New Technologies and Innovations in Agricultural Economics Instruction

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An Experiential Learning Game to Demonstrate Common Property and Open Access Resource Problems

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Introduction

The concept of property rights and their implication for natural resource use and policy is fundamental to the teaching of natural and environmental resource economics. In developing an understanding of the role of property rights in resource allocation, the allocative consequences of private property are typically contrasted with that of either common or open access property rights. Unfortunately, the difference between common and open access resources is often misunderstood. In contrast to the failure of the commons as described by Hardin (1968), the commons was in fact an effective resource management institution based on a set well defined entitlements to property held in common (Hanna, 1990). Similarly, anthropologists have documented numerous examples of common property resources with intricate formal and informal rules governing their use (McCay and Acheson, 1987). By contrast, there are few, if any, examples of open access resources for which sustainable resource use institutions have evolved.

The purpose of this experiential learning game is to contrast the effect of competitive open access exploitation with that of community management and exploitation of a natural resource. In the game, a computer model is used to simulate an open access competitively fished and a common cooperatively fished fishery. Both fisheries operate simultaneously, although the common and the competitive fleets fish from independent stocks. At the beginning of each fishing season each student (boat owner) must decide upon a fishing strategy for that season. For the competitive fleet each student makes his or her fishing decisions in the absence of any knowledge of the other boat's activities. In the cooperative fleet each vessel fishes the cooperatively determined strategy. In this manner, the differences in fishing strategies, yields, and stock biomass can be tracked over time. The typical outcome is one in which the cooperative fleet achieves a sustainable yield whereas the competitive fleet fails to do so.

The remainder of the paper is divided into three sections. First, the mechanics of running the game and the computer simulation model are described. Second, a recent trial using the game in a graduate level natural resources course is described. The final section offers some tips and suggestions for variations in the way the game may be administered.

Running the Model Computer Simulation

The computer model provides a simulation of growth, mortality, recruitment, and catch/effort relationships for a hypothetical single species gill net fishery. The computer model itself was written by Barry L. Johnson, formerly of the University of Wisconsin. What follows in this paper is a general overview of the model. Additional information on the exercise can be found in Johnson and Stein (1986)[1]. If the reader does consult this source he or she will note that the learning objectives for their fisheries management classes differ somewhat from that of a natural resource economics class. In fact, rather than demonstrating the "tragedy of the commons" as Johnson and Stein put it, the exercise demonstrates the potential effectiveness of the commons as a resource management institution.

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The gill net fishery consists of ten age classes, of which, ages two through nine are susceptible to fishing mortality. Growth is assumed to be constant. In the gill net fishery there are eight different sizes of mesh that can be fished. The mesh sizes are expressed in centimeters and correspond to the age of the fish each size will catch. Hence, 2 cm mesh will catch only two year old fish and so on up to 9 cm mesh[2]. In the hypothetical fishery, a maximum of 50,000 meters of gill net can be fished, and a maximum of ten boats can make up a fleet. Each boat is given a total amount of net that can be fished by that boat. A simplifying assumption is made wherein, the total length of net is fixed but the mesh size is not. This assumption makes it possible for students to allocate their net to any mesh size they wish without having to be worried about keeping track of exactly how much net and what mesh sizes they have available. The assumption also reduces the oversight requirements of the instructor.

Recruitment into the fishery is governed by a stock/recruitment relationship with a random component. Stock size is equal to the total number of mature fish, where fifty percent of all fish reach maturity at age two and all fish are mature by age three. Each mature fish contributes the same amount toward recruitment regardless of age or size. Recruitment is proportional to the total stock with random variation. The model also includes a random weather component that affects recruitment. Catch rates are subject to diminishing marginal product up to 7,000 meters of net, after which, marginal product is zero. Catch rates are adjusted by a proportional factor if the stock in any given year class falls below seventy-five percent of its initial size.

A flow chart of the computer model is shown in Figure 1. The first screen prompts the user to either run the lab model, run a random number generator, or quit. The random number generator allows the user to view the random sequence of weather that is generated by a seed number; a number ranging between zero and one hundred, inclusive. Each seed initiates a sequence of random numbers, however, the same seed will always result in the same random sequence. Each random number represents weather conditions for any given year, where fifty represents an average year and any number below fifty is a below average year. The reverse holds for any number greater than fifty. The random number generator allows the instructor to choose a sequence of weather events prior to running the model. The second screen prompts the instructor to enter a seed number.

The third screen prompts the user for a fleet choice. Both fleets may be run simultaneously. Alternatively, one or the other fleet may be run by itself. The user is then prompted to enter the total number of boats in each fleet. The maximum is ten boats, but given the limit of fifty thousand meters of net, fewer boats may be preferable. The choice will depend upon the size of the class.

After selecting the number of boats, the instructor is given the option of having all output printed to the screen or to a printer. The first output screen gives the total population of fish by age class at the beginning of year one, for the collective and the individual fisheries. The instructor is then given the choice of entering the random number for the upcoming fishing season. If the response is no, then the random number sequence generated by the seed number will be used. Otherwise, the computer selected random number will be substituted with the instructor's choice. The advantage of selecting your own random number is the ability to directly control the sequence of good and poor weather years. The length of the classroom exercise can be shortened by consistently selecting poor to average weather conditions. Once the random number is entered, either by the user or the computer, the fishing strategies are entered.

The fishing strategies are determined by each boat owner and given to the instructor. Each strategy is entered one boat at a time. The collective strategy is always entered first. Since each boat uses the same strategy only one strategy is entered. The computer then applies this strategy to compute catch for each boat in the collective fleet. The computer will prompt the user to check the accuracy of the effort data that is entered. However, this is only done one time after each boat's strategy has been entered. If the user indicates that the data is correct, there

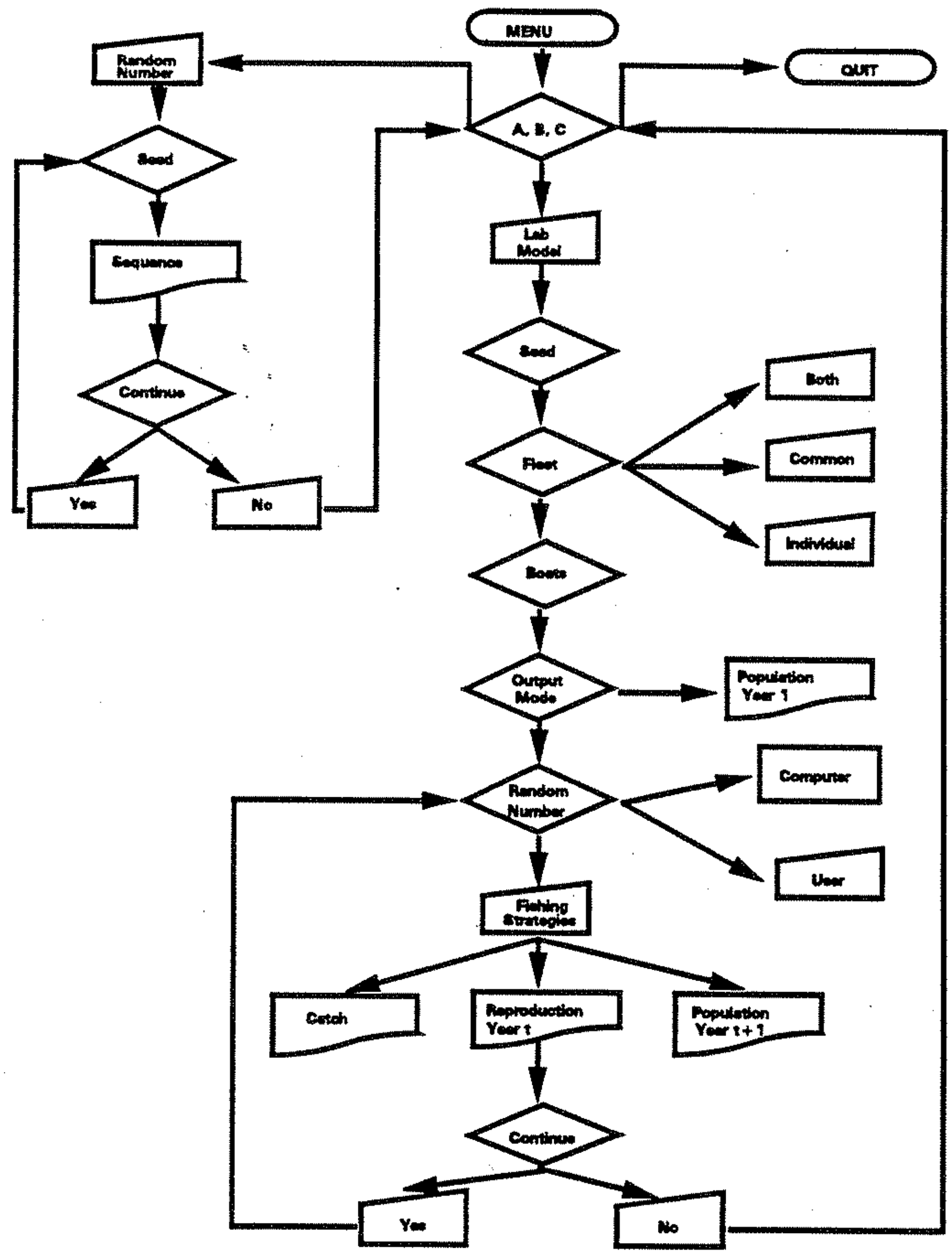

Figure 1. Computer Model Flow Chart

will be no other opportunity to make corrections even if a mistake has been made. A data entry error may completely alter the final outcome for that boat. Once all the fishing strategies have been entered, the computer prints out a summary of total meters of mesh fished by mesh size and total catch (quantity and weight). Cumulative weight totals for the year and for the exercise are also printed.

After the catch/effort tables are printed, the computer prints out recruitment data for the end of year one. The reproduction data includes the total stock size (the total number of mature individuals), the weather index for that year, the number of age 2 recruits, and a year class strength index. This information may or may not be given to the students. For fisheries managers this information may be particularly useful. However, for the typical natural resource economics class, this reproduction information is not likely to be very meaningful. Once the reproduction data is printed, the total harvestable population at the beginning of the next year by age class is printed. The user is prompted whether he or she wants to continue fishing, and the sequence of entering fishing strategies is repeated until the instructor stops the exercise.

Running the Classroom Game

The first step in running the experiential learning exercise is a brief orientation. During the orientation the biological functioning of the fishery, how a gill net operates, and the basic mechanism for recruitment into the fishery will need to be explained. The instructor may want to have a brief discussion of the role of property rights in natural resource use and may want to give the students some appreciation for the difference between open access and common property. Exactly how much detail to go into prior to running the game is up to the discretion of the instructor. After the orientation is completed, the class is divided into the two fleets. In the individual fleet more than one student may be assigned to a boat. The number of boats and students per boat will be a function of class size. All students operating in the common fleet will work together as one boat. Each fleet fishes independent stocks.

At the start of the game, students are informed that the objective is to catch the greatest cumulative amount of fish in terms of weight over the duration of the game. Various means of giving incentives to be the number one boat may be given. In a graduate class the promise of a free lunch was offered. Offering a grade incentive of some kind may also be used. Regardless of incentive, the mere presence of competition is usually sufficient motivation.

At the beginning of year one, the students may be given information about the age structure of the population and the number of individuals in each age class. Whether this information will be given at the beginning of each fishing season is up to the instructor. The students are told how many meters of net that they may use to fish. Each boat must decide upon a fishing strategy that must be given to the instructor to enter into the computer model. After the computer prints the results, each boat is given a summary of their own catch and effort, and the ranking of each boat is posted. Based on their prior year's results, each boat then makes any desired changes in his or her strategy and gives the revised strategy to the instructor for the second fishing season. The game continues in this manner until the instructor terminates the game. The game may be ended either at a pre-determined number of seasons or until the instructor concludes that one or the other fishery has crashed.

The usual outcome of the game is that the individual competitive fleet destroys the fishery in about seven to eight seasons while the collective fleet is able to obtain a sustainable level of landings. This outcome is due to the fact that while marginal yields are highest for age classes two through five, these age classes are the most productive in terms of recruitment. Fishing the younger age classes will produce significantly higher short run yields, but the long run sustainability of the fishery is jeopardized. Students in the common fleet seem to be much quicker to realize the importance of avoiding fishing the younger age classes too heavily, thereby, avoiding the fate of the competitive fleet. Even if the individual boats in the competitive fleet recognize the potential danger of fishing the younger age classes, there exists no mechanism for coercing other individual boats to resist targeting younger fish. Any cooperative strategy that may develop in the competitive fleet is easily broken as any given boat's relative ranking can be dramatically improved by reallocating effort toward smaller fish.

The most important part of the game is the debriefing period following the conclusion of the fishing activity. Unfortunately, at this time, the computer model does not store the data produced during the course of the game, therefore, the debriefing period may have to be held off until the next class period. One strategy for dealing with this problem is to hold a brief discussion period immediately after completing the game to get students impressions and to discuss the general role of property rights in natural resource use. Specifically, the contrast between open access and common property should be discussed. The students may then be given some additional reading assignments to prepare for further discussion in the next class period. The data from the exercise may then be entered into a spreadsheet program to produce a set of descriptive graphs to be discussed during the subsequent class.

Recent Classroom Experience

In February of 1992 the computer model was used in a graduate level natural resource economics class. The learning experience was administered basically as described in the previous section. Prior to the class, the students were exposed and had been assigned several readings dealing with the role of property rights in natural resources. No readings specifically contrasting open access and common property resources had been assigned. The only variation in this case was that students were allowed to choose whether they wanted to be in the cooperative or the competitive fishery. Also, due to time limitations, a ten year limit was placed on the game (as it turned out the game was stopped at the end of year eight). The ten year limit was announced at the outset, and as will be shown later, influenced the fishing strategy of the cooperative fleet. The students were given only basic information about the fishery and the initial age structure and number of fish in each age class. Other than their effort/catch summaries no other information was provided. Once the objective of catching the greatest cumulative weight total over the ten year period was explained, no other incentives were given, and as it turned out, no other incentives were needed. Figures 2 through 7 provide a summary of the outcome of the game.

Figures 2 and 3 show total population and total biomass respectively, in each fishery over time. In year eight the individual fleet experienced complete recruitment failure. The cooperative fleet also experienced a dramatic decline in recruitment in year eight, however, this problem was precipitated by a change in fishing strategy that really began in year five and became more pronounced as the game continued. Each year before year five the cooperative fleet was ranked fifth among six boats. Since it had already been announced that the game was to end in year ten, the cooperative fleet began shifting some of its effort from older to younger fish. By year seven, the cooperative fleet was in a panic and had adopted the competitive fleet's strategy of targeting younger fish. This change in strategy was successful in improving the cooperative fleet's ranking to second place.

Announcing the ten year limit to the game had an important affect on the outcome of the game, particularly with respect to the cooperative fleet. Figures 4 and 5 show total landings by number of fish and by weight respectively. These figures show that up until year five, the competitive fleet was landing more fish in terms of both numbers and weight than the cooperative fleet on an annual basis. However, after year five the collective fleet consistently outperformed the competitive fleet in terms of number and total weight of fish caught. This occurred for two reasons. First, the cooperative fleet began reallocating effort to younger age classes beginning after year five. And second, the competitive fleet had heavily fished the younger age classes during the first five years, therefore, the open access fishery had already begun to decline rapidly. Therefore, had the cooperative fleet stuck to the same strategy it was using during the first five years, it would have eventually overtaken the open access fishery

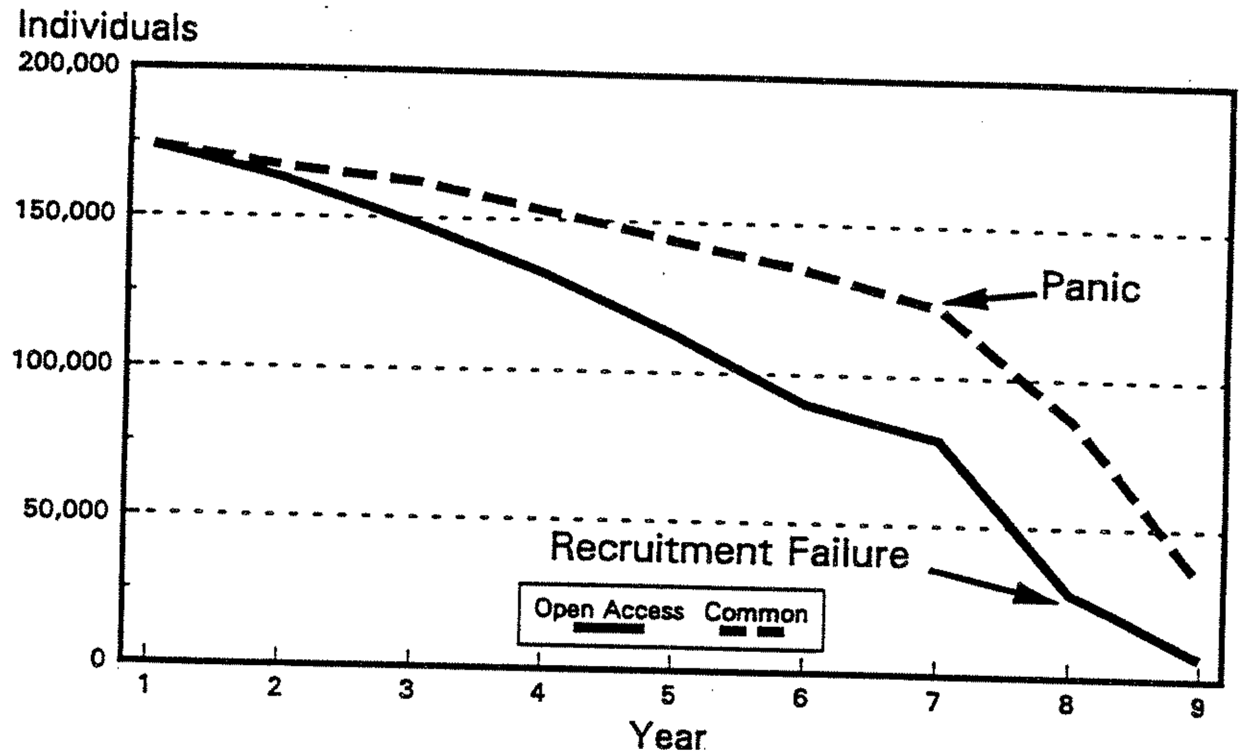

Figure 2. Total Population

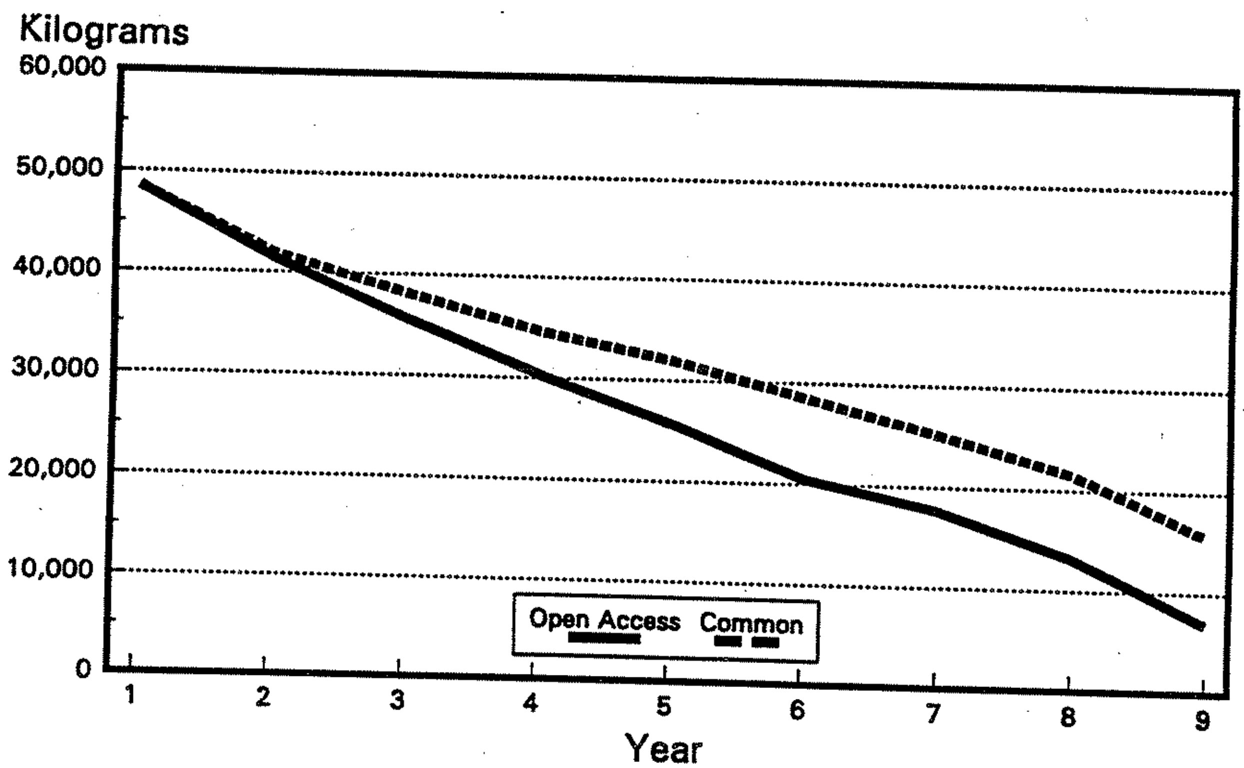

Figure 3. Total Biomass

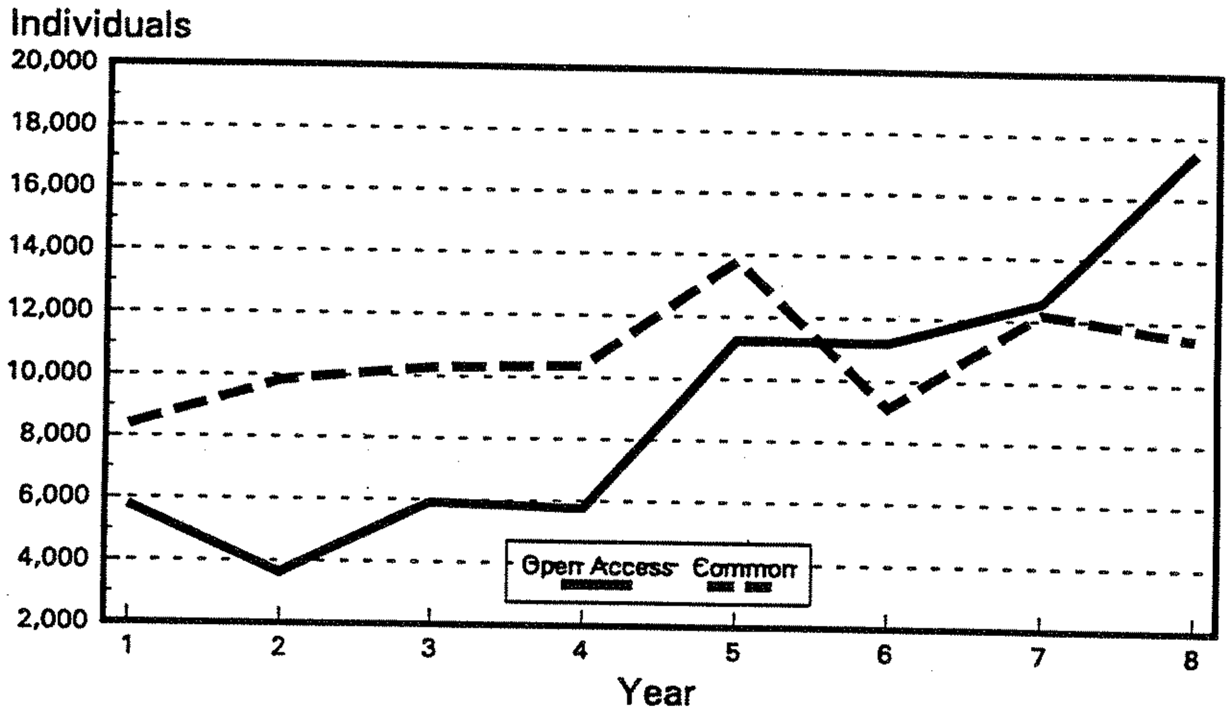

Figure 4. Total Landings
(Numbers of Fish)

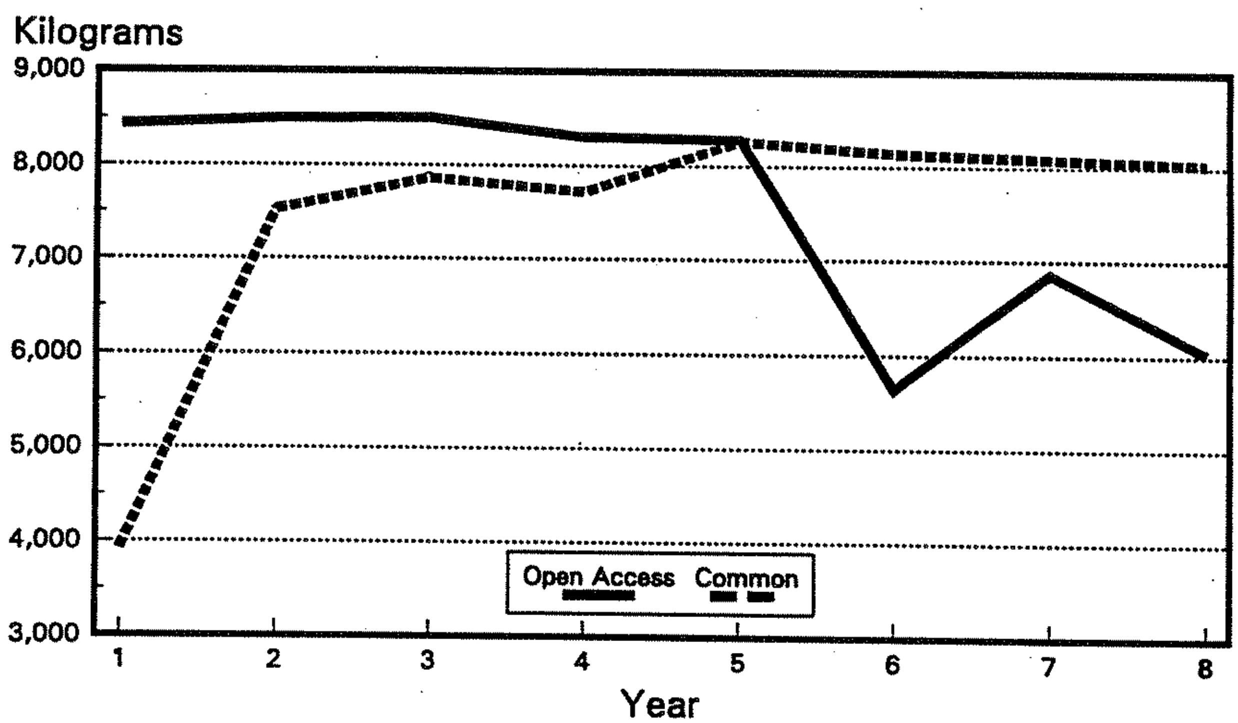

Figure 5. Total Landings
(Weight)

in the long run. Based on this experience it appears that a pre-determined stopping point may be better left unannounced.

An additional point that Figures 4 and 5 illustrate, is the fact that although the competitive fleet caught significantly more fish during the first five years, there was not a great deal of difference between the two fisheries in terms of weight. This is due to the simple fact that the lower number of fish caught by the cooperative fleet was offset by their greater size and weight. The dramatic increase in numbers of fish caught by the cooperative fleet after year five is due to the shift in emphasis toward smaller, relatively more abundant fish. The change in emphasis to smaller fish by both fleets is shown in Figures 6 and 7.

Figure 6 shows effort allocation for the collective fleet for three representative years. During the early portion of the exercise, the collective fleet used a relatively uniform strategy with the majority of effort being allocated toward age five and older fish. As the "panic" began to set in, the students began shifting more effort toward younger fish, and by year eight had shifted the majority of effort toward age classes four or less. By contrast, the open access fleet began targeting the younger age classes at the outset, a strategy that was only reinforced as the game continued.

Variations and Suggestions

The basic model that has been described can be used to effectively demonstrate the problems associated with open access resources. However, the instructor may wish to go beyond the basic model to introduce some other concepts. The instructor may wish to try and simulate the economic dimensions of a fishery by introducing input and output prices. The introduction of prices opens up a considerable number of options. For example, it may be desireable to conduct the exercise two times; first, using only biological objectives, and second combining biological and economic objectives. The differences in the time path of resource use can then be compared and discussed. Another example, might be to demonstrate the economic rationale for the extinction of a species. Yet another alternative would be contrasting resource rents under open access resource rents and sole ownership. In the latter case, the commons component could be used to represent the sole owner. The dynamics of entry and exit in a fishery could also be explored. Any number of other possibilities could be developed.

At this time the computer model cannot handle economic variables. However, the program could be modified by the user with programming experience. One way in which this problem can be overcome is to use the basic model to generate catch and effort results, while using a spreadsheet program to provide forecasts of output prices and costs and to calculate boat profits.

In addition to examining economic dimensions of a fishery, the instructor may want to introduce management effects. Restrictions may be placed on specific gear sizes, or the total length of net used by the boats may be reduced. The instructor may act as the manager, or a group of students may be given that authority. When combined with the economic dimensions quite a variety of natural resource issues and concepts can be introduced.

The game is most effectively run in a single time period. However, it is possible to keep the game running over several class periods. As long as the same initial seed number and any user imputed random numbers are entered in the proper sequence, the computer will always generate the same sequence of events. If careful records of each students fishing strategies are maintained, all cumulative totals can be recovered at the start of the next session.

The learning game described above has been an effective hands-on tool for helping students understand how property rights can affect natural resource use. Each time the exercise has been used, the game generated a lot of enthusiasm and, more importantly, a lot of questions and discussion. The unique insight that students gain from the exercise is that problems of resource overexploitation may not simply be a case of greedy profiteers wantonly destroying a valued public asset. Rather, overexploitation may be an artifact of the institutional

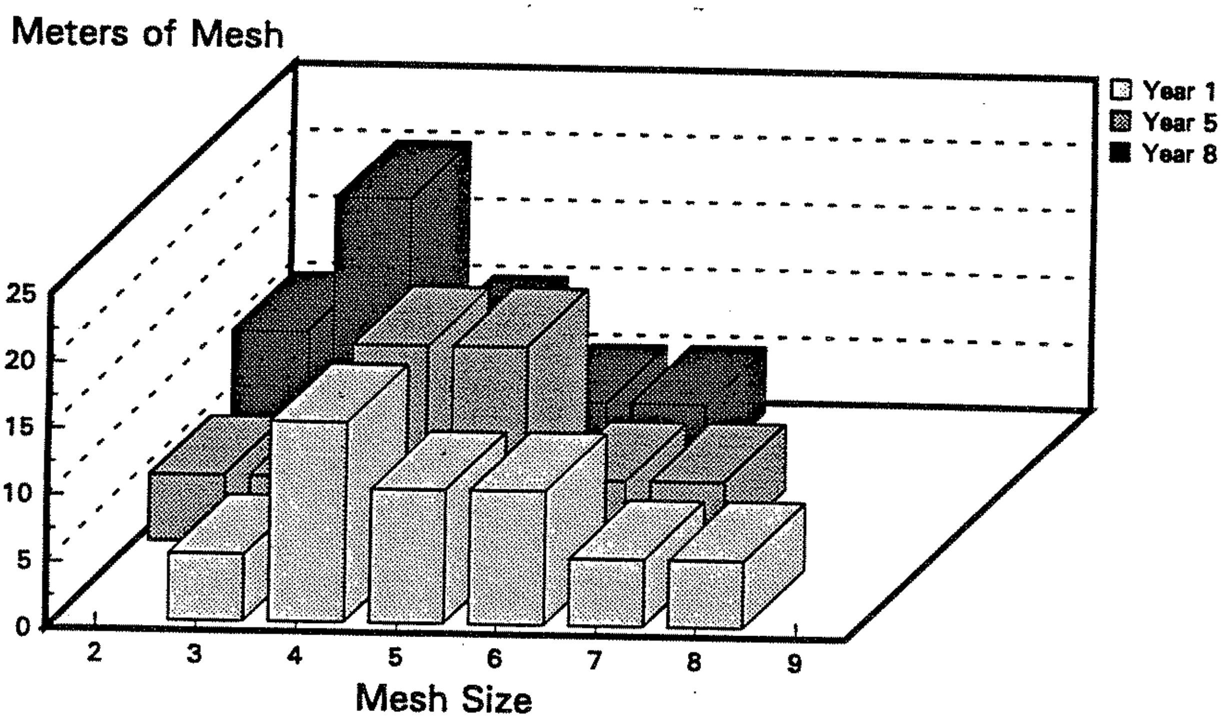

Figure 6. Effort Allocation
(Common Fleet)

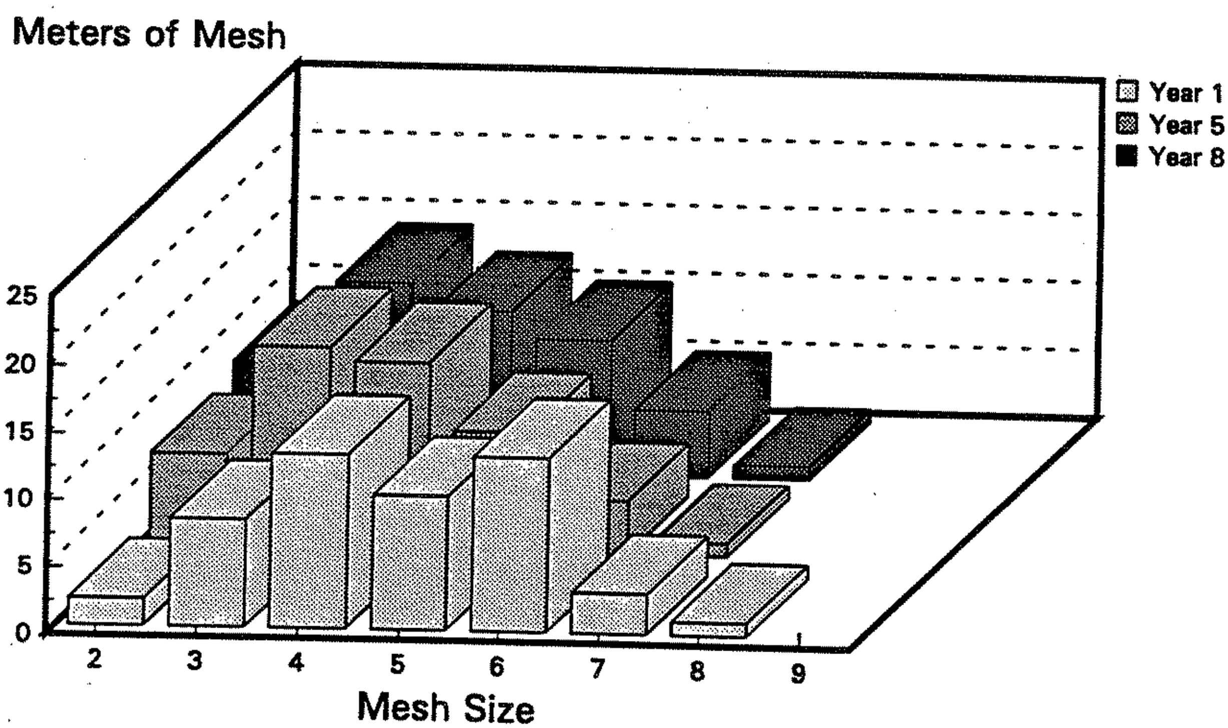

Figure 7. Effort Allocation
(Open Access Fleet)

environment resource users find themselves in. The experiential game gives the students an opportunity to gain this insight for themselves and goes beyond the level of understanding that may be achieved through reliance on a textbook alone.

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Endnotes

1. The computer model and documentation are not copyright and can be obtained directly from Dr. Thunberg. However, Dr. Johnson's creativity should be acknowledged whenever appropriate.

2. A gill net operates by ensnaring the fishes gills. Only fish of a specific size are caught, however, since smaller fish pass through the net while bigger fish are too large to fit through the mesh.