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The Codfish Game

Each of eight countries in a fishery decides how many fish to catch each decade. Each country i picks an integer number X_{it} as its fishing catch for decade t. The country's profit for decade t is

$$20X_{it} - X_{it}^2. \quad (1)$$

Thus, diminishing returns set in after a certain point and the marginal cost is too high for further fishing to be profitable.

The fish population starts at 112 (14 per country) and the game continues for 5 decades. Let Q_1 denote the fish population at the start of decade 1. In decade 2, the population is

$$1.5 \cdot (Q_1 - (X_{1t} + X_{2t} + X_{3t} + ...)), \textit{ rounded up}, \quad (2)$$

up to a maximum of 400, where X_{it} is country i's catch in decade t.

If $X_{11} = 30$ and $X_{21} = X_{31} = ... = X_{81} = 3$, then the first country's profit is $20 * 30 - 30^2 = 600 - 900 = -300$, and each other country earns $20 * 3 - 3^2 = 60 - 6 = 54$. The second-year fish population would be $Q_2 = 1.5 * (112 - 30 - 7[3]) = 1.5(82 - 21) = 1.5(61) = 92$.

(1) Britain is the only country.

(2) The International Codfish Commission chooses the catch for all eight countries. Each country gets to propose a per-country catch quota to the ICC, so the total catch will be 8 times that quota. The proposals will be discussed publicly,and the Commissioner will decide. Once the catch is finalized, the instructor calculates the next year's fish population, and the quota process will be repeated.

(3) The ICC dissolves, and we start over with 112 fish. The eight countries choose independently. Each country writes down its catch on a piece of paper, which it hands in to the instructor. The instructor opens them as he receives them. If the attempted catch exceeds the total fish population, those countries which handed in their catches first get priority, and a country's payoff is $(20Z_{it} - X_{it}^2)$, where Z_t is its actual catch and X_t is its attempted catch, what it wrote down. Do this for 5 decades.

(4) Repeat the entire process but this time allow any countries that so wish to form a binding treaty and submit their catches jointly, on one piece of paper.

Scoresheet for "Fisheries"

Your Name:

Your Country's Name:

Decade	Fish Population	Your Catch	Your Payoff	Fish Population	Your Catch	Your Payoff	Fish Population	Your Catch	Your Payoff
1									
2									
3									
4									
5									
Total Payoff	—	—		—	—		—	—	

	1	2	3	4	5
INITIAL POPULATION					
USA					
Canada					
Korea					
Japan					
Britain					
Russia					
France					
China					
TOTAL CATCH					

	1	2	3	4	5
INITIAL POPULATION					
USA					
Canada					
Korea					
Japan					
Britain					
Russia					
France					
China					
TOTAL CATCH					

	1	2	3	4	5
INITIAL POPULATION					
USA					
Canada					
Korea					
Japan					
Britain					
Russia					
France					
China					
TOTAL CATCH					

TABLE 2: Histories

Instructor's Notes

Equipment: Scoresheets

This game illustrates the common-pool resource problem. It is a variant on the Prisoner's Dilemma.

1. Discuss the profit function for one year, using the calculus of maximization. Diagram showing X and profit. Intuition of the shape.

(a) If the social planner wants the catch to be Z, it should spread that Z evenly across the 8 countries, since the cost of catching fish, $-x^2$, is convex– increasing marginal cost.

(b) If there were just one decade, the social planner would solve

$$\underset{x}{Maximize} \quad 8(20x - x^2), \tag{3}$$

which has the first order condition

$$160 - 16x = 0,$$

so $x^* = 10$. If we denote the total catch by y_t in decade t, that means if there is just one decade then $y^* = 80$. Beyond $x = 10$, the marginal cost exceeds the marginal benefit, so even if the fish population were higher than 80, it is inefficient to catch more than 10 fish per country.

(c) If there are 5 decades, then the socially optimal policy would bring the fish population to 0 at the end of the 5th decade. Thus, $y_5 = 80$ if $Q_5 \geq 80$.

(d) Suppose there is no discounting and 5 periods. In this case, the aim is to choose a harvest path that maximizes the total catch over the 5 decades. This path balances two things: (i) waiting to catch fish later results in a larger population, and (ii) it is never efficient to catch more than 80 fish per decade.

The optimal policy will be $y_5 = 80$.

(e) Suppose there is no discounting and an infinite number of periods.

The aim will be to get the fish population up to a level where a harvest of 80 fish per decade can be sustained forever. That requires a population of 160. One policy is to catch no fish until that population is reached.

A better policy is to approach 160 gradually. The integer problem makes it tough to solve for the optimum.

With an infinite number of periods and no discounting, it turns out that the optimum is to reach a "sustainable" level of fishing. That was not true when there were only five periods, however.

Also note that "sustainable" does not mean "maximum sustainable". If the fish population were to start above 160, it should immediately be fished down to stay at 160.

Decade	Fish Population	Total Catch	Fish Population	Total Catch	Fish Population	Total Catch
1	112	40	112	0	112	0
2	108	40	168	56	168	8
3	102	40	168	80	240	80
4	98	40	132	80	240	80
5	87	80	78	78	240	80
6	7	—	0	–	240	–
Total Payoff	——-	240	——-	294	——-	248

TABLE 3: Some Possible Histories