

Classroom Games: The Allocation of Renewable Resources Under Different Property Rights and Regulation Schemes

Kelly L. Giraud and Mark Herrmann

Abstract: The authors describe a renewable resource allocation game designed to stimulate students' interest in and understanding of market failure associated with open-access types of resource use. They also use the game to discuss the advantages and disadvantages of various property rights and regulation schemes. Because this exercise demonstrates the power of unregulated and regulated economic incentives, many types of students may benefit from this game, including undergraduates enrolled in the standard introductory and in more advanced microeconomics classes, as well as courses in environmental economics and natural resource economics. This game was specifically designed so that non-economics majors in natural resource management and environmental courses could also benefit.

Key words: classroom games, fisheries, property rights, renewable resources
JEL codes: A2, Q2

Just because a natural resource is renewable does not mean it is inexhaustible. Depending on the property rights of the resource and environmental factors affecting net growth rates and resulting biomass levels, a natural resource may tend to flourish or to fade. Commercial fishing is often used as a classical example of an open-access resource; its regulation has been problematic because of the difficulty in assigning property rights. A varied number of property rights and regulation measures have been designed to correct the problems associated with the open-access nature of the resource. Regulations have included limited entry, regulated season lengths, area closures, gear restrictions, sex restrictions, size restrictions, bycatch restrictions, individual and community quotas, and combinations of these regulations. These management tools are designed mainly to control the harvest and to reduce overcapacity on the fishing grounds. Because of the variety of measures used to manage fisheries, an in-class exercise focusing on this particular renewable resource allows a multitude of participatory examples that demonstrate the benefits and costs of various realistic property rights and regulation schemes.

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Open access occurs when a resource is available to all who care to harvest it. There are few or no restrictions, and harvesting will occur until industry rents are dissipated. Because marginal private cost can be significantly lower than marginal social costs, Ricardian scarcity rents are not realized. Inefficiencies are manifested by overexploitation of the resource and overcapitalization by the harvesting sector. Commercial fisheries have a long history of facing such management scenarios. In an open-access fishery, the fishing grounds are exploited on a first-come, first-served basis because no individual has the property rights to the fishery, and, thus no individual has the right to legally exclude others from its use. Open-access fisheries can occur in the absence of effective collectively managed fisheries, designated as common property. Although open-access fisheries are now scarce in the pure sense, many are categorized as regulated open-access fisheries. The expected outcome of an open-access fishery is the “tragedy of the commons.”

Although in the United States pure open-access fisheries have disappeared because harvest levels have been controlled, many of these regulated open-access fisheries still exhibit the “race-for-fish” problem (Homans 1993). The race-for-fish problem is the source of much inefficiency, including vessel and fleet overcapitalization, management and marketing problems caused by severely shortened seasons, low quality of final product, and poor vessel safety performance (Wheeler 1991; Wilen and Homans 1993). Many commercial fisheries have been improved following the imposition of more stringent property rights that enhance the salient features of common property (see Stevenson [1991] for a more thorough discussion of the attributes of common property).

Simply put, common property resources are not everybody’s property. The concept of common ownership implies that those who are not members of a group can be excluded. The group may be small or large, but the “property” will have no meaning without the feature of exclusion (Wantrup and Bishop 1975).

Common property is defined in such a way that it encompasses a wide range of participant structures. It is often in the best interest of the participants to form an association in order to prolong the life of the resource. The resource may be sustainable into perpetuity, depending on the agreements and their enforceability.

The last general resource-ownership category is the situation of property rights that are held either by individuals for an expected catch as individual transferable quotas (ITQs) or by a single resource manager. In the case of ITQs, each individual is guaranteed a right to an individual quota of fish and may harvest the fish, choosing gear and time combinations under relatively relaxed regulations. The sole resource manager may be an individual, a government, or a small group that acts as one manager. In this case, a benevolent manager can manage the fishery in such a way that economic scarcity rents are fully realized. However, even if the manager can determine such an optimal extraction rate and optimal harvest level, additional costs are associated with such management, and there is a danger of resulting monopoly power in the marketplace.

In this article, we explain a game designed to lead to an initial understanding of the problems associated with open access, using fisheries as an example. Depending on the size of the class and the time allowed, students can participate in a market for a renewable resource under conditions of unregulated open access, common property, regulated open-access, and a system of individual transferable quotas (ITQs) with a limited number of time periods.¹

To keep the classroom game relatively simple to understand and easy to play in a standard class period, we assumed the game's outcomes to be a step-function for marginal cost (zero until a point where it becomes infinite), a constant output price, and a discount rate of zero. Because of these limitations, to complete the education experience, the instructor should be sure to have a discussion following the game of the concepts put forth in each scenario (either in the same class period or the next),² and the homework assignment is highly recommended. The discussion and homework assignment examining a sole ownership problem (see Appendixes C and D) are intended to lead to a more comprehensive discussion of fishing costs and other limiting assumptions that could not be expanded without making the game unduly complicated.

We cannot overemphasize the importance of the game as a stimulus for discussion. The game is a good lead into further lectures on the economics of fishery management. Finally, an experienced instructor may alter this game to cover additional scenarios or to add further realism to the experience.

GENERAL GAME PROCEDURE

It is helpful to set up this exercise about 15 minutes before class. Using candy to represent fish offers a good incentive for participation. For a class of 15 to 30,³ the instructor needs to buy paper lunch bags to be used as holding tanks, five bags of small candy (miniature candy bars work best), and five bags of larger candy.⁴ Before class, the candy should be separated into a few bags of 70 pieces in order to save time (see the following scenarios for the mix of candy to be used). The instructor spreads exactly 60 pieces of candy around the classroom, placing single pieces separately and others in large groups. Ten pieces of candy should be held back to simulate a stock of fish that was not harvested (hard-to-find spawners). After the first harvest, the instructor should explain to the class that in many fisheries increasing marginal costs (prohibitively low catch-per-unit efforts) may make it unprofitable to fish a fishery to extinction, that is, catch these scattered last 10 fish.⁵ To allow for the possibility of the stock becoming extinct, the instructor should just place all 70 fish out for the students to harvest. When students arrive, give them each the Instructions to Participant and the Accounting Sheet (Appendixes A and B), as well as a paper lunch bag holding tank. Tell them they are candy fishermen about to go out for their first harvest and that their goal is to maximize their individual profits (number of fish).⁶

Explain to the class that whatever candy population remains after each 20-second harvest interval will double in quantity up to 70 total pieces. In other words, the candy fish will spawn and grow every 20 seconds (interval times may change after scenario 1).⁷ However, it is very important to let the class know that

the carrying capacity of the fishery is 70 (this will allow the students to visualize easily the maximum sustainable yield of 35 fish). Let students know that they must stop harvesting when time is called. Locate remaining candy and add it to the population. For simplicity, the population can simply double after every 20 second interval but may not exceed the carrying capacity of 70 in any given round. Because this game is best played by using three or more rounds per scenario, for the purpose of this article, the game is explained using three rounds. Make it explicit that the discount rate for this game is zero. The effects of a positive discount rate are very important and should be discussed after playing the game. Make sure to collect the candy from the students after each round. This candy will be needed for succeeding rounds. An assistant may be used for candy collection and redistribution, but a single instructor can handle all aspects of this exercise.

At the end of each scenario, have the students fill in their individual catches on their Accounting Sheet (Appendix B). It is very important to tell them not to total the profits for each scenario until after *all* the scenarios have been played and the instructor has given further instructions. Before the game begins, some questions may arise that focus on the rate of population growth and candy size and type. We assume that all candy, no matter the size or type, is the same species. For the start of the game, we also assume that all candy is sold for the same amount (and has the same reproductive potential) regardless of size. Therefore, for simplicity, in the initial rounds it does not matter what mix of candy size remains after each round. In reality most fish are sold by the pound (larger fish may receive a higher price per pound). The sale of fish is simulated in the option to scenario 5. The instructor may try, however, to keep the population demographics (proportion of small to large candy) similar when the population is allowed to grow.

SCENARIOS

Scenario 1: Open-Access Scenario

During the explanation of the game, students are likely to become hungry and want to get started. Let the students know that the candy fish will represent the profits and are not to be eaten (yet).⁸ In our experience, the candy population that is set out usually becomes depleted within the first round. The profits for students are calculated and the number of fish harvested is written on their Accounting Sheet (Appendix B). For the second and third round, leave the unharvested candy fish on the ground and add any hard-to-catch spawner stock that was held back. Then double the fish up to the carrying capacity of 70 fish, again holding 10 back, and let a new round begin. After each round, have the students tally their profits and record them on the Accounting Sheet. In our experience, most classes will harvest until all the 60 candy fish are gone. The sustainable fishery will then yield 10 fish per year (those in which the cost is too high to harvest). For simplicity, this game focuses on revenues; however, the classroom discussion and homework assignment help to teach the students that open-access profits are predicted to yield zero economic profits.

Scenario 2: Regulated Open Access: Capital Restrictions

In this round, allow open access again, with exactly 60 pieces of candy spread around the room. This time, tell the students that they must put their paper bags down and may not use their hands to pick up the candy.⁹ This restriction should make candy harvesting somewhat more difficult. If a student asks if they can use their hands at all, or something else, repeat the phrase, “You must put down your paper bags and you may not use your hands, to *pick up* the candy.” This time around, students will probably have more candy-harvesting savvy. Watch as they invest in other forms of capital, such as using the end of a shirt or a pocket to hold the candy as they pick up additional pieces of candy with their teeth or their foot and a piece of paper. This exercise simulates a fishery with severe gear limitations. Treat the rest of the scenario in the same way as scenario 1. The capital restrictions may or may not be successful in slowing down the fishery but should lead to additional capital investments. Whether the fishery is slowed down or not, the race-for-fish aspects of the fishery remain intact and again, as in an actual fishery, economic profits might be fully dissipated. Again, see discussion suggestions and the homework assignment (Appendixes C and D) as additional aids for explaining this topic more fully.

Scenario 3: Regulated Open Access: Time Restrictions

In this experiment, allow only 5 seconds for students to harvest the 60 pieces of candy. The time limit can be combined with scenario 2’s capital restrictions, if desired, to teach the students that in many fisheries several regulations are used in combination. If the classroom is big enough, the students should not be able to make the candy go extinct in one round. Watch as they find the larger piles of candy, leaving the stray pieces and the pieces that are difficult to reach. They may, however be experienced enough to collect all of the candy in five seconds. Record profits as in scenario 1.

Alternative Option. An alternative to setting a time limit is to set a quota for harvest. Discuss with the class that a fisheries economist has determined that the long-run optimal harvest rate is set to leave the fishery with 35 fish after the harvest has taken place. Choose a student fisheries (candy) manager and tell that student that only the exact quota should be harvested under this regulated open-access fishery. Have the student manager pick the exact time that he or she believes will achieve the goal. Tell the harvesting student fishers that the time limit has been set to maximize their profits and they should harvest only as much as they desire. After the candy reproduces (if over 35 fish remain) for the next round, set another quota (remining fish over 35) and give the student manager another chance to set the time. If after reproduction, less than 35 fish remain, have the manager announce a season closure for the round.¹⁰

Scenario 4: Common Property

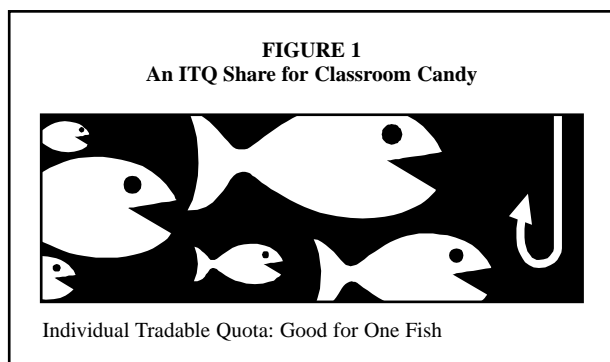
In this round, students should be broken up into groups of about five with their paper bags. Collect the candy from the open-access scenario and place a pile of

exactly 60 pieces on a table (with 10 held back) placed *behind* each group of students. Tell the students that they will take turns going up to the candy and that the others will not be allowed to see them harvesting. The students are allowed to discuss their harvesting plans before the harvest begins and to reach agreements if they desire. Students may collude if they wish, but each student will harvest his or her candy in turn, allowing them to cheat if they want to. The fish population (including the 10 held-back spawners) will have time to increase up to 70 after each student in the group has had a turn harvesting. If there is more than one group, have the students divide their individual fish profits by the number of groups when entering their profits. Otherwise, the profits will not be comparable to those in scenario 1.

Scenario 5: Individual Transferable Quotas

Play this scenario as a single round. Announce that although all the students are expected to maximize their profits from the fishery, only half of the students will be given quotas. The quotas need not be given out in equal amounts.¹¹ Give each student a share (Figure 1) of candy to harvest that will total to the maximum sustainable yield (MSY) level of 35 fish.¹² Tell the students that after they harvest their share of the candy and payments are recorded and totaled, they can sit down and eat (or keep) it.¹³ Place a long-time limit (of three minutes or more) that would emulate an annual season that was set on biological principles. Secretly time the harvest. Afterward discuss the amount of time (season length) that it took to harvest the candy under an individual transferable quota system vs. the amount of time to harvest under an open-access system. On the Accounting Sheet, the individual profits will be multiplied by two (see Filling Out Instructions Sheet section and Instruction Sheet in Appendix B) to make the profits comparable to move from the other scenarios.

Alternative Option—Highgrading. For more realism, the problem of highgrading¹⁴ associated with ITQs can be added. This time, use 70 pieces of different-sized candy (35 small and 35 large). Tally the candy, keeping track of not only the total number but also the number of large versus small pieces harvested.¹⁵



Scenario 6: Sole Resource Manager versus Open Access— Homework Assignment (Appendix C)

Assign this round for homework. Because the computations are very easy, the benefit of this exercise is in the discussion. Each student is to act as the sole resource manager of the 70 fish and to optimize harvest for an infinite time period. Again, assume the discount rate is zero. The MSY is a harvest of 35 fish, which is what a sole resource manager would harvest. In this case of constant price and zero marginal cost (up to a harvest of 60 fish), MSY is also the optimal economic yield.¹⁶ Tell the students that the open-access fishery has two fishermen who do not communicate with each other, and each assumes the other will harvest as much as possible. The open-access solution is to harvest all 60 fish (excluding the 10 hard-to-find spawners) in the first round and then 10 fish each subsequent round. Have the students calculate total profits for five rounds (175 fish for the sole owner and 100 fish for open access). The discussion questions for the students are shown in Appendix C.

Filling Out the Accounting Sheet

Two total profits are important for this game—the total individual profits and the total industry profits. For simplicity, we assume that marginal cost is zero for the first 60 pieces and infinite for the last 10 pieces (which are held back by the instructor). The price is simply one dollar per piece. Because of the importance of the idea of sustainability, total profits should be calculated in the following way. For scenarios 1, 2, and 3 add only rounds 2 and 3 into the total profits. This approach ignores the first round harvest glut with the idea that including only subsequent rounds gets at the idea of sustainability more closely. This method is a function of the short amount of time in which to play the game. If there were time for more rounds, the first-round harvest would dissipate in the average total harvest as the rounds continued.¹⁷ For scenario 4 (the common property scenario), add rounds 1 and 2 only. In the common property scenario, the last round (round 3) might be rationally harvested to extinction by the group, because it is the terminal round for the game. This is just an artificial terminal round and not a true representation of the fishery. Therefore, round 3 of the common property scenario is ignored, and the steady state is calculated from rounds 1 and 2. Finally, for scenario 5 (ITQs), double just the first round because this is only a one-round game. It is very important that the students do not know what rounds will be used in the total before all scenarios have been completed so that they will not try to manipulate the outcome.

DISCUSSION

Classroom discussion can take place after each scenario or at the end of the game (either the same day or the next class period after the homework assignment has been completed). The game was designed specifically to stimulate classroom discussion rather than to simulate every nuance of an actual fishery setting. After each scenario (or after all have been completed), the class should

discuss what were the incentives and particulars of the fishery that led to the game outcomes and how an actual fishery might follow a similar pattern or deviate from the exercise outcomes.

It has been our experience that students enjoy this activity. They report that hands-on exercises help them to understand and retain difficult economic concepts. Students have said that they were able to appreciate more fully the difficulty of natural resource policy design and that the life-like examples were useful. We have also found that students feel freer to discuss concepts after they have been actively engaged in learning them.

After the game has ended, have a discussion of the comparison of the different outcomes of each scenario. It is important that in this discussion both individual profits and industry profits are discussed and compared. Use the industry profits to introduce the concept of efficiency into the analysis of each scenario. Have the students discuss which might be the best way to manage the fishery. The discussion questions listed in Appendix C will help facilitate the discussion.

We have included two handouts for the end of the class period. The first (Appendix D) is a follow-up homework assignment designed to expand on some areas of the game's limitations caused by its simplifying assumptions. This homework assignment is merely a framework and was designed to be modified by each instructor. Also included is a handout (Appendix E) that gives an example for each of the above games of U.S. fisheries managed under similar policy scenarios. Additional copies of this handout (and all appendixes) can be acquired by e-mailing the lead author. If desired, have the students research a resource of their choice that is being managed by one of the above scenarios or other common management schemes (fisheries are also managed on gender and size restrictions, territorial right use, transferable pot quotas, etc.).

APPENDIX A

Instructions to Participants

In this game, you will be asked to become a candy fisher. *Your goal is to maximize your profits.* You will receive a holding tank in which to keep your candy. There will be three rounds per scenario. At the end of each fishing round, you will be told to stop harvesting candy. Your profit will be measured by the amount of fish you catch, each fish is equal to one dollar in profit. Write down the number of pieces you harvest after each round. *Do not* fill in the total profits for now.

Round 1: Open access

You are the captain of a candy-fishing vessel; you and your classmates have open access to the candy. When your instructor says, "Go," start harvesting the candy any way you see fit. The candy will spawn and regenerate every 20 seconds. Time will be called every 20 seconds, and you must stop harvesting.

Round 2: Regulated Open Access: Capital Restriction

In this round, there is open access but there are restrictions on the types of capital that are legal for specific uses. You may not use the lunch bags or your hands to harvest the candy. The population will be allowed time to regenerate every 20 seconds. You must stop harvesting when time is called.

Round 3: Regulated Open Access: Time Restrictions

Harvesting in this round will last only 5 seconds (or whatever the student fishery manager picks if this option is used). You must stop when time is called.

Round 4: Common Property

Please get into groups of about five, facing in the same direction. Set a desk or table behind you. This is where the candy will be found. You may collaborate if you wish, but you will take turns harvesting the candy while the rest of your group faces the other way. The candy population will regenerate after each member of your group has had a turn.

Round 5: Individual Transferable Quotas

Your instructor will give some of you an individual quota to harvest, which you may not exceed. These quotas do not expire after one round. Once harvest begins you have two minutes to harvest. After you are done with your harvest you may keep and eat the candy (after you record your profits).

APPENDIX B Accounting Sheet and Instruction Sheet

TABLE B1
Accounting Sheet
(Distribute one to each student)

	Round 1 Individual profit	Round 2 Individual profit	Round 3 Individual profit	Total Individual profit	Total Industry profit
Scenario 1 Open access					
Scenario 2 Capital restrictions					
Scenario 3 Time restrictions					
Scenario 4 Common property					
	Round 1 Individual profit			Total Individual profit	Total Industry profit
Scenario 5 ITQs					

Do not fill in the two total columns until after all scenarios have been played, and the instructor gives you additional instructions.

TABLE B2
Instruction Sheet
XXXs mark the rounds that are deleted from the final student accounting
DO NOT DISTRIBUTE THIS SHEET.

	<u>Round 1</u> Individual profit	<u>Round 2</u> Individual profit	<u>Round 3</u> Individual profit	<u>Total</u> Individual profit	<u>Total</u> Industry profit
Scenario 1 Open access	XXX				
Scenario 2 Capital restrictions	XXX				
Scenario 3 Time restrictions	XXX				
Scenario 4 Common property			XXX	<i>These profits should be divided by the total number of groups for direct comparison with scenarios 1–4.</i>	
	<u>Round 1</u> Individual profit			<u>Total</u> Individual profit	<u>Total</u> Industry profit
Scenario 5 ITQs		XXX	XXX	<i>These profits should be doubled for direct comparison with scenarios 1–4.</i>	

APPENDIX C
Discussion Questions¹⁸

1. Open Access
 - a. Was the fishery fished to a suboptimal profit level or to near extinction? Why?
 - b. Given the rules of this scenario and the resulting outcome, did the fishers act irrationally?
 - c. What did you learn about incentives (what was the individual profit maximum found for each fisher)?
 - d. In an actual open-access fishery, economic profits are predicted to be zero. Why? Are fishers fishing at zero economic profit rational?
 - e. What kind of market failure is this?
 - f. Will open access *always* lead to exploitation and/or extinction? Discuss this in terms of the value of the fish harvest and the cost of fishing. Would there be a difference if the open-access fishery were for blue whales vs. flounder?
 - g. If you determined the fishery was overharvested, should it be shutdown?
 - h. What are some of the other (nonmonetary) losses associated with overharvesting?
 - i. When might you want to fish a fishery to near extinction (or would you ever)? Discuss the effects of not totaling the first-round profits and how investment income from first-round profits might alter the optimal solution. Also discuss what a very high discount rate would mean.

2. Regulated Open Access with Capital Restrictions
 - a. What was the change in behavior that resulted from the restrictions? Did anyone make additional “capital investments”? (Like using a hat or untucked shirt to hold the catch or pens or pencils to stab the fish.) Why?
 - b. If additional capital investments in an actual fishery were made, what might happen to individual and industry profits?
 - c. Would you choose to invest in extra capital if this candy was your best chance to make a living?
 - d. If capital restrictions led to a more profitable fishery it might well be the case that the resulting positive economic rents will fully dissipate just as in the case of the open-access fishery. Why?

3. Regulated Open Access with Time Restrictions
 - a. Discuss the advantages and disadvantages of controlling a fishery through season length.
 - b. Discuss the real-life implications to a fishery manager, of having set the time limit too long and having too much fish harvested, or too short and having too few fish harvested.

4. Common Property
 - a. What was gained through cooperation?
 - b. Why did the instructor only allow you to count your first two rounds of harvest? Why might your optimal decision on the first two rounds differ from your decision on the last round?
 - c. What are some common types of cooperative agriculture?
 - d. What are the features of fisheries that make cooperation among harvesters difficult?
 - e. Do you have any ideas on how these difficulties could be overcome in actual fisheries?

5. Individual Transferable Quotas
 - a. How did the speed of harvesting change?
 - b. Discuss lengthening the season by this technique versus the capital and time restrictions in scenarios 2 and 3.
 - c. Discuss the fairness of possibly giving the individual quotas to only half of the class and leaving the other half without quotas.
 - d. In an actual fishery, discuss who should receive the permits. Should the recipients buy them?
 - e. In an actual fishery participants would be able to buy and sell permits from one another. What might the expected price of the permits reflect?
 - f. If highgrading was added, discuss what happens to the fishery when the largest and most valuable fish are removed and the smaller ones remain.

In summary, which scenario is the “best” way to manage a fishery? What criteria did you use to make this decision?

APPENDIX D

Homework¹⁹

1. *Round 6: Sole Resource Manager vs. Open Access:* You are the sole resource manager of a fishery that has a carrying capacity of 70 fish; you have the task of managing it to maximize profits for an infinite time horizon. Total annual harvest may not exceed 60 fish, as the last 10 are very difficult to find and it would cost too much to do so. The total number of fish that are not harvested will double after each round. Assume that the discount rate is zero (i.e., you treat each time period as equally valuable when you start the first round). As the manager, you will determine how many fish will be harvested in each round.

TABLE D1
Profits

Round	Sole manager	Open access
1		
2		
3		
4		
5		
Total		

a. As the sole manager, how many fish would you harvest in each round to maximize your total harvest for an infinite time horizon? Write down the harvest for the first 5 time periods and add the total (Table D1).

b. Now assume that this same fishery was harvested by two fishermen who do not communicate and who each assume the other will harvest as much as possible (open-access situation). What do you expect would be the total harvest in the first five rounds under this scenario? Total the five-period profits and compare to the sole manager solution.

c. Under part (a) if you reached the correct optimal solution you will have reached the Maximum Sustainable Yield (MSY). Although many fishery quotas are set based on the MSY principle, optimal economic yield is rarely at the harvest level that MSY is. Assuming that output price is constant, discuss why MSY would be an economic optimum if the fishery was harvested based on a revenue maximum principle or had constant marginal harvest costs.

d. How would the use of a positive discount rate change the discrepancies that are found between the sole manager and the open-access solutions?

2. In general, explain why the optimal economic yield will not be at MSY when fishing costs are considered.

3. When we played the game we assumed a harvest cost of zero. How would your answers for the total industry profits change in each scenario played in class if it was assumed that the total industry harvest cost of fishing was 10 fish/year (or \$10 per year if each fish is sold at \$1.00). Are the new profit levels consistent with economic theory?

4. If economic profit increased with scenario 2 (capital restrictions) why would economic theory predict that eventually any additional profits might be either partially or fully dissipated?

5. In general terms, what factors might influence the market price for ITQs (scenario 5)?

APPENDIX E

Handout to Distribute after Game Is Played

Some Fish for Thought: Examples of Real Live (or Dead) Fisheries

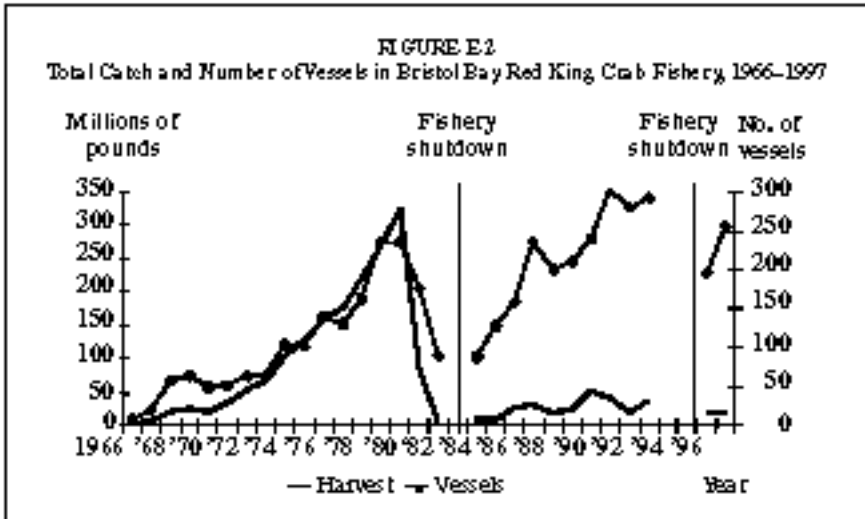
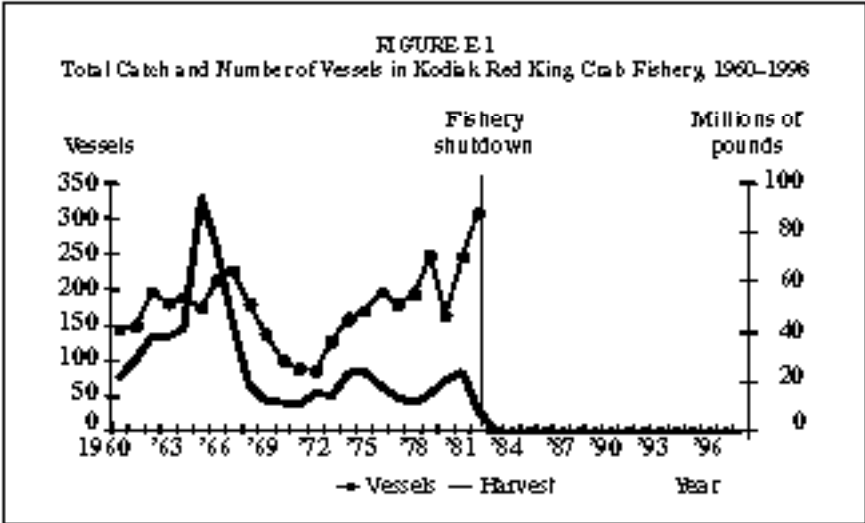
Open Access

The Kodiak, Alaska, crab fishery was once among the most lucrative fisheries in the world. It was also once an open-access fishery. In 1971, the fishery peaked with a harvest of 94.4 million pounds of red king crab. In 1982, the last year of the fishery, the number of vessels peaked at 309, an upward trend that continued from 1972, for a 250 percent increase. The Kodiak red king crab fishery was permanently shutdown in 1982. Figure E 1 shows the relationship between catch and the number of vessels each year. See any connection?

Open Access with Capital Restriction

The red king crab fishery of Bristol Bay was even more lucrative than the Kodiak fishery. It was also once an open-access fishery. The Bristol Bay fishery peaked with a harvest of 130 million pounds in 1980 (worth \$115 million to the 236 vessels). Three years later, the fishery had shut down. It reopened in 1984, and although total harvest remained flat, vessels grew to a record 302 in 1991. The Bristol Bay fishery shut down again in 1994 and continues to struggle today under strict regulations. Figure E 2 shows the relationship between catch and the number of vessels fishing each year.

You will notice that the number of vessels remains high. In addition, the number of pots each vessel carried was growing each year. The Alaska Department of Fish and Game



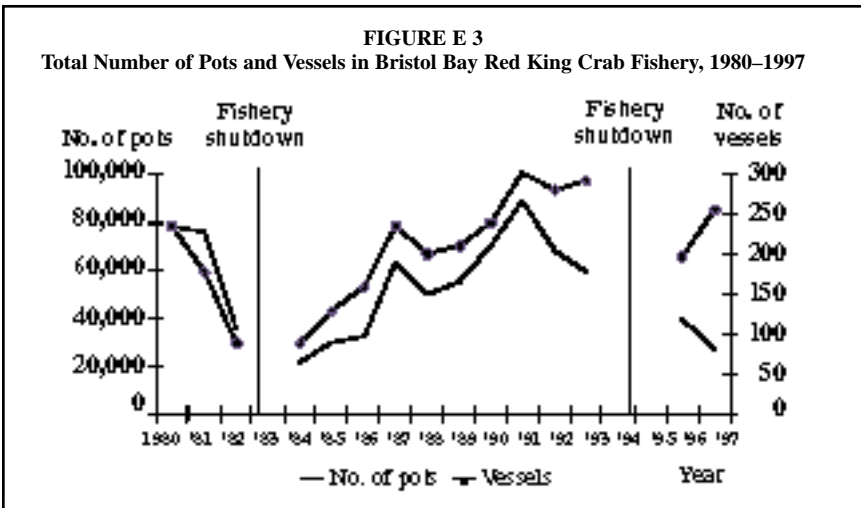
requires at least a five-day season, and preferably seven, to be reasonably assured that they can manage the fishery so that the total harvest will not exceed the industry quotas. To combat this tremendous effort in a fishery, where the season length had dwindled to just 4 days, pot limits were introduced. In 1981, the average vessel was fishing 482 pots, because of regulations; in 1997 the average vessel fished just 107 pots. Therefore, despite the increase in vessels, the number of total pots on the crabbing grounds has diminished (see Figure E 3).

Open Access with Time Restrictions

Nearly every fishery has time restrictions. In addition to protecting the stocks at vulnerable times of the year, time restrictions are used to limit effort to a level where the total allowable catch (TACs), set by the regulatory agencies, can be harvested. In some fisheries, such as the salmon fisheries, permitted hours of harvesting may vary during the week. A salmon fishery may have a one-day opener and then three days off to let a sufficient number of salmon escape to spawn before the next opener is set. Some fisheries, such as some Pacific herring fisheries, have become so overcapitalized that the season has been as low as two hours, just enough time to make one set. A short season can be problematic for managers. In the 1996 fragile king crab fishery a four-day season led to a harvest that was 65 percent over the guideline harvest. The Alaska Department of Fish and Game has stated that they need five days at the very least (although preferably seven) to properly manage that fishery in order to monitor progress and have enough time to make emergency closures.

Common Property

One of the most interesting types of common property is said to occur in Adak, Alaska, with the brown king crab fishery. In this fishery, there is no formal, or legal, association to control harvest or effort. Instead, quasi-property rights appear to have developed in the fishery, resulting in fishery prosecution occurring under a regime that more closely resembles that expected for a common property resource than an open-access resource. Christy (1982) described territorial rights as TURFs (territorial use rights in fisheries). Under current conditions of relatively low fishing pressure, common property rights



appear to have effectively regulated spatial distribution of fishery effort to avoid conflict, gear loss, and excessive capitalization (Herrmann, Greenberg, and Criddle 1998).

How has this thriving fishery managed to avoid the problems associated with open-access fisheries? In the Adak brown king crab fishery there is a “gentleman’s agreement” among harvesters not to fish near other participants or in regions others have repeatedly harvested in prior seasons. Crabbing grounds are marked by use of excess crabbing pots tied to buoys, facilitating harvesters’ ability to return to the same fishing grounds. This ability to retain and protect fishing grounds (including crab rookeries) has led participants to manage their crabbing ground much in the same way as a sole proprietor would, maximizing benefits over the long term.

Individual Transferable Quotas

Individual transferable quotas are the most controversial, and one of the most important, fisheries management tools today. An excellent literature review of the ITQ system can be found in Squires, Kirkley, and Tisdell (1995). There are literally hundreds of publications on ITQs, but one of the most recent works regarding ITQs has just been undertaken by the National Research Council (1999). One of the most beneficial aspects of ITQs is that they transfer the right to a fish before it is harvested. In other words, a fisherman is guaranteed the right to a harvest, freeing him/her up from the frantic race for fish that results when an industry-wide quota is set and the fishery is operated on a first come first served basis. In this case a fisherman can choose, within a season, when and where to fish, instead of being forced to frantically compete for a pool of fish during small seasonal openings.

In the halibut fishery, the seasons in Alaska for Pacific halibut had dwindled to just two days. Halibut fishermen raced for fish when the seasons opened despite the fact that weather and market conditions many times made fishing hazardous and unprofitable. In Figure E 4, we show that season lengths for halibut had decreased from 120 days in 1974 to just two days in 1990 as the number of vessels grew and, concurrently, their harvesting power. In 1995, Alaska went to an individual fishery quota program (IFQ) in which each halibut vessel received a quota based on past performance. The resulting season length increased from 2 days to the current regulated length of 245. At the same time the price of halibut increased as more fresh halibut has entered the market (Herrmann 1996, 2000).

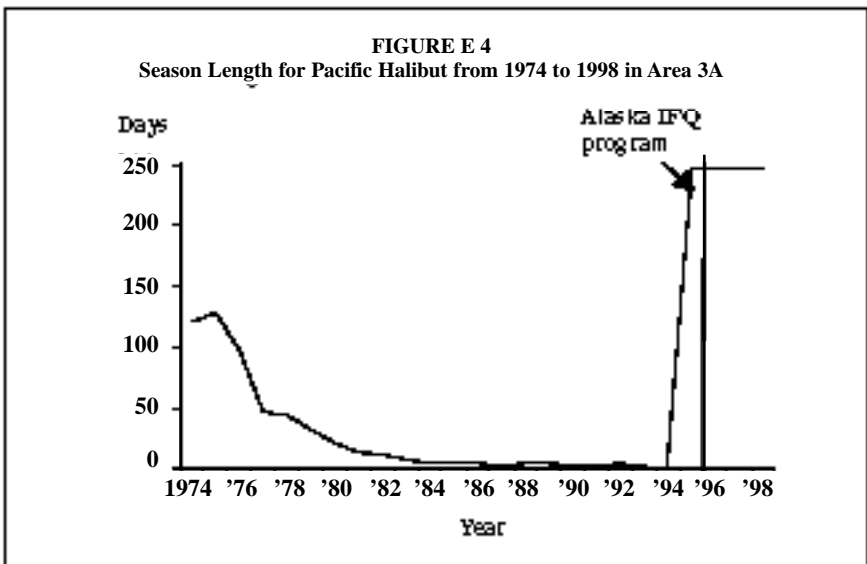
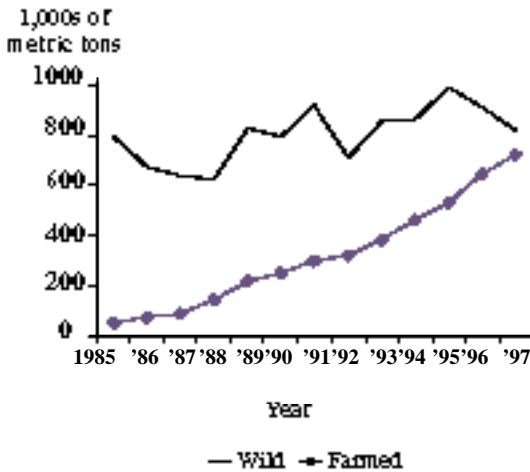


FIGURE E 5
Worldwide Harvests (1,000 Metric Tons) of Wild and Farmed Salmon, 1985–1997



Sole Resource Manager

Most commercial fisheries are not conducive to a sole resource manager. Instead, management can aim to achieve the same outcomes as if there were a benevolent sole manager. The problem is that, unlike farming, it is hard to give fishermen complete property rights to an area, and a fish species, for them to make long-run harvesting decisions. (The individual transferable quota example described in the previous section is one of the best ways to transfer the property right of a guaranteed harvest to the fishermen.) Exceptions to this are aquaculture. In particular, there has been a recent great success in salmon aquaculture, led by Norway. Salmon aquaculture allows farmers to farm salmon within floating net pens giving them the property right to a salmon much of the same way that ranchers have property rights to cattle. The amount of salmon produced in the world via aquaculture vs. wild harvests is shown in Figure E 5.

NOTES

1. Play the scenarios in order: in a one-hour class, scenarios 1 (2 or 3) and 4 can be played; in a 1.5-hour class, scenarios 1–3 and 4 and/or 5 can be played; and all scenarios can be played in a 2-hour class.
2. Alternatively, we usually partially discuss each scenario following the specific scenario and then have a more comprehensive discussion of the scenarios following the entire game, either during the same class period or in the next class period.
3. For classes larger than 30, it may be useful to break the class in half in two separate groups and use the help of another instructor. We have tried this exercise with large classes, having some students participate while others watch. We found that the observing students tended to get bored.
4. Double-check the number of candy pieces per bag on the back label of the bag. The number of pieces may vary across brands—about 120 large pieces and 200 small pieces works well. Supplies have cost about \$25 for premium candy in Alaska in 2000. This cost may be reduced by purchasing only miniature sized candy or waiting for postholiday sales.
5. This might be a good place to discuss a minimal viable population. For the purpose of this game, we assumed that any leftover fish could reproduce and increase the population.
6. For simplicity, in this game we use the number of fish to proxy for profits. However, in the sce-

narios in this game, the students are actually maximizing sustainable revenues (assuming a constant price and a zero discount rate). Although many of the important open-access lessons with regard to sustainability can be learned from focusing on revenues, a more complete analysis must include a discussion of costs. Therefore, the subsequent discussion suggestions and homework assignment are an important component of this exercise.

7. The instructor can use a logistic growth function instead if desired.
8. Implicit here is an assumption of the fishermen being price takers and also facing zero marginal costs (except on the spawners held back each round). For added realism, grade points can be substituted for pieces of candy. This can increase incentives as well as the stress level to that of real fishermen! We have found that using the point method increases the level, and understanding, of fairness and distribution.
9. An alternative option is to not allow the students to use their right hands.
10. Although the lesson from the option to scenario 3 is not as common in textbooks, it is very important in some fisheries. Essentially, the problem is that in fisheries with a lot of stock pressure and a very short season, it is difficult for managers to set a season in such a way that total harvest quota will be reached within a reasonable margin of error (see example in Appendix E).
11. In actual fisheries where ITQs have been used, the initial quota is usually based on harvest history. Therefore one option is to give all the quota shares to the half of the class with the highest previous earnings in proportion to what they earned.
12. Another option is to let students argue over who should get permits. For example, maybe they were early to class; maybe they are in-state students.
13. An additional option is to let the students trade the ITQs. To make this option more realistic the instructor needs to lengthen the time of the harvesting periods to multiple periods. Although we have used this technique, we find that the students are usually tiring of the game by this point.
14. Highgrading is when fishermen selectively harvest the larger fish and throw back the smaller ones. An additional twist to this scenario option is that the race for fish may continue with the race for the larger candy.
15. Note that in many fisheries, ITQs are established on the basis of weight, not the number of fish. However, you can explain to the class that here the incentive to harvest larger fish can reflect that many larger fish fetch a higher price per pound, not that they bring in more weight.
16. Because the marginal cost of fishing (for the first 60 fish) is zero, and the sales price is assumed constant and the discount rate zero, the optimal sustainable yield is the MSY. This is, of course, usually different from the optimal economic yield. This was designed for game simplicity and more realistic assumptions and resulting outcomes must be discussed in class (see Discussion Sheet and Homework Assignment in Appendix D). However, it also can be noted that whether economically optimal or not, many times fisheries are managed on an MSY target less a certain amount of stock held back to cover biomass estimation uncertainty.
17. It may be somewhat misleading to ignore the first-round harvest even in the idea of sustainability (i.e., first-round profits would be invested to provide a stream of future revenues). To partly address this, homework assignment number 6 compares an open-access solution and the sole manager solution, including the first-round profits. This is possible as five rounds are calculated.
18. It is not expected that the students will know all of these answers. They were designed primarily to introduce further discussion.
19. These are only suggested questions that can be altered by the instructor. For ease of alteration, an electronic copy of the homework can be obtained from the authors.

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