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

Quinn Ryan Williams [1]
Advisor: Jodi Pickle [1]

[1]Concord Academy, MA

Background

Common-Pool Resources (CPRs) are shared ecological systems susceptible to overexploitation.

- Game theory (e.g., Prisoner's Dilemma) models individual vs. collective incentive misalignment.
- "Tragedy of the Commons" illustrates systemic failure when self-interest dominates.
- Prior models like MIT Sloan's *Fishbanks* were time-bounded, synchronous, and small-scale.

CPRs remain central to debates around climate policy, biodiversity, fisheries, and international regulation. Simulation-based approaches offer an ethical, scalable way to explore systemic outcomes.

OpenFishbanks Platform

OpenFishbanks extends CPR simulations to a scalable, persistent, web-based model.

- Built with Django, deployed on AWS EC2.
- Players fish, trade, manage fleets asynchronously.
- Features:
  - No turn boundaries; users can play any time.
  - Data-logged behavior for detailed post-hoc analysis.
  - Supports simultaneous participation from hundreds of users.

This platform enables study of long-term strategies, social group formation, emergent economies, and ecological tipping points.

Research Questions

This study investigates behavior and outcomes in a persistent CPR simulation.

- 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?

Insights can inform educational models, economic design, and sustainability research.

Experimental Setup

- **Participants:** 197 users (students and faculty at Concord Academy).
- **Duration:** 6-day live simulation with no enforced sessions or resets.
- **Incentives:** Real cash prizes awarded to the top 2 balances. Leaderboard visible to all users.
- **Initial Conditions:** All players began equally equipped.
- **Data Logged:**
  - Ship purchases, fish harvests, trades, species population, user balances.
- **Analysis Tools:** Python (pandas, seaborn, matplotlib) used for post-simulation visualization and evaluation.

Simulation Design

Key Mechanics:

- **Agents and Assets:** Each player begins with one low-efficiency ship and 20,000 credits.
- Ships have varying capacities and efficiencies. Assets are modeled as Django objects.

Fish Population Model: A logistic growth curve defines species regeneration:

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

where P_f is the population, k_f the intrinsic growth rate, and C_f the carrying capacity.

Harvesting Formula: Player yield is governed by ship stats and environmental availability:

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

which reduces the fish population:

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

Revenue Model:

$$\text{Revenue} = \sum_s \sum_{f \in F_{hs}} F_{s,f} \cdot w_f \cdot v_f$$

Trading System: Decentralized, user-to-user trade of ships and credits enables emergent cooperation, speculation, and sabotage.
Auction System: System to sell ships on open market with bidding and "buy now" functionality

Key Results

Ecological Collapse:

- Most fish species declined rapidly, especially low-value, high-density ones.
- Collapse driven by aggressive early overharvesting.
- Oscillations observed as players migrated boats between regions.

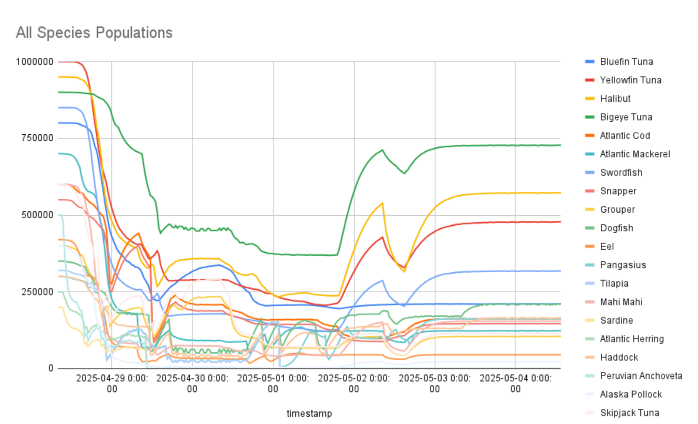
Wealth Inequality:

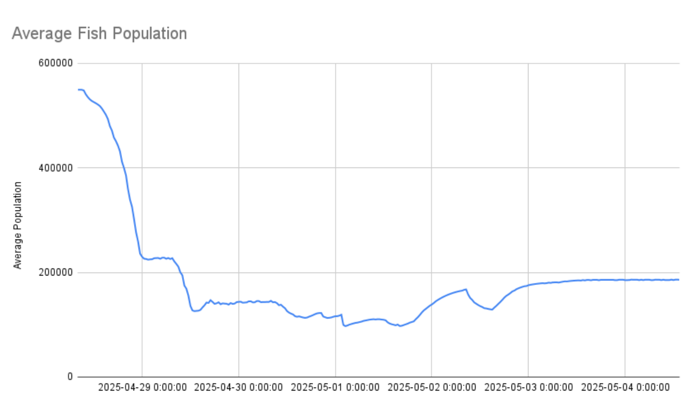
- Gini Coefficient reached 0.978 by end of simulation.
- Top users rapidly acquired additional ships.
- Poorer users unable to catch up, leading to disengagement.

Emergent Group Strategy:

- Cartels formed: users traded ships internally at favorable rates.
- Coordinated actions to corner ship supply and control markets.
- Ecosystem sabotage: some users overfished to hurt competitors.

Ecological Figures





Left: Populations by species. Right: Average population over time.

Economic Figures

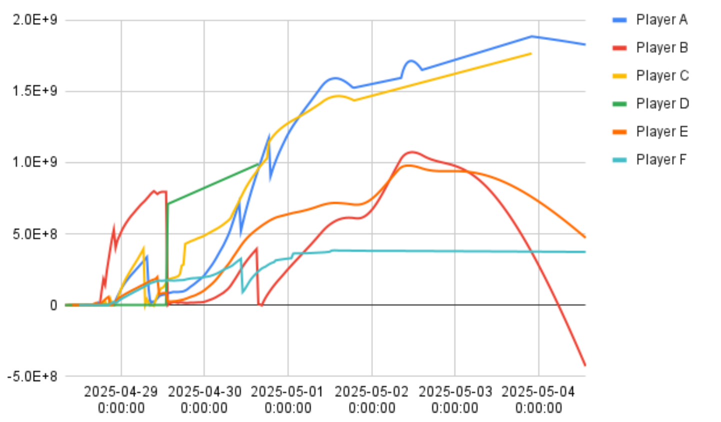


Figure 1. Top 6 Players Balance v Time

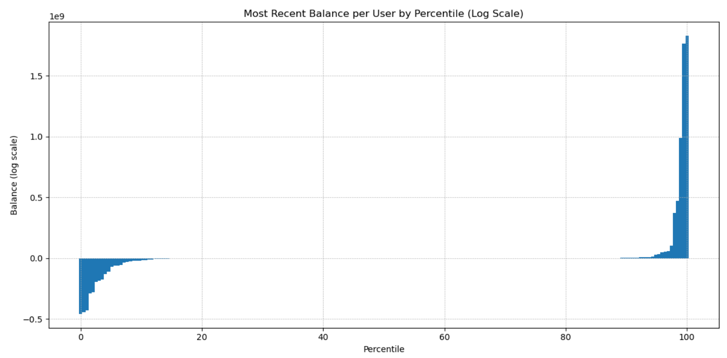


Figure 2. Wealth Distribution by Percentile

Discussion & Implications

- **Ecological Insight:** Demonstrates CPR collapse from individually rational strategies.
- **Economic Inequality:** Wealth concentration closely tracked asset accumulation.
- **System Structure Matters:** Lack of regulation enabled destructive behavior.
- **Simulation Value:** OpenFishbanks is a powerful tool for understanding emergent market failures.

Conclusion

- Persistent asynchronous simulation allows long-term strategy observation.
- Unregulated CPRs tend toward collapse and inequality without corrective forces.
- Educational use: ideal for game theory, economics, sustainability modules.
- Future work: introduce taxes, quotas, or regulations.

References

[1] G. Hardin, *The Tragedy of the Commons*, Science, 1968.
P.J. Deadman et al., *Simulating Common Pool Resource Management*, JASSS, 2000.
D. Meadows et al., *Fishbanks Simulation*, MIT Sloan, 1990.