April 21, 2011 Eric Rasmusen, Erasmuse@indiana.edu. Http://www.rasmusen.org.

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

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

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

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

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-decade 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.

(3) 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.

(2) Start over with 112 fish. An 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.

(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.

I have also tried starting the game with 230 fish, to show how the number would shrink, stopping it after a few rounds to note that eventually the number would drop to zero.

I usually haven't tried the last variant, the one where they can form binding agreements.

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

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

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

which has the first-order condition

$$160 - 16X = 0,$$

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

(c) 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 include $Z_5 = 80$, catching all the fish in decade 5, since we don't care about any future periods. That is artificial, of course.

(d) Suppose there is no discounting and an infinite number of periods. It turns out that the optimum is to reach a "sustainable" level of fishing. 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 240, so that 240 = 1.5(240-80). One policy is to catch no fish until that population is reached. Another is to approach 160 gradually.

Note that "sustainable" does not mean "maximum sustainable". If the fish population were to start above 240, it should immediately be fished down to stay at 240.

These tables show some spreadsheet calculations (see http://rasmusen.org/GI/games/01_fish.xls).

The Optimum over Just Five Decades (approximated, because of rounding)

Year	Fish	Catch	End Fish	cost of catch	Benefit of catch	Net benefit	Total benefit
1	112	26	129	84.5	520	435.5	3341.25
2	129	44	127.5	242	880	638	
3	127.5	55	108.75	378.125	1100	721.875	
4	108.75	63	68.625	496.125	1260	763.875	
5	68.625	68	0.9375	578	1360	782	

Getting to a Sustainable Catch Quickly

Year	Fish	Catch	End Fish	cost of catch	Benefit of catch	Net benefit	Total benefit
1	112	0	168	0	0	0	2552
2	168	8	240	8	160	152	
3	240	80	240	800	1600	800	
4	240	80	240	800	1600	800	
5	240	80	240	800	1600	800	

Getting to a Sustainable Catch Slowly

Year	Fish	Catch	End Fish	cost of catch	Benefit of catch	Net benefit	Total benefit
1	112	0	168	0	0	0	2789.5
2	168	40	192	200	800	600	
3	192	50	213	312.5	1000	687.5	
4	213	52	241.5	338	1040	702	
5	241.5	80	242.25	800	1600	800	