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Devising modern Fintech solutions to combat global illegal, unreported and unregulated fishing and protect marine ecosystems

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Abstract

Illegal, Unreported, and Unregulated (IUU) fishing remains a major threat to marine ecosystems and coastal livelihoods, yet existing enforcement mechanisms rely on periodic inspections, manual reporting, or static financial incentives. We propose a novel closed-loop compliance-to-finance system in which multi-sensor vessel data are transformed into real-time financial signals that directly govern access to capital. In the proposed architecture, heterogeneous onboard and port-side sensors feed into an off-chain AI compliance model whose outputs are transmitted on-chain via decentralized oracle services. These compliance attestations programmatically adjust lending terms in Decentralized Finance (DeFi) protocols, dynamically reducing interest rates and increasing liquidity for compliant operators while restricting capital access for non-compliance. Loans are issued in USD-pegged stablecoins and overcollateralized using real-world fishing assets, including vessels, licenses, quotas, and contracts. Unlike prior approaches that treat sustainability incentives as external subsidies or reputational mechanisms, this system embeds regulatory compliance directly into the cost of capital, creating continuous, automated enforcement with minimum centralized intermediaries. We illustrate the feasibility of this architecture using existing low-cost sensing technologies, oracle infrastructure, and DeFi lending primitives, and discuss its potential to expand sustainable financing in small-scale and low-income fisheries where IUU fishing is most prevalent.

Keywords

Fintech, IUU Fishing, Overfishing, Blockchain, Sustainability, Artificial Intelligence, Vessel monitoring systems, Coastal communities, ESG standards, DeFi, Chainlink, Smart contracts

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1. Introduction

1.1 Summary

Global marine fishing activity removes fish biomass on the order of millions of tons annually.—an unsustainable rate that threatens marine ecosystems, requiring a technological intervention (1). The harvesting at this unsustainable rate negatively affects not only the ocean environment, but also the fishing industry. The deterioration of these feed stocks threatens the food source of billions and livelihoods of ~ 600 million people globally (2). However, the fishing industry often prioritizes profit growth over the long-term health of marine populations; in a classic affirmation of the 'Tragedy of the Commons".

Overfishing is one of the deadliest threats the ocean is currently facing, jeopardizing the existence of ~a third of international fish stocks (3). Overfishing refers to extracting fish at a rate that prevents populations from replenishing, disrupting the natural balance of marine ecosystems. This has led to the decline of numerous key species in the food chain. These figures help regulate the careful balance of the ratio between predator and prey. Humans often disrupt this balance by overharvesting either predators or prey, causing cascading effects across the ecosystem. For example, the overharvesting of cod in the North Atlantic has led to an explosion in small fish and invertebrates (4). Though this might seem beneficial, these prey will exact an increased toll on the environment around them as their food and shelter needs increase, which harms other species. For example, algal blooms have increased ~13% from 2003 to 2020 (5). This is due to the overharvesting of marine algae predators and causing algae to multiply and explode in population. These blooms release toxins harmful to both humans and marine life, deplete oxygen levels, and block sunlight essential for aquatic vegetation. These areas are then labeled dead zones, as marine life can no longer survive there.

Only about 150 years ago, the ocean was widely regarded as an inexhaustible resource. In 1883, renowned biologist and scientist Thomas Huxley argued at the International Fisheries Exhibition that certain fish stocks, such as cod, offered an infinite resource of food, stating, 'The cod fishery… and probably all the great sea fisheries, are inexhaustible; that is to say, that nothing we do seriously affects the number of the fish' (6). In the present, however, using improved scientific tools and measurements, this perception has been repudiated. However, some industry stakeholders continue to emphasize short-term economic benefits over long-term sustainability, even in the face of overwhelming evidence. This once-common belief in the ocean's inexhaustibility has been overturned by clear evidence of overfishing and ecosystem degradation.

One main cause of overfishing is due to coastal communities. These countries often have underdeveloped economies, forcing many of their citizens to exceed sustainable limits and overharvest. These governments are often powerless to either aid or enforce sustainable limits on their ocean due to a lack of financial resources. In 2021, the Food and Agriculture Organization (FAO) reported that 46% of fish stocks in the Southeast Pacific - a region harboring many low-income coastal communities such as in Peru and Ecuador - were harvested at biologically unsustainable levels (7). This is significantly higher than the global average of ~a third of overfished stocks, highlighting intense overfishing pressure from small-scale fisheries in these underdeveloped economies reliant on fishing for livelihoods.

This paper argues that blockchain technology, when used with verified industry partners, can track annual fish harvests and curb illegal fishing that undermines regulated, sustainable practices. There is little incentive for fishers and fishing companies to comply with regulations if they interfere with profits. Fintech companies, or companies that implement online programs and technology to provide financial services, could implement strict Environmental, Social, and Governance (ESG) reporting standards with live tracking technologies to ensure that rules are being followed, with compliance rewarded with enhanced access to the banking system. By extending existing Fintech initiatives through Decentralized Finance (DeFi) protocols, real-time compliance data automatically adjusts interest rates and liquidity access with minimum centralized intermediaries or ongoing public subsidies.

1.2 Overfishing drives species extinction and habitat destruction

Overfishing and unregulated fishing pose a significant threat to marine ecosystems, driving species to extinction and jeopardizing the ocean's capacity to sustain life and livelihoods. The Chinese Paddlefish, a species that thrived for 200 million years and survived the dinosaur extinction, was declared extinct by 2022. The species is speculated to have vanished between 2005 and 2010 due to relentless overfishing and habitat destruction. In the 1970s, humans harvested around 25 tons of this ancient fish annually, a rate that led to a substantial decline its population (8). This tragic loss now serves to highlight the devastating consequences that overfishing can induce, but could have been easily prevented with sustainable fishing practices. According to the FAO, 35% of global fish stocks are overfished, while 57% are fished at their maximum sustainable levels, leaving little room for recovery (9). Though a great portion of marine life species are being threatened with a risk of extinction, there is still time to prevent them from a fate similar to that of the Chinese Paddlefish.

Modern advancements in the fishing industry, while boosting efficiency in seafood harvesting, serve as a double-edged sword, since they intensify the rate of overfishing. Bottom trawling, using a giant heavy net dragged across the seafloor to catch as many fish and crustaceans as possible, paired with sonar, a modern method to scan for fish, is highly efficient at harvesting seafood. Trawling leaves too few fish to repopulate the vast areas it reaps. Though this method can catch more than any other fishing method, it destroys marine habitats, since the trawling nets carve away the seabed, which can rip apart seagrass and coral reefs. Coral reefs provide homes for ~25% of all marine species as well as providing habitat for juvenile marine species (10), while seagrass absorbs carbon dioxide, depleting this greenhouse gas from the atmosphere. In the modern age, fishing methods provide an easy method of sustenance, but in the process damage ocean environments.

Bottom trawling also results in bycatch—the unintended capture and killing of non-target species such as dolphins and sea turtles. This common occurrence eventually decimated the dolphin population, forcing companies to produce tuna safe stickers, claiming tuna cans are “dolphin-safe”. By some accounts, Bycatch accounts for up to 40% of global catches, highlighting its destructive capabilities on the environment (11).

The fishing industry has extracted fish at levels far exceeding sustainable limits. For example, the Pacific bluefin tuna has declined more than 80% since the 1970s (12). As it becomes harder for fishermen to make a living due to declining stocks, they take to unreported fishing. Unreported fishing occurs when fishermen under-report or do not report the true number of fish caught, thus undermining sustainability and ESG regulations as well as plans to rebuild marine life fish stocks. Weak regulatory enforcement, coupled with creative evasion allows unreported fishing to continue, as many regions lack the resources necessary to enforce these regulations. It is now estimated that one-fifth of all wild-caught fish are caught illegally.

In coastal regions like West Africa, dire economic conditions force local communities to overfish to secure enough income to feed their families. Fishing is a primary livelihood for many in these developing areas, yet poverty and limited economic opportunities push villagers to exploit marine wildlife beyond sustainable limits. In West Africa, an estimated 40% of fish caught are from IUU fishing, making it the largest source of such catches globally (13). Coastal communities often are a major source of overfishing due to economic pressures, and hence should be considered when providing a technological solution.

1.3 United Nations high Seas treaty to protect marine biodiversity

The critical potential threats that overfishing can pose has even attracted the attention of the United Nations, leading to the creation of Goal 14: to conserve and sustainably use oceans, seas, and marine resources for sustainable development. To address this, the UN, after 35 hours of intense debate, signed the High Seas Treaty, formally known as the Biodiversity Beyond National Jurisdiction (BBNJ) Agreement, on September 20, 2023. This treaty seeks to conserve 30% of the world’s oceans by 2030 by creating marine protected areas (MPAs) in international waters, strengthening environmental impact assessments for fishing, and promoting the shared use of marine genetic resources(14). Through global cooperation, with many nations implementing monitoring systems, enforcing regulations, and investing in sustainable fisheries management to curb overfishing and habitat destruction, these goals can be achieved. The treaty’s focus on protecting critical habitats like coral reefs is vital, as overfishing, especially bottom trawling, devastates these ecosystems, which, despite covering less than 1% of Earth’s surface, support 25% of marine species, a biodiversity that sustains 500 million people globally. This destruction is projected to cost the US ~$500 billion per year by 2100. Ocean habitats must be preserved as they are essential for marine life and serve as a financial asset for various nations (15).

1.4 Economies of scale

In many small fishing communities, fishing struggles to scale beyond a subsistence economy due to limited refrigeration and storage, poor transportation access to established markets, and the absence of cooperatives or unions. These constraints create downward pressure on prices through buyer monopsony and time-sensitive spoilage, reducing incentives for small vessels to increase catch, invest in larger boats, or venture into less exploited waters. Over time, weak profitability and limited oversight leave these communities vulnerable to IUU overfishing—often by external actors—accelerating economic and ecological decline. Breaking this cycle does not require permanent subsidies but rather a closed-loop compliance-to-finance system (discussed later) that internalizes the cost of compliance into access to capital. By converting verified, real-time vessel data into financial risk signals, the system enables private capital providers, buyers, and technology vendors as well as DeFi capital pools to underwrite initial adoption costs, in accordance with on-chain smart contracts, in anticipation of future cash flows. Once operational, compliance lowers risk, unlocks financing, and sustains itself through market mechanisms rather than through external support (see the Discussion section below).

2. Discussion

2.1 Fintech innovations foster sustainable fishing practices

Since the early 2010s, finance and Fintech companies have aided in advancing ocean conservation, utilizing technologies to promote sustainable fishing practices and protect marine ecosystems. Fintech companies usually harness technology to deliver financial services like digital payments and investment platforms. The Nature Conservancy advances an innovative approach to sovereign debt refinancing, using credit enhancement and blended commercial capital to secure lower interest rates and extended maturities for participating countries. These transactions—often structured as blue bonds or debt-for-nature swaps—free up fiscal space that governments commit to long-term ocean conservation and sustainable fisheries management. While ecological recovery depends on effective implementation rather than the financing mechanism alone, successful marine protection efforts—such as Cabo Pulmo National Park in Mexico, where fish biomass increased by ~ 400% following the establishment of a no-take reserve—illustrate the potential outcomes that well-funded and well-enforced conservation policies can achieve. In the Republic of Seychelles, starting in 2016, the program generated $430,000 annually for conservation, protecting 86 million acres of ocean by 2020 (16). While the Blue Bonds program provides macro-level debt restructuring, Decentralized Finance (DeFi) offers micro-level, real-time incentives by embedding compliance directly into lending terms.

To our knowledge, no prior work treats environmental compliance as an on-chain financial risk variable governing liquidity access. We propose a novel closed-loop enforcement mechanism in which multi-sensor fisheries compliance data is transformed via AI and oracle services into on-chain financial signals that automatically adjust lending terms in decentralized finance protocols. Unlike prior incentive-based approaches, compliance directly and programmatically reduces the cost of capital, creating continuous, behavior-linked enforcement without centralized oversight. The proposed closed-loop compliance-to-capital enforcement mechanism embeds real-time environmental compliance directly into the cost of capital using AI, oracles, and DeFi with minimal human intervention.

2.2. Formal compliance-to-capital mechanism

This section formalizes the proposed system as a closed-loop incentive mechanism that links environmental compliance to financial access. The objective is to propose a novel enforcement structure in which compliance dynamically governs the cost and availability of capital.

2.3 Set up

The mechanism involves four primary actors/layers.

2.3.1 *Fishing operators*

These are vessel owners or cooperatives who seek access to working capital for fuel, maintenance, crew wages, or equipment.

2.3.2 *Sensing and data layer*

This layer is composed of onboard and port-side sensors (e.g., GPS, accelerometers, engine power draw, cameras, port scales) that generate continuous observational data related to fishing activity.

2.3.3 *Compliance inference layer*

This layer is composed of an off-chain AI model that aggregates multi-sensor data and outputs standardized compliance indicators, such as [1] a *Composite Fishing Activity Index (CFAI)* (degree of active fishing over time), and [2] a *Confidence-Weighted Violation Score (CWVS)* (likelihood of regulatory breach).

2.3.4 *Financial execution layer*

This layer consists of smart contracts deployed on decentralized finance (DeFi) lending protocols that programmatically adjust lending terms—such as interest rates, credit limits, and liquidity access—based on compliance indicators supplied by oracle services. While contract execution is automated, the system remains dependent on off-chain data generation, oracle governance, and parameter calibration, which may involve minimal institutional or human oversight. Off-chain data ingestion and governance are designed to require minimal human intervention, relying primarily on automated oracle networks and incentive-compatible verification mechanisms. Human or institutional oversight is limited to exceptional circumstances—such as oracle disputes or protocol upgrades—analogous to governance interventions in mature Proof-of-Stake blockchain systems.

2.4 Compliance as a state variable

In traditional fisheries governance, compliance is assessed retrospectively and enforced through inspections, penalties, or license revocation. In contrast, the mechanism proposed in this paper treats compliance as a continuous system state that evolves over time.

At regular intervals (e.g., every 15–30 minutes at sea, and upon port arrival), sensor data is evaluated by the AI inference layer to produce a compliance score reflecting whether observed vessel behavior is consistent with declared catch, authorized fishing zones, and permitted effort levels. This compliance score is [1] forward looking: affecting future financial conditions rather than punitive measures, [2] probabilistic: allowing uncertainty to be priced in, rather than ignored and [3] machine readable and implementable: enabling direct use in smart contracts.

2.5 Oracle-mediated translation to financial signals

Since DeFi protocols cannot directly access physical-world data, compliance scores are transmitted on-chain via decentralized oracle networks (e.g., Chainlink). These oracles do not verify legality themselves; they merely attest the veracity of a given output produced by a specified off-chain model under predefined rules. This separation ensures the transparency of inputs and the scoring logic, their being resistant to single-point manipulation and being auditable by regulatory agencies. Once delivered on-chain, compliance scores become financial control variables.

2.6 Cost of capital as enforcement

The core mechanism design innovation in this work lies in how compliance affects financial outcomes. Instead of fines, subsidies, or reputational scoring, the system enforces sustainability through capital access conditions, which include lower interest rates, higher borrowing capacity or liquidity availability or Loan-To-Value (LTV) ratios for consistently compliant operators and automatic freezing of collateralized assets or tightening of credit – including callback-of-lent-capital for sustained non-compliance. Because fishing operations are capital-intensive and often liquidity-constrained, especially in small-scale and low-income fisheries, access to affordable capital directly affects operational viability. Therefore, under this proposed mechanism, compliance reduces operating costs while non compliance increases the cost of capital, lending and financial friction. Enforcement occurs continuously and automatically, rather than episodically. This transforms sustainability from an external obligation into an endogenous economic constraint.

2.7 Collateral and dynamic risk adjustment

Loans are overcollateralized using real-world fishing assets such as vessels, licenses, quotas, or supply contracts. Unlike static collateralization, the recognized collateral value in this system is behavior-dependent rather than fixed. While the underlying market value of physical assets continues to be governed by supply and demand, the proportion of that value that can be mobilized as financial collateral dynamically adjusts based on observed compliance. Sustained compliance preserves or enhances collateral usability by maintaining favorable loan-to-value ratios and leverage limits, whereas repeated violations increase perceived risk and automatically reduce effective collateralization and financial leverage. In this way, lender risk exposure is aligned with real-world environmental behavior without requiring discretionary human judgment or manual intervention.

2.8 Incentive properties

A key limitation of compliance-linked financing mechanisms is the availability of alternative capital sources that do not impose comparable monitoring or sustainability requirements. The effectiveness of the proposed approach therefore depends on the extent to which ESG-aligned financing offers materially superior terms—such as lower cost of capital, greater liquidity, or preferential market access—relative to informal or non-compliant alternatives. In practice, adoption is most likely where access to downstream markets, insurance, or licensing is contingent on verified compliance, thereby increasing the opportunity cost of seeking unregulated finance.

Incentives adjust in near real time, eliminating the lag between violation and consequence. Operators unwilling to comply face progressively worse financial terms, while compliant operators benefit automatically. Because enforcement is embedded in capital markets rather than public budgets, the system can scale without ongoing government approval for budgets or expenditure.

2.9 Distinction from prior and conventional approaches

Unlike traditional fisheries enforcement, which relies on inspections and penalties, or ESG finance, which relies on disclosure and reputational incentives, this proposed mechanism ties compliance directly to the price of capital. It uses AI-inferred behavior, rather than self-reporting or on periodic inspections. Finally, it executes enforcement automatically via smart contracts. To our knowledge, no prior fisheries governance or DeFi framework formalizes environmental compliance as an on-chain financial state variable governing liquidity access.

Table 1 compares the proposed mechanistic model with conventional compliance monitoring and financial incentive approaches. Unlike traditional systems, the closed-loop model operates continuously through automated smart contracts, with minimal human intermediaries, to determine the cost of capital and the treatment of collateralized assets. The AI algorithm dynamically adjusts financing terms in real time, approximating the economic effects of subsidies for compliant behavior and penalties for non-compliance.

Table 1. Distinguishing the circular compliance-to-capital mechanism from conventional approaches

Mechanism	Continuous	Automated	Capital-based	No intermediary
Inspections	X	X	X	X
Fines	X	X	X	X
Subsidies	X	X	X	X
Blue Bonds	X	X	√	X
This work	√	√	√	√*

* Does require minimal off-chain custodians and legal oversight

3. Financial incentives and blockchain to ensure marine sustainability

Fishermen and fishing companies currently operate under minimal surveillance and have little incentive to respect catch limits when compliance reduces short-term profits. Fintech platforms can address both issues by directly linking ESG compliance to financial benefits. Operators who follow the rules gain access to lower-interest loans, premium market prices, and sustainability-linked payments, creating a self-reinforcing system that aligns private profit with long-term environmental sustainability.

3.1 Blockchain vulnerabilities and mitigation

While blockchains can provide immutable records, the human actors responsible for entering data remain vulnerable to error and corruption. One proposed safeguard is the use of port-based weighing stations to verify catch volumes, but this approach can be circumvented by transferring illegally caught fish to vessels that avoid ports altogether. A more effective deterrent is the deployment of low-cost Vessel Monitoring Systems (VMS), including GPS trackers, accelerometers, and basic onboard cameras. For vessels above a certain size (e.g., over 10 meters), installation of such systems can be mandated, with data automatically transmitted to a blockchain-based ledger. For smaller or resource-constrained operators, affordable, low-maintenance systems can be supported by governments, NGOs, or international bodies—an approach that has already seen real-world implementation.. In Timor-Leste, a solar-powered monitoring system using basic GPS and digital tech was launched in 2019, providing near-real-time data at minimal cost to fishers, with funding from development partners like WorldFish (17). This model relies on affordable components and community training, making it scalable for low-income areas. Prototype architectures using long-range, low-power wireless tech networks (LoRaWAN) have been developed to track small vessels at a fraction of traditional VMS costs, being energy-efficient and not requiring constant power, ideal for boats without reliable electricity (18).

3.2 Sensors on fishing vessels

Table 2. Sensor data and AI predictive contribution for detecting active fishing versus transit

Sensor	**Primary Indicator of Active Fishing**
GPS Coordination and Trajectory	Loitering, haul patterns, repeated in same area - Checks all devices - Ensures fishing only occurs in designated fishing ground
Accelerometer (list to roll ratio)	Vessel heels when heavy nets are hauled aboard [Time spent accelerating/Time spent cruising] ratio
Hull immersion depth meter*	Deeper draft when hold is full of fish - Cargo quantity - Bottom Trawling
Engine / drivetrain power draw (current)*	Power spikes during winch operation and net hauling - Bottom trawling - Cargo quantity
Propeller RPM	Higher RPM and sudden changes during net deployment - Fishing location - Time spent fishing
Mileage (nautical miles to fuel consumed)*	Fuel consumption rate - Cargo quantity - Fishing location - Bottom trawling
Underwater camera and turbidity	Visible net in water, sediment cloud from bottom trawling - Vessel speed - Location
Automated scale or volume scan at port	Declared catch quantity

* - Check if illegally caught fish have not been fraudulently transferred to other boats who do not have such sensors or bypass ports at weighing stations. The data is fed into blockchain and analyzed by machine language algorithms.

The data from such VMS can be used to construct and train AI models that can predict the probability that a fishing vessel has been actively fishing for (x hours) using GPS trajectories, speed, stop-and-go patterns, underwater camera images and turbidity, power draw of engine or drivetrain, fuel levels, vessel list-to-roll ratio, propeller RPM, and hull immersion depth. If the amount of time/location of fishing is incommensurate with the amount of fish recorded (this can be automatically input into a blockchain) when the boat docks after a fishing run, this can be taken as fraudulent overfishing activity and can be fined accordingly. If however, the amount of time of fishing is commensurate with the amount of fish caught (and reported), the Fintech financial and loan incentives can then be activated for that boat/organization. The diagnostic value of each sensor is summarized in Table 2.

By combining these sensor streams in real time, the trained AI model can output a probability of active fishing every 15–30 minutes while the vessel is at sea, allowing authorities or the Fintech platform to issue warnings or freeze incentives long before the vessel docks.

3.3 Closed-loop compliance-to-finance system

In the proposed system, multi-sensor data from the fishing vessel is directly fed into a blockchain oracle such as Chainlink. This data is then operationalized by an off-chain AI algorithm which outputs the previously proposed CFAI and CWVS related scores. Based on a prior pre-written and stakeholder-approved smart contract written into the blockchain, these scores then directly unlock liquidity or interest rate reduction mechanisms from DeFi platforms such as Compound or Aave that are designed also to ingest non-financial data. The liquidity or interest rate reduction protocols are overcollateralized using assets such as fishing vessels, fishing rights, contracts, and licenses. Once unlocked, these loans or liquidity is directly deposited into fishing vessel operators' financial accounts in the form of USDC cryptocurrency backed by US dollars.

Using fishing vessels, licenses, quotas, and contracts as collateral conditioned on behavior is still relatively unexplored academically, especially when collateral value is dynamically adjusted based on compliance, and the proposal is not just static tokenization. This approach positions the DeFi aspect as a systems architecture whose contribution is mechanism design, not necessarily empirical deployment. Specifically novel elements include: oracle-mediated compliance feeds (Chainlink as a bridge from physical-world sensors), AI-based compliance scoring used as an on-chain financial variable, automatic interest-rate and liquidity adjustments via DeFi liquidity platforms such as Aave and/or Compound, minimal human intermediary intervention, and capital cost as enforcement, not fines or subsidies. This is not standard in either fisheries governance or DeFi applications (which rarely ingest real-world compliance signals), hence positioning this work as novel.

3.4 Perspectives

Deployment of this circular compliance-to-capital model will require mechanisms (integrated into the VMS/blockchain and/or smart contract) for tamper-resistant sensing, robustness to adversarial behavior (sensor tampering, AIS/GPS spoofing, side-selling, data outages) and oracle/lender-side failures, reliable connectivity, DeFi/KYC access for small-scale fisheries, and enforceability of Real World Assets (RWA) collateral; these, in turn will require failure-mode analysis and mitigation. The mechanism will [1] need to be formalized with equations (e.g., mapping CFAI/CWVS to interest-rate and LTV schedules; incentive-compatibility and participation constraints); [2] detailing governance, dispute resolution, auditability, and model transparency and [3] adding a cost–benefit analysis and an implementation roadmap with Key Performance Indicators (KPIs). The legal feasibility of collateral seizure will need to be addressed to show that compliant equilibria are stable and attractive in real settings. In addition, data privacy and consent for continuous monitoring, fairness and due process for appeal of adverse decisions (such as loan freezes) will need to be incorporated into the smart contract.

4. Conclusion

IUU fishing remains one of the most persistent threats to marine ecosystems and coastal livelihoods, particularly in regions with limited enforcement capacity and financial resources. Existing governance approaches rely heavily on inspections, subsidies, penalties or reputational mechanisms, all of which are costly, episodic, and difficult to scale. This paper argues that sustainability in fisheries cannot be achieved through monitoring alone; it requires a restructuring of incentives that continuously align economic survival with environmental compliance.

To that effect, a novel compliance-to-capital mechanism was introduced that embeds real-time fisheries compliance directly into the cost and availability of capital. By transforming multi-sensor vessel data into AI-derived compliance indicators, transmitting these signals on-chain via decentralized oracle services, and programmatically adjusting lending terms within decentralized finance protocols, the proposed system replaces retrospective punishment with continuous, automated enforcement. In this architecture, capital access itself becomes the regulatory lever, eliminating the need for centralized intermediaries, discretionary enforcement, or ongoing public subsidies.

Unlike prior ESG-linked financing models, which treat sustainability as an external reporting or reputational layer, this framework internalizes environmental behavior as a financial risk variable. Compliance dynamically reduces interest rates and expands liquidity, while non-compliance increases capital friction and constrains operational capacity. This shift is particularly relevant for small-scale and low-income fisheries, where IUU fishing pressures are the most severe and access to affordable capital is often the primary constraint on livelihoods.

Importantly, the contribution of this work lies in mechanism design rather than the (re)invention of new sensing, AI, or blockchain technologies. All system components—low-cost vessel monitoring systems, probabilistic compliance inference, decentralized oracles, and DeFi lending primitives—are already available or emerging. The novelty of this work arises from their integration into a closed-loop enforcement architecture that redefines how environmental regulation can be operationalized through decentralized financial systems.

Future work should focus on pilot deployments, governance of model transparency and dispute resolution, and empirical evaluation of behavioral responses under real-world conditions. Extensions of this framework may also apply to other resource-intensive industries facing enforcement challenges, including forestry, mining, and carbon-intensive supply chains. By embedding sustainability directly into financial infrastructure, this approach offers a scalable pathway toward aligning economic incentives with long-term environmental stewardship, ensuring that compliance is not merely encouraged—but economically indispensable.

A significant share of today's fish comes from IUU fishing, pushing species closer to extinction and threatening the livelihoods of millions of people worldwide. Much of this overfishing occurs in coastal communities where fishing is essential for survival and local economies; yet access to capital is limited, often worsened by weak government oversight. By using blockchain-based Fintech solutions to promote transparency and sustainable fishing practices, we can curb IUU fishing, protect ocean ecosystems, and secure livelihoods for future generations.

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