la protección de los ecosistemas marinos. Este estudio examina a fondo el vínculo entre las normas en este dominio, explica las áreas de aplicación de la ley que aún representan desafíos y pronostica desarrollos futuros.

Palabras clave: tokenización, gestión pesquera, principio de precaución, Convemar

Introduction

The global fishing industry faces numerous challenges, including overfishing, habitat degradation, fluctuating fuel prices, and the impact of climate change. To ensure sustainability, monitoring and managing fish harvesting and supply chains are crucial. Traceability implementation can reduce risks and costs, minimize product recall expenses, enhance production efficiency, and increase sales of premium products. Small-scale fisheries are subject to export regulations set by foreign markets, which can potentially increase the cost of their produce.[1] Fish laundering is a transnational crime that involves multiple jurisdictions, allowing stolen fish and counterfeit legal documents to enter the market at competitive prices. This practice disrupts supply chains in the fisheries product trade, compromising product authenticity and introducing unfair competition. The complexity of involving multiple jurisdictions adds complexity to law enforcement efforts and underscores the need for international cooperation to effectively combat such criminal activities.[2]

According to Kevern L. Cochrane from the Fisheries Department of the Food and Agriculture Organization (FAO), presently there are no binding international agreements regarding a definition of fisheries management, which technically can be characterized as a series of actions including "…the integrated process of information gathering, analysis, planning, consultation, decision-making, allocation of resources and formulation and implementation, with enforcement as necessary, of regulations or rules which govern fisheries activities in order to ensure the continued productivity of the resources and the accomplishment of other fisheries objectives."[3] Fisheries management, however, is considered in several international agreements, including the UN Convention on the Law of the Sea (UNCLOS), the UN Fish Stocks Agreement, the FAO's Code of Conduct for Responsible Fisheries, and the International Plan of Action to Prevent, Deter, and Eliminate Illegal, Unreported, and Unregulated Fishing (IPOA-IUU). The FAO launched a comprehensive assistance program for developing and managing fisheries in Exclusive Economic Zones (EEZs) in 1979, with one of its aims being to support rational management

1 Ahm Shamsuzzoha, Jarno Marttila, and Petri Helo, "Blockchain-Enabled Traceability System for the Sustainable Seafood Industry," *Technology Analysis and Strategic Management* (2023): 1–15, https://doi.org/10.1080/09537325.2023.2233632.

2 Ika Riswanti Putranti, "Implementation of Trade Regulations on Fisheries To Prevent Fish Laundry in Indonesia," *Jurnal Hukum Ius Quia Iustum* 25, no. 1 (2018): 1–23, https://doi.org/10.20885/iustum.vol25.iss1.art1.

3 Food and Agriculture Organization of the United Nations, *Chapter 1: Fisheries Management*, accessed December 1, 2023, https://www.fao.org/3/y3427e/y3427e03.htm#bm03.2.

and full use of EEZ fisheries resources by developing nations. As part of the UN's drive to establish a New International Economic Order, the program also intended to assist developing nations in reaping greater advantages from marine resources.[4]

Under the UNCLOS, fisheries management is linked to concerns of sustainable fisheries and the jurisdiction of the coastal State in each marine zone. In the Territorial Sea, for example, the coastal State enjoys full sovereignty, allowing unlimited competence to control resource development, exploitation, and conservation. The coastal State has sovereign rights in the EEZ, suggesting management power over resource exploration and exploitation within it, as established in UNCLOS Article 56(1)(a).[5] Peaceful purposes and forbidding any State from claiming any part of the high seas are addressed in Article 87 on Freedom of the High Seas, in conformity with UNCLOS Articles 88 and 89. UNCLOS Articles 61 and 62 govern the conservation and utilization of living resources in the EEZ. It is the responsibility of the coastal State to ensure that living resources in its EEZ are not overexploited. This includes establishing allowed catch limits, adopting conservation and management measures, and collaborating with other States and international organizations to sustain or restore the populations of caught species.[6] The coastal State can evaluate its capacity to use living resources in its EEZ to encourage optimal exploitation. If the State is unable to collect the whole allowed catch, it may enable other States to receive the surplus. Access is granted through agreements that take into account a variety of criteria, including the economic interests of the coastal State, the requirements of developing countries, and the avoidance of economic damage to governments whose citizens typically fish in that area. Nationals from other States fishing in the EEZ must follow the conservation measures of the coastal State, which may include permits, quotas, seasons, gear limitations, size limits, data reporting, research, observer placement, landing regulations, training, and enforcement processes.[7]

The development of new technologies, especially those based on blockchain, such as tokens, offers an alternative for coastal States to manage sustainable fisheries effectively. Tokenization simplifies administrative procedures and eliminates unnecessary paperwork by automating the process of quota distribution, catch documentation, and fish certification.

4 R. P. Anand, "The Politics of a New Legal Order for Fisheries," *Ocean Development and International Law* 11, no. 3–4 (1982): 265–295, https://doi.org/10.1080/00908328209545698.

5 United Nations, *United Nations Convention on the Law of the Sea*, (n.d.), https://doi.org/https://www.un.org/depts/los/convention_agreements/texts/unclos/unclos_e.pdf.

6 United Nations.

7 United Nations; Shigeru Oda, "Fisheries Under the United Nations, " *American Journal of International Law* 77, no. 4 (2014): 739–55, https://doi.org/10.2307/2202532.

The use of tokens as a derivative of blockchain technology in managing capture fisheries has spurred measurable, transparent, and innovative management approaches. The use of token technology in fisheries management can help reduce excessive paperwork and enhance the quality of government public services. Blockchain technology is transforming the fishing sector by fostering supply chain transparency and sustainability. It has the potential to prevent unlawful actions, improve supply chain coordination, increase operational efficiency, promote sustainability, and identify market trends. Blockchain provides a transparent and immutable record for examination, as well as for recording transaction processes and satisfying customer requests.[8]

Tokenized fisheries management represents a significant paradigm shift that introduces transparency, accountability, and efficiency into the legal framework of fisheries resource management, leveraging blockchain technology and digital tokens. By ensuring procurement legality, controlling fisheries crimes, and streamlining administrative processes, this framework has the potential to comply with accepted legal principles and offers a comprehensive response to address complex issues affecting fisheries internationally. Further research is needed to understand the legal implications of this technology, including compliance with national and international regulations, as well as its role in preserving marine habitats while promoting sustainable fishing practices.

Blockchain: A Novel Technology in Fisheries Management

Blockchain technology is viewed as a viable trust mechanism to address supply chain transparency and security challenges. Its decentralized structure comprises time-stamped blocks connected by cryptographic hashes, which prevents any single entity from modifying data. The widespread acceptance of blockchain stems from its success in addressing trust and security issues, maintaining transparency, and preventing data manipulation.[9] Several previous research projects have examined the development of blockchain technology, including inquiries into the use of tokens in the context of supply networks related to the fishing industry. For instance, Miguel Cordova et al. explore the use of blockchain technology in fishery supply chains to improve reliability and sustainability. It uses a qualitative, exploratory approach and

8 Shamsuzzoha et al., "Blockchain-Enabled Traceability."

9 Huanhuan Feng et al., "Applying Blockchain Technology to Improve Agri-Food Traceability: A Review of Development Methods, Benefits and Challenges," *Journal of Cleaner Production* 260 (2020), https://doi.org/10.1016/j.jclepro.2020.121031.

literature review to provide theoretical insights. The study highlights the importance of real-time information and a strategic sequence for blockchain integration in fishery supply chains. It provides a model for future research on sustainable supply chain management and blockchain technology.[10] Additionally, numerous other research endeavours examine the intersection of blockchain technology and supply chains, particularly within the food industry and various other sectors.

Vincent Charles et al. discuss the integration of blockchain and AI technologies in revolutionizing data management across industries.[11] Akshay Patidar et al. studied a blockchain-based framework for the food supply chain, aiming to reduce handling losses and improve efficiency.[12] Abderahman Rejeb et al. analyse blockchain research in supply chain management and logistics, identifying key academic papers, influential scholars, and research trends.[13] Naoum Tsolakis et al. examine the design of blockchain-centric food supply chains aligned with the Sustainable Development Goals (SDGs) in the Thai fish industry.[14]

Traceability throughout the food supply chain is acknowledged as a challenging process due to the numerous data collection nodes involved, each of which provides different types of information, such as product life, transit details, and environmental data. To overcome the problems of building an efficient traceability system, it is necessary to first identify the traceability units before initiating the creation of a food traceability system. This system should enable the comprehensive management of production, manufacturing, commerce, and logistics by capturing and recording trustworthy and accurate data at each stage, thereby improving

10 Miguel Cordova and Karla Maria Nava-Aguirre, "Achieving Transparency through Blockchain: Sustainability of Fishery Supply Chain Management," *Internext* 17, no. 3 (2022): 398–412, https://doi.org/10.18568/internext.v17i3.679.

11 Vincent Charles, Ali Emrouznejad, and Tatiana Gherman, "A Critical Analysis of the Integration of Blockchain and Artificial Intelligence for Supply Chain," *Annals of Operations Research* 327, no. 1 (2023): 7–47, https://doi.org/10.1007/s10479-023-05169-w.

12 Akshay Patidar et al., "A Smart Contracts and Tokenization Enabled Permissioned Blockchain Framework for the Food Supply Chain," in *Advances in Production Management Systems. Artificial Intelligence for Sustainable and Resilient Production Systems. APMS 2021*, ed. Alexandre Dolgui et al., IFIP Advances in Information and Communication Technology, vol. 630 (Cham: Springer, 2021), 227–235, https://doi.org/10.1007/978-3-030-85874-2_24.

13 Abderahman Rejeb et al., "Blockchain Technologies in Logistics and Supply Chain Management: A Bibliometric Review," *Logistics* 5, no. 4 (2021): 1–28, https://doi.org/10.3390/logistics5040072.

14 Naoum Tsolakis et al., "Supply Network Design to Address United Nations Sustainable Development Goals: A Case Study of Blockchain Implementation in Thai Fish Industry," *Journal of Business Research* 131 (July 2021): 495–519, https://doi.org/10.1016/j.jbusres.2020.08.003.

efficient traceability.[15] In supply chains, traceability and transparency are critical principles. Traceability refers to the ability of stakeholders such as corporations, suppliers, and consumers to identify the origins of a product. Traceability is defined in the *Principles for traceability/product tracing as a tool within a food inspection and certification system* (CAC/GL 60-2006), as "the ability to follow the movement of a food through specified stage(s) of production, processing and distribution." It is "a tool that when applied in a food inspection and certification system can contribute to the protection of consumers against deceptive marketing practices and facilitation of trade on the basis of accurate product description."[16]

Transparency in the supply chain provides stakeholders with access to all important information about items in transit, enabling data-driven analytics and informed decision-making. This increased openness reduces time and cost burdens by decreasing delays, waste, and inefficiencies. Open and transparent access to transaction data promotes accountability and real-time monitoring, fostering system regulation.[17]

Martin Westerkamp et al. discuss the increasing demand for supply chain traceability due to growing consumer awareness and manufacturers' internal quality requirements. They propose a blockchain-based supply chain traceability system using smart contracts, where manufacturers specify product composition through recipes, with each ingredient represented by a non-fungible token corresponding to a batch of physical goods. The system is implemented for the Ethereum Virtual Machine and can be adapted to any blockchain configuration.[18]

Konstantinos Demestichas et al. examine the use of blockchain technology to improve traceability in the agri-food industry. The paper discusses the advantages of blockchain, including its functionality and benefits, as well as its ability to safe-

15 Ashish Kumar Tripathi, K. Akul Krishnan, and Avinash Chandra Pandey, "A Novel Blockchain and Internet of Things-Based Food Traceability System for Smart Cities," *Wireless Personal Communications* 129, no. 3 (2023): 2157–2180, https://doi.org/10.1007/s11277-023-10230-9.

16 Codex Alimentarius Commission, *Principles for Traceability/Product Tracing as a Tool within a Food Inspection and Certification System*, CAC/GL 60-2006 (2006): 1, http://scholar.google.com/scholar?hl=en&btnG=-Search&q=intitle:PRINCIPLES+FOR+TRACEABILITY+/+PRODUCT+TRACING+AS+A+TOOL+WITH-IN+A+FOOD+INSPECTION+AND+CERTIFICATION+SYSTEM#0.

17 United Nations Development Programme, *Blockchain for Agri-Food Traceability* (Singapore: UNDP Global Centre for Technology, Innovation and Sustainable Development, 2021).

18 Martin Westerkamp, Friedhelm Victor, and Axel Kupper, "Blockchain-Based Supply Chain Traceability: Token Recipes Model Manufacturing Processes," in *Proceedings - IEEE 2018 International Congress on Cybermatics: 2018 IEEE Conferences on Internet of Things, Green Computing and Communications, Cyber, Physical and Social Computing, Smart Data, Blockchain, Computer and Information Technology, IThings/Gree* (2018): 1595–1602, https://doi.org/10.1109/Cybermatics_2018.2018.00267.

guard data irreversibly and unalterably. Blockchain has the potential to increase trust and develop a more sustainable food business, but it must consider legislation, stakeholder relationships, data ownership, and scalability.[19]

Huanhuan Feng et al. examine the importance of traceability for food quality and safety, highlighting the need for comprehensive knowledge of blockchain-based food traceability systems, their benefits, challenges, and development methodologies. The paper aims to enhance researchers' and practitioners' knowledge and application of blockchain-based traceability systems, offering valuable insights for academics and practitioners seeking to promote food sustainability.[20]

Ahm Shamsuzzoha et al. examine supply chain traceability issues in the seafood supply chain in several countries, including the Philippines. Existing centralized systems face trust issues due to data quality difficulties. These drawbacks have prompted the idea of a decentralized traceability system based on a *Hyperledger Fabric* blockchain platform. The system performs well and minimizes single points of failure, making it an effective solution for improving traceability in the food and agriculture sectors.[21]

Tokenization

Tokenization is a method that uses blockchain technology to digitize real-world assets or rights, such as fishing quotas, catch documentation, and certifications, and reflect them on the blockchain as digital tokens. This approach in fisheries management allows for safer buying, trading, and transfer of these tokens, which can be used to track fishing privileges, licenses, and activities. Tokenized fisheries management can enhance fisheries governance by improving transparency and traceability in the seafood supply chain, addressing issues such as illicit, unreported, and unregulated fishing, and ensuring the legality and sustainability of seafood.

Jules Repusseau examines the challenges posed by urbanization, including fraudulent fish supply, overfishing, unscientific handling, and quality concerns. Blockchain-based systems in the seafood industry are proposed to address these issues by providing access to traceability, allowing consumers and authorities to

[19] Konstantinos Demestichas et al., "Blockchain in Agriculture Traceability Systems: A Review," *Applied Sciences (Switzerland)* 10, no. 12 (2020): 1–22, https://doi.org/10.3390/APP10124113.
[20] Feng et al., "Applying Blockchain Technology."
[21] Shamsuzzoha et al., "Blockchain-Enabled Traceability."

verify the legality, ethics, hygiene, and economic aspects of seafood. Platforms like Ethereum facilitate secure digital collaboration across the supply chain, eliminating intermediaries.[22]

T. Asha Vijay et al. discuss the challenges posed by urbanization, including false fish supplies, overfishing, improper treatment, and quality concerns. Blockchain-based solutions in the seafood industry allow customers and authorities to check the legality, ethics, sanitary, and economic elements of seafood. Again, platforms like *Ethereum* enable secure digital communication throughout the supply chain, eliminating the need for intermediaries.[23]

Numerous blockchain-based solutions have been suggested in the literature to address existing challenges related to ensuring product quality, compliance with legal obligations, and combating fraud. Despite the various approaches to supply chain traceability, they primarily focus on tracking individual, unmodifiable goods. These approaches aim to establish the authenticity and ownership of goods through multiple stages. For example, Kim and Laskowski introduce an ontology using the *Ethereum* blockchain to enhance provenance in supply chains. However, their proposed contract, implemented in *Solidity*, has limitations in defining new functions and properties due to a rigid type system. Additionally, the production of new goods from existing resources is not supported.[24] As highlighted in recent studies, one common issue in supply chain traceability is the representation of physical goods in a digital format.[25] To overcome this, tokenization technology is designed to bridge the gap between the physical and digital realms of the supply chain. By creating a digital equivalent of physical goods, tokenization can help bridge the gap, increase transparency, and foster a more efficient supply chain. This technology is particularly useful for supply chains involving perishable goods, such as fish, where real-time tracking and accurate representation are crucial for ensuring quality and compliance.

22 Jules Repusseau, "Tokenize the Food: A Permission Less NFT Information System," *Journal of Current Trends in Computer Science Research* 2, no. 2 (2023), https://doi.org/10.33140/jctcsr.02.02.12.

23 T. Asha Vijay and M. S. Raju, "Blockchain Applications in Fisheries," *E3S Web of Conferences* 399 (2023): 1–8, https://doi.org/10.1051/e3sconf/202339907008.

24 Henry M. Kim and Marek Laskowski, "Towards an Ontology-Driven Blockchain Design for Supply Chain Provenance," *Intelligent Systems in Accounting, Finance, and Management* 25, no. 1 (2016): 18–27, https://doi.org/10.2139/ssrn.2828369.

25 Westerkamp et al, "Blockchain-Based Supply Chain."

The Legal Landscape of Fisheries Governance

Precautionary Principle

The precautionary principle was first associated with sustainable development in the 1990 Bergen Declaration on Sustainable Development, emphasizing that policies must align with the precautionary principle. Principle 15 of the 1992 Rio Declaration on Environment and Development is the most widely recognized formulation of the precautionary principle, allowing States to apply it widely according to their capabilities and avoid postponing cost-effective measures to prevent environmental degradation.[26] "…In order to protect the environment, the precautionary approach shall be widely applied by States according to their capabilities. Where there are threats of serious or irreversible damage, lack of full scientific certainty shall not be used as a reason for postponing cost-effective measures to prevent environmental degradation..."[27]

The precautionary principle, firmly anchored in international law and enshrined in the UNCLOS, is crucial in fisheries management.[28] It is an essential guiding concept for decision-making, particularly when scientific ambiguity exists regarding the potential dangers of various fishing tactics. Regardless of total scientific confidence, this approach encourages pre-emptive steps to reduce potential harm to marine ecosystems and resources.[29]

[26] Lynna Patricia Cortés Rueda, "The Precautionary Principle in Fisheries Management: A Differentiated Approach to Implementation," (doctoral dissertation, University of Tasmania, 2021), https://web.archive.org/web/20220524143343id_/https://eprints.utas.edu.au/45871/1/Cortes_Rueda_whole_thesis.pdf.

[27] Principle 15, United Nations Conference on Environment and Development, *Report of the United Nations Conference on Environment and Development* (Rio de Janeiro, June 3–14, 1992): Annex I, Rio Declaration on Environment and Development, A/CONF.151/26 (Vol. I) (1992), https://www.un.org/en/development/desa/population/migration/generalassembly/docs/globalcompact/A_CONF.151_26_Vol.I_Declaration.pdf.

[28] Food and Agriculture Organization of the United Nations, *The Precautionary Approach to Fisheries And Its Implications for Fishery Research, Technology and Management: An Updated Review*, accessed October 31, 2023, https://www.fao.org/3/w1238e/W1238E02.htm; Food and Agriculture Organization of the United Nations, 3. *Precautionary Approach to Fishery Management*, accessed October 31, 2023, https://www.fao.org/3/w3592e/w3592e07.htm; FishSec, *Precautionary Approach*, accessed October 31, 2023, https://www.fishsec.org/management-strategies/precautionary-approach/; Fernando González-Laxe, "The Precautionary Principle in Fisheries Management," *Marine Policy* 29, no. 6 (November 1, 2005): 495–505, https://doi.org/10.1016/J.MARPOL.2004.09.002.

[29] Sonia Boutillon, "The Precautionary Principle: Development of an International Standard," *Michigan Journal of International Law* 23, no. 2 (2002): 429–70.

The precautionary principle is a notion that entails taking action to avert potential damage even when scientific data is inconclusive.[30] The precautionary principle in fisheries management has been widely acknowledged as a general principle of international law in the field of international environmental law. It acts as an essential principle that guides the interpretation and creation of international treaties. However, considering the variety of state practices and varying interpretations among institutions and States, its status as customary international law is up for debate.[31]

The UNCLOS has suggested the precautionary approach in fisheries conservation, requiring the coastal States to use "the best scientific evidence available" in deciding fisheries conservation and management measures.[32] However, this item makes no explicit reference to the precautionary principle and hence requires operational regulations before it can be applied to national legislation and successfully accomplish fisheries management objectives.[33]

Precautionary management of a fishery entails explicitly considering precautionary steps that will be followed to avoid inevitable adverse consequences.[34] The approach requires that all fishing activities are subject to prior review and authorization, that a management plan is in place that clearly specifies management objectives and how fishing impacts are to be assessed, monitored, and addressed, and that interim management measures are applied to all fishing activities until a management plan is in place.[35] An essential component of the precautionary approach is the establishment of legal or social management frameworks for all fisheries, which should set regulations on access to fisheries, data reporting requirements, and systems for planning and executing more extensive fishery management.[36]

30 Food and Agriculture Organization of the United Nations, *The Precautionary Approach.*

31 Emmy Latifah and Moch Najib Imanullah, "The Precautionary Principle in Fisheries Management under Climate Change: How the International Legal Framework Formulate It?," *IOP Conference Series: Earth and Environmental Science* 129, no. 1 (2018), https://doi.org/10.1088/1755-1315/129/1/012038; Runyu Wang, "The Precautionary Principle in Maritime Affairs," *WMU Journal of Maritime Affairs* 10, no. 2 (2011): 143–65, https://doi.org/10.1007/s13437-011-0009-7.

32 Latifah and Imanullah, "The Precautionary Principle"

33 Latifah and Imanullah.

34 Food and Agriculture Organization of the United Nations, *The Precautionary Approach*; Food and Agriculture Organization of the United Nations, *3. Precautionary Approach.*

35 Food and Agriculture Organization of the United Nations, *The Precautionary Approach.*

36 Food and Agriculture Organization of the United Nations, *The Precautionary Approach*; Food and Agriculture Organization of the United Nations, *3. Precautionary Approach.*

The precautionary principle is a concept, whereas the precautionary approach is a management practice that involves developing specified preventive activities to avoid inevitable harmful consequences.[37]

The precautionary approach requires the use of the most reliable available scientific evidence; yet, in many situations, data on fish populations and the ecosystem are still lacking. This poses challenges in assessing the effects of fishing and in developing appropriate management strategies.[38]

The legal implications of applying the precautionary principle to fisheries management are complex and rely on how the concept is defined and used. In times of great uncertainty, the precautionary principle seeks to avoid irreparable damage and significant costs to resources and society.[39]

The precautionary method entails creating legal or social management frameworks for all fisheries, including regulations governing access to fisheries, data reporting requirements, and mechanisms for planning and executing more extensive fishery management. The precautionary principle and the precautionary approach to fisheries management can help ensure the adoption of sustainable fishing methods. However, there are still difficulties in putting these notions into action, such as ambiguity, a lack of data, opposition to change, enforcement concerns, and a lack of legal or social management frameworks. Blockchain and tokenization can help to overcome some of these issues and enhance fisheries management.[40]

Both environmentalists and the industry must acknowledge the negative effects of short-term economic goals on resources and the environment. The precautionary principle presents an opportunity for enhanced management and raises potential concerns for fisheries industries. The principle aligns with heightened environmental

[37] FishSec, *Precautionary Approach*; Food and Agriculture Organization of the United Nations, *The Precautionary Approach*; Food and Agriculture Organization of the United Nations, *3. Precautionary Approach.*

[38] Fredric M. Serchuk et al., "A Conceptual Framework for the Implementation of the Precautionary Approach to Fisheries Management within the Northwest Atlantic Fisheries Organization (NAFO)," in *Proceedings of the Fifth NMFS National Stock Assessment Workshop*, NOAA Tech. Memo. NMFS-F/SPO-40 (1999); Food and Agriculture Organization of the United Nations, *The Precautionary Approach*; Food and Agriculture Organization of the United Nations, *3. Precautionary Approach*.

[39] S. M. Garcia, "The Precautionary Principle: Its Implications in Capture Fisheries Management," *Ocean and Coastal Management* 22 (1994): 99–125; Pamela M. Mace and Wendy L. Gabriel, "Evolution, Scope, and Current Applications of the Precautionary Approach in Fisheries," in *Proceedings of the Fifth NMFS National Stock Assessment Workshop*, NOAA Tech. Memo. NMFS-F/SPO-40 (1999): 65–73; Food and Agriculture Organization of the United Nations, *3. Precautionary Approach.*

[40] Garcia, "The Precautionary Principle," 99–125.

awareness, underscoring the unpredictability and hidden costs of current decisions for future generations. It emphasizes integrated fisheries management within the context of long-term resource sustainability and environmental conservation.[41]

Fisheries management practices have slowly evolved over the past 50 years, with insufficient research and competition in open-access contexts hindering progress. Emerging environmental conservation aspects may require an accelerated evolution of fisheries management. Part XII of UNCLOS emphasizes the duty to protect the marine environment from pollution but lacks detailed instruments for implementing ecosystem conservation. A balance between environmental and fisheries provisions is essential for sustainable exploitation.[42]

Internationally, the precautionary principle has gained prominence in environmental law as a response to the uncertainty associated with assessing the impact of toxic substances on ecosystems and human health. Since the 1970s, it has been increasingly incorporated into international agreements and conventions. Its introduction on the global stage occurred at the First International Conference on the Protection of the North Sea in 1984, focusing on persistent toxic substances prone to bioaccumulation in marine ecosystems.[43]

Over time, the application of the principle broadened from addressing persistent toxic substances to encompassing all synthetic persistent substances, natural substances released in large quantities, and emissions contributing to global warming. It has been invoked in various environmental issues, including those related to the ozone layer, the greenhouse effect, and the conservation of nature.[44]

A notable example of the radical application of the precautionary principle is evident in the United Nations General Assembly resolution 44/225, adopted on December 22, 1989, which addressed large-scale pelagic driftnet fishing and its impact on marine resources. This resolution expressed concerns about fleet size, net length, operational methods, potential impacts on species, bycatch, and the condition of resources near EEZs. The consequences of the resolution included the discontinuation of fishing licenses and research into alternative techniques in Japan and Taiwan, as well as vessel docking and conversion in the Republic of Korea, and the implementation of European Union regulations. While large-scale

41 Garcia, "The Precautionary Principle," 99–125.
42 Garcia, "The Precautionary Principle," 99–125.
43 Garcia, "The Precautionary Principle," 99–125.
44 Garcia, "The Precautionary Principle," 99–125.

driftnet fishing ceased in the South Pacific in 1993, some activity persisted in the Mediterranean and Gulf of Biscay, accompanied by scientific experiments evaluating its impact on associated small cetaceans.[45]

The precautionary principle, rooted in uncertainty of impact assessments and management decisions, has gained prominence in international environmental soft law. It emphasizes preventive management and aims to rectify an unbalanced slant toward economic sectors. The UNCLOS mandates the use of the best scientific evidence in designing and adopting conservation measures, but does not provide criteria for situations where scientific consensus is lacking. Critics argue that the principle relies on suspicion rather than scientific evidence, treating potential culprits as guilty until proven innocent. The paper suggests that fishery decisions should adhere to the UNCLOS' basic requirement of relying on the best scientific evidence when available.[46]

The "best available technology" is a requirement for precautionary management or development, similar to the "best scientific evidence available." International environmental policy instruments mandate this requirement, emphasizing all technologically feasible measures to prevent harmful effects. This often involves creating lists categorizing fishing practices, such as "black" and "grey" or "red," "orange," and "green." However, classifying fishing technologies into such lists can lead to confusion and unjustified amalgamation, contributing to the depletion of marine living resources. The "best management methodology" would be a value-based concept, acknowledging techniques well-suited to specific socio-economic and cultural contexts. Critics argue that the 'best available fishing technology' concept lacks defined qualitative or quantitative terms for "best" and that the accumulation of "best technologies" may be detrimental without controlling total effort. The General Assembly Resolution 44/228 on UNCED mentions "environmentally sound" technology but emphasizes the importance of considering socio-economic values, aligning with the FAO definition of sustainable development.[47]

Paul de Bruyn et al. emphasize the importance of a paradigm shift in fisheries management, with a focus on conservation and environmental considerations. Their paper emphasizes the precautionary approach as a formal framework for addressing these concerns, which is grounded in international agreements such as the Code of

[45] Garcia, "The Precautionary Principle," 99–125.
[46] Garcia, "The Precautionary Principle," 99–125.
[47] Garcia, "The Precautionary Principle," 99–125.

Conduct for Responsible Fisheries and the United Nations Fish Stocks Agreement. The article examines how tuna regional fisheries management organizations are implementing these standards and provides recommendations for best practices. Concerns regarding the sustainability of fisheries resources arose as a result of the historical background of the international fisheries sector's fast expansion, prompting the formation of the voluntary Code of Conduct and the International Conference on Responsible Fishing. The Code incorporates precautionary management sections, similar to those outlined in the United Nations Fish Stocks Agreement, laying the foundation for the precautionary approach. The paper provides insights into how tuna Regional Fisheries Management Organisations integrate the precautionary approach and offers suggestions for best practices.[48]

Pamela M. Mace and Wendy L. Gabriel describe the history of the precautionary approach in fisheries, outline its comprehensive scope with a focus on biological reference points and harvest control rules, and investigate the approaches taken by fisheries organizations that are currently adapting or developing precautionary measures. Scientists predict that the precautionary approach will significantly alter the nature and degree of conservatism in scientific advice.[49]

Tim Lauck et al. discuss that the persistent issue of overexploitation in marine fisheries, even those strictly governed by coastal governments, is caused by a variety of factors. This topic focuses on the long-term and unavoidable scientific uncertainty surrounding marine ecosystems. This unpredictability, along with the usual issues of uncontrolled captures and unintentional death, suggests that traditional fisheries management measures will likely fall short in the long run. The proposal is to include vast protected areas, such as marine reserves, as major components in future management schemes. These protected zones can serve as a buffer against inevitable management limits, considerably improving long-term sustainable use of fishing resources. Furthermore, marine reserves provide an alternative to the need for increasingly extensive and costly stock assessments, and they play an important role in conservation.[50]

Fernando Gonzalez-Laxe discusses the notions of the precautionary principle, a preventive approach proportional to potential environmental risks, and a risk-

[48] Paul de Bruyn, Hilario Murua, and Martín Aranda, "The Precautionary Approach to Fisheries Management: How This Is Taken into Account by Tuna Regional Fisheries Management Organisations (RFMOs)," *Marine Policy* 38 (2013): 397–406, https://doi.org/10.1016/j.marpol.2012.06.019.

[49] Mace and Gabriel, "Evolution, Scope, and Current Applications."

[50] Tim Lauck et al., "Implementing the Precautionary Principle in Fisheries Management Through Marine Reserves," *Fisheries Economics Volume II: Collected Essays* 2, no. 1 (2020): 143–49, https://doi.org/10.4324/9780429288500-12.

eradication approach. It was applied in the fishing sector to address challenges of resource depletion and sustainability. This document examines the application of the principle in fisheries, assessing its implementation in community policy, and addressing the associated challenges. The failure of the Common Fishery Policy is attributed to non-compliance, producer doubts, and difficulty articulating instruments for ensuring fishing resource sustainability.[51]

Emmy Latifah and Moch Najib Imanullah examine the application of the precautionary principle in fisheries management and the responsibilities of decision-makers in taking deliberate steps to prevent or mitigate harmful practices. The notion is generally acknowledged in international environmental law and is seen as a means of achieving long-term development in fisheries and natural renewable resources. The urgency with which the concept is being applied to fisheries management reflects the awareness that fisheries cannot be addressed in isolation but must be integrated into a comprehensive long-term strategy for resource sustainability and environmental protection.[52]

S. M. Garcia explains how the precautionary principle might be used in the context of capture fisheries, particularly at the international level. He examines research, management, and legal implications, as well as related topics such as the burden of proof, the use of the best available scientific knowledge and technology, dependence on past scientific consensus, assimilation capability, and acceptable effect levels in fisheries. According to the report, a restricted application of the precautionary principle might lead to socioeconomic upheaval. However, when interpreted correctly, the principle offers a tremendous opportunity to enhance sustainable fisheries development. The report offers recommendations for the prudent application of precautionary techniques in fisheries management.[53]

Challenges and Opportunities

The use of tokenization technology for fisheries management aligns with UNCLOS Article 61, which emphasizes the conservation of biological resources. According to this article, coastal States are responsible for determining the allowable catch of biological resources within their EEZ, including fish. The tokenization of fish-

[51] González-Laxe, "The Precautionary Principle."
[52] Emmy Latifah and Moch Najib Imanullah, "Applying Precautionary Principle in Fisheries Management," *Jambe Law Journal* 1, no. 1 (2018): 13–34, https://doi.org/10.22437/jlj.1.1.13-34.
[53] Garcia, "The Precautionary Principle."

eries management can help coastal States provide accurate scientific evidence for the conservation and management of fisheries tailored to their specific needs. In addition, the use of tokenization must also comply with paragraph 3 of UNCLOS Article 61 which must comply with the rules of sustainability both economically and environmentally, including considering the issue of the digital divide for fishing communities in developing countries where not all can reach access to technological infrastructure and legal tools that support tokenization. State compliance with the concept of sustainability is also in line with Part XII, which focuses on the protection and preservation of the marine environment. As declared in Article 192, the State has an obligation to protect and preserve the marine environment. Furthermore, Article 193 declares that States have the sovereign right to exploit the natural resources at their disposal with their environmental policies and in accordance with their duty to protect and preserve the marine environment.

The issue of the digital divide can be addressed by the concept of technology transfers in the UNCLOS. The UNCLOS provides a legal framework for the responsible use and conservation of marine resources. Technology sharing under the UNCLOS encourages countries to cooperate in areas such as marine scientific research and environmental protection. It encourages collaboration to address challenges such as climate change and sustainable resource management through the exchange of technological advances and information. Part XIV of the UNCLOS deals with the development and transfer of marine technology. Article 266 outlines three fundamental principles in technology transfer. Furthermore, Article 268 regulates more specific technology transfer practices carried out by countries, such as promoting the acquisition, evaluation, and dissemination of marine technology knowledge and facilitating access to such information and data; the development of appropriate marine technology; the development of technological infrastructure necessary to facilitate the transfer of marine technology; and the development of human resources through training and education.

In addition, the complexity of regulations regarding data sharing, data protection, and data flow is a significant barrier to the implementation of tokenization in fisheries management. The existence of unestablished or varying regulations in different jurisdictions can create legal uncertainty, which may hinder the widespread adoption of tokenization. Technology neutrality is also a concern, as differences in blockchain infrastructure may affect the extent to which tokenization can be integrated and used. The concept of neutral technology in law aims to regulate various technological activities without specifying technologies or hindering future development. The law should

be broad, including all possible technical tools in the relevant regulatory framework. This neutral concept reduces the risk of existing effective regulations becoming irrelevant or lagging behind in large-scale technological advancements. The concept of technology neutrality is outlined in the preamble of the United Nations Convention on the Use of Electronic Communications in International Contracts, covering all situations where information is generated, stored, or transmitted in electronic communications, regardless of the technology or media used. However, this principle may be seen as a political tool to support one type of software license or freedom of techno-philosophical groups, potentially leading to technology discrimination.[54]

Another issue in tokenization is about data exchange, data protection, and data flow. According to paragraph 5 of UNCLOS Article 61, available scientific information, statistics on fishing and fishing effort, and other data relevant to the conservation of fish stocks shall be contributed and exchanged regularly through competent international organizations, whether subregional, regional, or global, as necessary and with the participation of all parties. Data exchange is also regulated in paragraph 2 of UNCLOS Article 119, which governs the conservation of living resources of the high seas. The paragraph states that the availability of scientific information, statistics on fishing and fishing effort, and other data relevant to the conservation of fish stocks shall be contributed and exchanged regularly through competent international organizations, whether subregional, regional, or global, as necessary and with the participation of all concerned States. Furthermore, the concept of non-discrimination in all conservation measures in the high seas, as stipulated in paragraph 3 of Article 119, can serve as a basis for applying the principle of technology neutrality in tokenization. In this context, the tokenization technology of interested countries must guarantee the implementation of non-discrimination principles, ensuring equal treatment for all interested parties, including fishermen from any country. This principle of non-discrimination is also a crucial requirement for the application of interoperability. In the application of tokenization technology, a legal framework is necessary to regulate interoperability standards, ensuring that various entities in the fisheries sector can share and access information on the blockchain smoothly. System weaknesses that are not neutral and lack interoperability to communicate and interact smoothly can limit tokenization and create new barriers that are discriminatory, thus contravening the principle of sustainable conservation.

[54] Ika Riswanti Putranti, "Principle of Technological Neutrality in Trade Facilitations: A Legal Perspective," *Jurnal Hukum Novelty* 13, no. 2 (2022): 216–36, https://doi.org/10.26555/novelty.v13i2.a23177.

The adoption of tokenization is often hampered by the mismatch between national data protection principles and international requirements, creating intractable conflicts that need to be bridged. The role of international organizations such as RFMOs is strategic in bridging existing legal conflicts and digital divides, as well as facilitating data exchange and encouraging increased data flow. The role of international organizations is in line with the mandate in Article 197, in which UNCLOS states contracting parties shall cooperate on a global basis and, where appropriate, on a regional basis, directly or through competent international organizations, in formulating and elaborating rules, standards and recommendations on international practices and procedures consistent with the UNCLOS for the protection and preservation of the marine environment with due regard to its characteristic regional features. Data exchange through competent international organizations is also mentioned in Article 200 related to marine pollution. The application of tokenization in fisheries management will undoubtedly accelerate the flow of fisheries data and enhance fisheries management, particularly by enabling policymakers to design more effective rules in response to dynamic changes in the biological environment, thereby promoting the sustainable conservation of the marine environment.

The issue of data flow is also covered in Article 244 that requires States, either individually or in cooperation with other States and with competent international organizations, to actively promote the flow of scientific data and information and the transfer of knowledge resulting from marine scientific research, in particular to developing countries, as well as the strengthening of autonomous marine scientific research capabilities in developing countries through, inter alia, programmes to provide adequate education and training for their technical and scientific personnel. Thus, Article 270 governs the instrument of international cooperation for marine technology development and transfer through existing bilateral, regional, and multilateral programs, as well as expanded and new programs, to facilitate scientific research, technology transfer, and ocean research and development.

Conclusions

The application of tokenized fisheries management as a strategy based on blockchain technology and tokenization can contribute to overcoming global challenges in fisheries governance, increasing transparency, combating fisheries crime, and promoting sustainable fishing practices. Sustainable fisheries management, including the application of traceability as support for the implementation of

the precautionary principle, is very important for the long-term sustainability of marine ecosystems. This highlights the significance of linking the UNCLOS and the precautionary principle when considering fisheries management decisions. The integration of blockchain technology and tokenization in fisheries management is presented here as a solution to overcome problems such as overfishing, fraud, and regulatory complexity. Regulatory challenges persist, including the need to apply neutral technology principles, ensuring data protection, and bridging the digital divide. On the other hand, UNCLOS has provided a framework and rules that encourage collaboration among countries to transfer technology, exchange data and information, and regulate responsible and non-discriminatory data flows, with the hope that it will encourage the application of tokenization in fisheries management.

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