OpenFishbanks: A Human-Driven Asynchronous Simulation of Ecological and Economic Dynamics

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***Abstract*—OpenFishbanks is a web-based simulator that models a fishing economy. Through player-driven interactions, the platform revealed key dynamics of resource exploitation, including overfishing, wealth concentration, and strategic manipulation. Despite the simplicity of the system, participants exhibited emergent complex behaviors. Patterns of cooperation, collusion, and anti-competitive tactics emerged, mirroring real-world market failures and reinforcing the challenges of managing common-pool resources. These findings underscore the tension between individual incentives and collective sustainability, offering insights relevant to environmental policy, economic inequality, and human decision-making in shared systems.**

I. Introduction

A. Background: Common-Pool Resources and Strategic Behavior

The management of common-pool resources (CPRs), natural systems shared by multiple users, presents enduring challenges in economics, environmental science, and public policy. These systems are vulnerable to exploitation due to the misalignment between individual incentives and collective sustainability, a conflict epitomized by the *tragedy of the commons* [1]. Game theory provides a valuable framework for understanding such dynamics, particularly through the *Prisoner's Dilemma*, wherein individually rational strategies lead to collectively suboptimal outcomes.

Simulation-based environments have proven effective for studying CPR dynamics, enabling researchers and educators to explore the behavioral and systemic consequences of unregulated resource competition under controlled conditions. [2]

B. Prior Work: The MIT Sloan Fishbanks Simulation

One of the most prominent simulations in this space is *Fishbanks*, developed at the MIT Sloan School of Management [3]. In *Fishbanks*, players manage fishing fleets over a series of discrete time rounds, aiming to maximize profit while fishing from a shared population. The model emphasizes resource dynamics and strategic decision-making and is typically used in classroom or workshop settings.

While *Fishbanks* has been widely used for both research and education, it imposes several structural limitations. It is synchronous and bounded to a fixed time frame, usually spanning only 10–15 rounds with active facilitator oversight. The player base is typically limited to dozens of participants, and data collection is often qualitative or manually recorded. As a result, the model provides valuable but constrained insight into short-term strategies rather than long-term or emergent phenomena.

C. Extending the Model: The OpenFishbanks Platform

To address these limitations, we developed *OpenFishbanks*, a web-based, asynchronous simulation platform that expands the scope of traditional CPR models. Built with Django, *OpenFishbanks* allows players to fish, trade, and manage virtual assets continuously over extended periods, creating a persistent and scalable economic-environmental system.

Key differentiators from the original *Fishbanks* model include:

- **Asynchronous Gameplay:** Users can interact with the system at any time, allowing for organic and diverse strategies.
- **Extended Simulation Time:** Sessions run over multiple days or weeks, enabling the observation of long-term behaviors and ecological trends.
- **Scalable Participation:** The platform supports dozens to hundreds of concurrent users through its cloud-based architecture.
- **Robust Data Collection:** Every user action is logged to a backend database, supporting fine-grained analysis of behavior, economy, and ecosystem health.

This extended design facilitates and highlights the emergence of complex social and economic behaviors, including cooperation, competition, and manipulation, that are difficult to capture in facilitator-driven synchronous simulations like *Fishbanks*.

D. Research Questions and Contribution

This study investigates behavioral trends and systemic outcomes within *OpenFishbanks*, with a focus on how human decision-making shapes resource sustainability and economic disparity. Specifically, we ask:

- How do users behave in an unregulated, persistent fishing economy?
- What trade-offs emerge between profit-maximization and resource sustainability?

- How do group dynamics influence ecological stability and wealth concentration?

II. Methods

A. Model Implementation

OpenFishbanks is a persistent, web-based simulation built with the Django framework and hosted on an AWS EC2 instance. It models a simplified but dynamic fishing economy in which human players interact asynchronously over time. The simulation consists of the following core components:

1) Agents and Assets: Each player controls a digital fishing operation and starts with a fixed initial balance and one small fishing ship. Ships can be used to harvest fish, traded with other players, or sold to other players through the auction system. Ships vary by type, capacity, and efficiency. Every asset is modeled through Django's model objects.

2) Fish Population Dynamics: The simulation models a regenerating fish population distributed across one or more virtual regions. Fish availability in each region is updated on a regular interval using a predefined population growth model. The regeneration function is defined as:

$$\frac{dP_f}{dt} = k_f \cdot P_f \left(1 - \frac{P_f}{C_f}\right) \tag{1}$$

where:

- P_f is the population of fish species f
- k_f is the intrinsic growth rate of species f
- C_f is the carrying capacity of species f
- t is time (measured in consistent units)

The population function is based on logistic growth, commonly used to model simple populations.

3) Fishing and Economy: Players recieve a "paycheck" every 30 minutes, with profits determined by their ship fishing rate, location, and fish prices. Player revenue is defined as the following:

$$F_{s,f} = \min\left(\frac{r_s}{w_f}\left(\frac{P_f}{C_f}\right)^2,\ \frac{c_s}{w_f}\right) \tag{2}$$

$$P_f \leftarrow \max(0,\ P_f - F_{s,f}) \tag{3}$$

$$\text{Revenue} = \sum_s \sum_{f \in \mathcal{F}_{h_s}} F_{s,f} \cdot w_f \cdot v_f \tag{4}$$

$$\text{Total Cost} = \sum_s (c_s \cdot g\ +\ c_s\ +\ H_s) \tag{5}$$

where:

- s indexes ships and f indexes fish species at ship s's harbor
- r_s is the fishing rate of ship s
- w_f is the weight of fish species f
- P_f is the population of fish species f
- C_f is the carrying capacity of species f
- c_s is the fishing capacity of ship s
- v_f is the value per unit weight of species f
- g is the gas price
- H_s is the harbor fee for ship s
- $\mathcal{F}_{h_s}$ is the set of fish species at the harbor of ship s

4) Trading System: A player-to-player trading system allows for the exchange of ships and currency. Trades are initiated by one user and must be accepted by the other to be executed. No centralized market constraints are enforced, allowing the emergence of both cooperative and competitive strategies.

5) Game State and Data Logging: All player actions, including fishing, trading, ship purchases, and market activity, are logged in a Sqlite3 database. The global game state, including fish populations, fish market values, ship stock, and auction listings, is recalculated periodically via Celery shared tasks running on Redis to ensure synchronicity across users.

B. Experimental Design

1) Participants: Students and Faculty of Concord Academy were invited to play through an all school announcement and email. Player count totaled to 197 by the end of the simulation, with a little under half being active users throughout the simulation.

2) Simulation Timeline: The simulation was conducted over a period of six days. Players could log in and interact with the system at any time. No resets or hard rounds were enforced, encouraging organic temporal behavior. Changes were made to the fish stock price algorithms to ensure natural progression.

3) Initial Conditions: All players began with a uniform allocation of 20,000 in-game currency and one low-efficiency fishing vessel. No initial guidance or strategy was provided, though a short onboarding page described the controls and rules of the system.

4) Incentive Structure: Players were informed that the objective was to maximize their balance by the end of the simulation period. No in-game penalties were enforced for overfishing or unsustainable practices. A prize of 30 and 20 dollars was presented to first and second highest balance players at the end respectively. Players could also view a leaderboard page that displayed all users and their balances, encouraging competition.

5) Data Collection and Analysis: System logs were used to track player activity, including:

- Quantity of fish harvested and sold
- Player balances
- Trades between users (ships and currency)
- Fish population levels over time
- Distribution of wealth and ship ownership
- Fish Stock Prices

Post-simulation analysis focused on identifying strategic patterns, potential ecological impacts, and indicators of inequality, collusion, and emergent cooperation or sabotage. Visualizations and statistical summaries were generated using Python (pandas, matplotlib, seaborn).

III. RESULTS

The OpenFishbanks simulation revealed a range of emergent behaviors among human participants that reflect complex dynamics between economic incentives and ecological sustainability. Below, we report key findings in four thematic areas: overfishing and ecological collapse, wealth disparity and consolidation, cooperative groups and anti-competitive behavior, and game-theoretic strategy patterns.

A. *Overfishing and Ecological Collapse*

The population of fish species fluctuated throughout the simulation. Certain species had their populations drop to zero, which was particularly common among species with lower weights. Each species ended with significantly lower populations.

Figure 2 shows the fish population over time, highlighting a dramatic decline initially, then oscillations as the players moved boats.

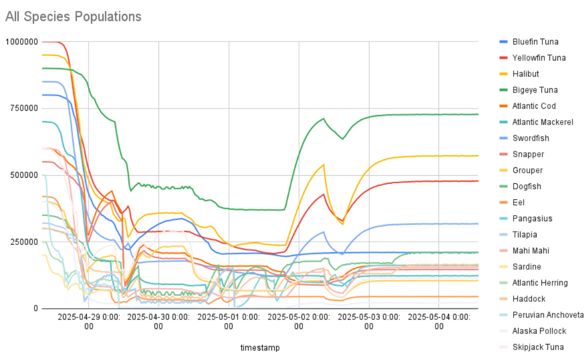

Fig. 1. Fish species populations over time.

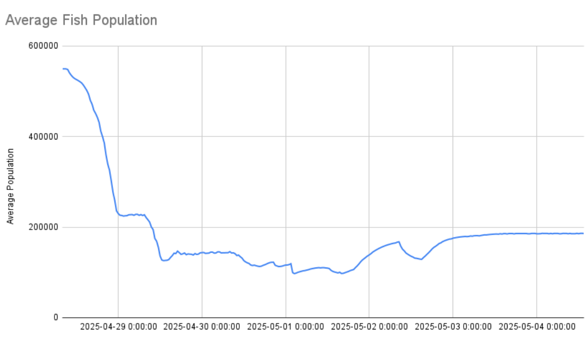

Fig. 2. Average fish population over time.

B. *Wealth Disparity and Resource Access*

A Gini coefficient of 0.9778 was calculated at the end of the simulation, indicating a high degree of inequality in wealth distribution. Players who acquired ships early and reinvested profits accumulated disproportionate resources over time.

Figure 3 and Figure 4 shows the distributions of wealth.

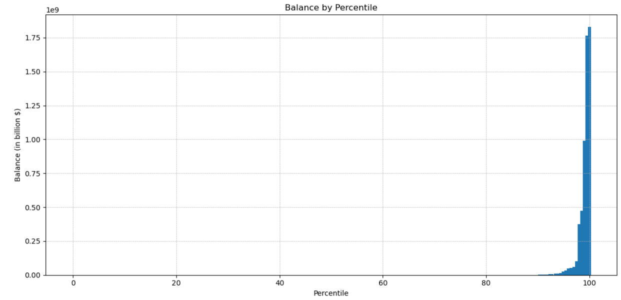

Fig. 3. Final non-negative in-game balance by player. A small elite held the majority of wealth.

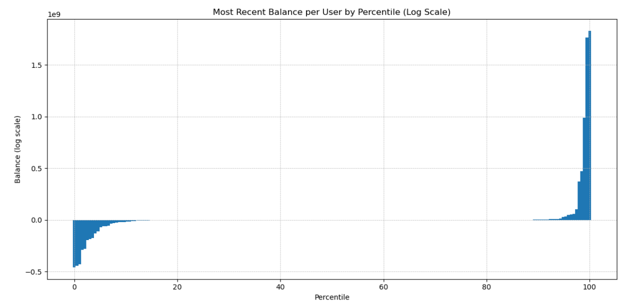

Fig. 4. Final in-game balance with negative values.

Many users stopped participating in the simulation prematurely after being unable to compete with better-resourced players.

C. *Emergent Cooperation and Market Manipulation*

In the absence of enforced regulation, several groups of users formed alliances. These groups traded among themselves at favorable rates and coordinated fishing efforts to gain strategic advantages. Some cartel-like structures even attempted to monopolize ship supply by buying and hoarding all available vessels. Figure 5 Show the top players balances over time, where transfers between players can be seen(C and A + B, D and E).

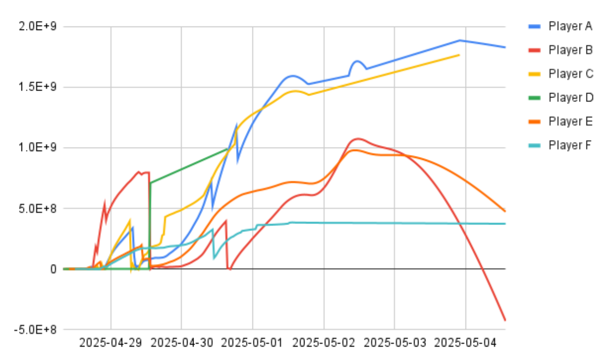

Fig. 5. Player Balances over duration of Simulation

In one case, a group of players engaged in what appeared to be ecosystem sabotage: overfishing intentionally to damage the economic potential of competitors. This behavior accelerated collapse of certain species and created a "scorched earth" dynamic, where destruction of the environment prevented anyone from earning profit.

These dynamics mirror real-world CPR scenarios where the absence of enforced cooperation leads to short-term individual gain at collective long-term loss.

IV. Discussion

The OpenFishbanks simulation surfaced a number of important dynamics that highlight the complexities of managing common-pool resources (CPRs) in unregulated environments. Despite the simplicity of the digital ecosystem, player behaviors closely mirrored real-world strategic decision-making and economic phenomena.

A. Incentives and Ecological Degradation

Overfishing occurred rapidly and extensively, especially in the early phase of the simulation. This behavior reflects the tragedy of the commons [1], where individual profit-maximizing incentives override considerations for long-term ecological sustainability. The logistic fish population model allowed for regeneration, but the persistent pressure from unsustainable harvesting practices caused repeated collapses. While many species did not become fully exctinct, the majority ended with a fraction of their original populations. The effects of such large changes in population would cause a trophic cascade, leading to effects on other species beyond extinction. These results suggest that OpenFishbanks can recreate the destabilizing feedback loops observed in real-world resource systems.

B. Emergent Economic Inequality

The Gini coefficient of 0.9778 observed at the end of the simulation reveals a highly unequal wealth distribution, largely driven by early capital accumulation and strategic reinvestment. Players who failed to scale their operations early were effectively locked out of the economy, often ceasing participation. This trend highlights how market-based systems without regulatory or redistributive mechanisms can quickly consolidate wealth in the hands of a few.

C. Social Dynamics and Strategic Collusion

Several user groups formed alliances, coordinating trades and monopolizing ship resources to dominate the market. These behaviors illustrate the emergence of collusion, cartel formation, and anti-competitive strategies. Some alliances even engaged in deliberate ecosystem sabotage to undercut competitors, an unexpected strategy with real-world analogs in hostile market behavior and resource denial tactics.

D. The Role of Structure in System Outcomes

The asynchronous and persistent nature of OpenFishbanks allowed for the observation of long-term strategies that are often invisible in short, synchronous games. Without artificial turn boundaries or facilitator intervention, players were free to explore a wide range of tactics, many of which echoed classical game-theoretic models such as the Prisoner's Dilemma. These findings reinforce the notion that unregulated CPR systems such as OpenFishbanks are prone to collapse and inequity unless bounded by institutional, temporal, or cooperative constraints.

E. Implications for Real-World Resource Relationships

The behaviors observed in OpenFishbanks reflect deeper truths about our real-world relationship with nature. Just as players prioritized short-term gains over long-term sustainability, modern financial systems often incentivize exploitation through profit-driven structures. Those who expanded rapidly by reinvesting and accumulating assets dominated the game—mirroring how capital access and aggressive growth strategies often succeed in real markets, regardless of ecological cost.

The high wealth inequality and ecosystem collapse in the simulation underscore how unregulated environments allow destructive behaviors to flourish. Without constraints that align financial incentives with ecological preservation, both virtual and real-world commons remain vulnerable to degradation.

These results highlight the need for systemic change. Economic frameworks must reward cooperation and sustainability if we are to maintain the natural systems on which we depend. OpenFishbanks illustrates how exploitation is not just a failure of ethics, but a consequence of our system's incentives.

F. Conclusion

Through a week long simulation, OpenFishbanks was successful in replicating patterns found in real-world CPR system. The extended timeframe, asynchronous gameplay, larger playerbase, and focus on data collection enabeled and highlighted complex dynamics between players and their environment. The OpenFishbanks model and the lessons learned from it can be used for education on the role of larger systems in economic disparity and ecological collapse. These insights lay the groundwork for future studies in behavioral economics, resource governance, and sustainability education, emphasizing the power of simulation-based tools to foster understanding and drive meaningful change.

References

[1] G. Hardin, "The tragedy of the commons," *Science*, vol. 162, no. 3859, pp. 1243–1248, 1968.

[2] P. J. Deadman, E. Schlager, and H. R. Gimblett, "Simulating common pool resource management experiments with adaptive agents employing alternate communication routines," *Journal of Artificial Societies and Social Simulation*, vol. 3, no. 2, 2000. [Online]. Available: https://www.jasss.org/3/2/2.html

[3] D. Meadows *et al.*, "Fishbanks: A renewable resource management simulation," https://mitsloan.mit.edu/LearningEdge/simulations/fishbanks/Pages/Fishbanks.aspx, 1990.