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MICROCOMPUTER FISHERIES SIMULATIONS AS TRAINING AND TEACHING TOOLS

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Microcomputer Fisheries Simulations as Training and Teaching Tools

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ABSTRACT

The lessons learned in using three microcomputer-based fisheries management training simulations are described. We found that training simulations should be built to specifically illustrate a few points, with much detail and realism sacrificed to avoid obscuring the essential elements of the simulation. Pre-simulation lectures and post-simulation discussion should be an integral component of such simulations. The basic elements in the use of simulation trainers are 1) briefings, 2) a user interface that includes visual displays, error checking and error recovery, 3) scoring, and 4) post-simulation follow up. We describe the general structure of three such simulations that have been used with fisheries management personnell, and describe the evolution of the different elements of these simulations and accompanying lectures and follow up.

INTRODUCTION

Over the last 5 years we have given a series of short courses for commercial fisheries managers, biologists, and commercial fishermen on the principles of fisheries stock assessment and management. The courses are a mixture of lecture, data analysis, and microcomputer-based training simulations. The training simulations have proved to be an extremely effective tool for teaching the methods of stock assessment and management as well as illustrating the difficulties inherent in specific management situations. The advent of inexpensive microcomputers with graphics capabilities has provided a teaching and training tool of great power and potential.

Teaching and training using computer simulations has been available for many years and began to see wide use in natural resource management during the early 1970's. Bare [1], Walters and Bunnell [2] and Paulik [3] all describe simulation models of natural resource systems intended for use by students and actual managers. During this period most games were run on terminals to large mainframes, although the original implementation of the Walters and Bunnell range management model ran on an IBM 1130 in interactive mode, much like one would use a current micro-computer, albeit a very expensive one. A modest number of examples of simulations used for training and teaching during the 1970's include Schreck and Everhart [4], Titlow and Lackey [5], Clark et al [6], Muetzelfeldt [7], and Kuipers [8]. A common characteristic of these models is that the number of actual management personnell who used the models was reasonably small, and the evolution of the process of using the models was of less importance than the actual development of the models themselves.

We were involved in a number of similar excercies during the 1970's, but we continued to concentrate on model construction rather than evolution of the process. The acquisition of microcomputers in 1980 changed this completely. We began to bring microcomputers into our training courses for fisheries managers and commercial fishermen. Initially, we used the computers for data analysis and display, but we rapidly experimented with a few teaching simulations and then began a long process of evolution of the simulations and the approach for using them.

We developed a wide range of computer training games, three of which have proved to be of lasting value. Each of these games has undergone considerable change due to feedback from users, and they are of different levels of complexity, competitiveness, and time required to play. In this paper we describe the games and some lessons we have learned from them. Our hope is to provide ideas to others involved in resource management training so that they will use similar games more often, and so that they may avoid many of the mistakes we have made. We also describe some of our experiences with simulations that have relevance to how managers perform in the real world of fisheries management.

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must be held very close to the actual optimum to obtain good yields. The game graphically illustrates that stock recruitment relationships are very robust and that near optimum yields can be obtained by a wide variety of harvest policies. The final point we discuss is the relationship between total yield and variability of catch. A fixed escapement policy will maximize the variance of the catches, and that is not necessarily desirable to fishermen. We use the simulation to illustrate that the variation in catch can be reduced at little cost in average yield.

Extensions to basic game

We provide a number of optional extensions to this simulation that let us develop other points discussed in lectures on stock recruitment analysis. There is an option to let the spawning stock be measured imperfectly, so that the stock recruitment relationship that appears on the screen is a biased version of the real stock recruitment curve. This is accomplished by plotting the escapement on the screen as the real escapement multiplied by a lognormally distributed random variable. The user has control over the standard deviation of the random variable. One or two simulations with very large observation errors are usually sufficient to emphasize the importance of reliable escapement counts.

A second extension we often use is to provide the player with an estimated optimum stock size each year based on fitting the "data" up to that year to the Ricker curve. Thus, during each year the player has his own "eyeball" estimate from the graph on the computer as well as a statistical estimate. The principal purpose is to illustrate that in general the statistical estimates converge rapidly (toward the actual value printed out at the end of the game), when escapement is varied, but can be very bad if there is insufficient variation in spawning stocks.

The third extension has the game take all control from the player and use the statistically estimated optimum stock sizes. This automatic play commences after 4 simulated years; if the player has not provided much variation in early stock sizes, the automatic control often becomes stuck on a very small stock size.

Critique

This simulation has proved extremely effective with a wide variety of players, ranging from experienced fisheries managers to commercial fishermen to members of the general public. It is most effective when combined with lectures on stock and recruitment. Players who have not been exposed to the theory will often play enthusiastically, but conversations reveal that they do not really understand what biological processes are represented. A particular strength of the game is that play is rapid, and each individual will normally have the opportunity to play the game many times, encountering different types of stocks each time.

The game is specifically tailored to the biology and life history of salmon. This life cycle is often regarded as too simple by managers and biologists who work on species where spawning stock is difficult to measure.

SKEENA RIVER MANAGEMENT

Player's objective

This game simulates the detailed management decisions over a single summer fishing season for sockeye and pink salmon of the Skeena River in British Columbia. The player's objective is to meet specific escapement (number fish spawning) targets for both species by regulating the number of days of fishing allowed each week. Since the run timings of the two species overlap and their relative abundances may differ, it is often quite difficult to harvest both species at the appropriate level. The simulation runs for 15 weeks of the fishing season and usually takes 30 minutes to play.

Training objective

The Skeena game illustrates the complexity associated with mixed species harvest management and the need for the manager to have reliable data on catches, escapements, and fishing gear. Initially it was built as a training device for salmon managers, but it subsequently proved quite effective with commercial fishermen. The simulation is built on a data base of actual weekly runs to the Skeena River and thus provides a realistic analog to actual management decision making.

Rules of the game

The core of the simulation is a data base of 15 years of weekly returns of sockeye and pink salmon to the Skeena River. At the beginning of play the player is given his escapement objective for each species. Play proceeds on a week-by-week basis. Each week the player is given total catch and escapement to date as well as historical averages for the proportion of the total run that has normally reached the river by that date. The player must decide how many days' fishing to allow given the number of fishing vessels that are in the area; this fleet size is also stored from historical data. The simulation then uses a relationship between effort (days fishing times number of vessels) and harvest rate to calculate what the catch would have been and how many fish would have escaped to spawn. The player is then advanced to the next week where he must again decide how much fishing to allow.

At the beginning of each simulation a random number is chosen which determines which historical year to simulate. All weekly returns and fleet sizes associated with that year are then taken from the data base. The player does not know what year he has been dealt until after the simulation is complete.

At the end of the simulation the player is given a summary that includes the escapements actually achieved, the target escapement, and a management score. This score is based on the deviation from the target escapements as well as the constancy of the fishing policy. A player who allows many days' fishing one week and no fishing the next week is penalized. The score is used to determine advancement and promotion within a hypothetical hierarchy of the Canadian Department of Fisheries and Oceans; departmental

Critique

This program provides a very realistic simulation of a real decision problem and hence is very effective with people involved in salmon fisheries. However, the structure of the decision problem is almost totally unique to salmon, and its applicability to other resources is limited. The game also takes about one half hour to play, and this precludes each individual from playing the game many times.

FISH WARS

Player's objective

This is a competitive game for 2-4 players in which each player represents a country that tries to accumulate the most money by building boats and hatcheries and catching salmon. The game consists of 20 annual decision cycles. In each year each player must make a number of decisions regarding investments and allocation of vessels. These decisions determine income, expenses, and the health of various fish stocks. One twenty-year simulation usually requires 45 minutes to play.

Training objective

Fish Wars illustrates a number of lessons about international fisheries management. The most important lesson is that cooperative management can result in a highly profitable, sustainable fishery for all nations, wheras competitive management can result in overfishing, financial ruin and destruction of stocks.

There are two major biological elements to the game, modelled after the life history of salmon. The first is that each player's (i.e., country's) fish are found at some times of the year in international waters in which all players can fish. Thus players are able to overexploit each other's stocks. The second biological element is the differential productivity of natural and hatchery-produced stocks. Players may build hatcheries which produce fish that can sustain high harvest rates (83%), whereas natural stocks can only sustain low harvest rates (67%). The natural and hatchery stocks are perfectly mixed at all times of the year in the open seas, and thus a player cannot optimally exploit his hatchery stocks without overfishing his wild stocks.

Fish Wars also illustrates fundamental economics of fishing. First there is no harvest of fish without a fleet, and to build and maintain a fleet costs money. Since the optimal size of fleet depends on stock abundance, players must resist the temptation to overbuild a fleet because of temporary high abundances. In addition, there is a banking system through which players can borrow money to build boats and hatcheries, and they must pay interest on the loans. Likewise, if players have a positive bank balance, they will receive interest. The player with the most money at the end of 20 years of simulation wins, and it is quite common for players to make much more money from interest in the last few years of the game than from the operation of the fishery.

Rules of the game

Fish Wars is modelled loosely on Pacific salmon. Each country is endowed with abundant natural stocks that will produce 3 million fish from a spawning stock of 1 million. Any spawners in excess of 1 million do not add any additional production and if spawning stock is less than 1 million, then there is a 3:1 rate of return from spawners to adult. The fish are available for fishing in international waters during one season, and then in the country of origin in another season. All stocks are equally mixed and available in proportion to their abundance in international waters.

Players have the option of building hatcheries (which cost money, of course) and produce fish at a higher rate than the natural stocks. The cost structure of hatcheries is such that if there is no interception of fish by other countries in international waters, a hatchery is profitable, but if other countries are fishing the high seas, it does not pay to build hatcheries. Players, however, are not told this before playing the game. Since the hatchery stocks are mixed with the wild fish, there is an intrinsic conflict over optimum harvesting of the two stock types.

At the beginning of the game there are no boats, so that players must buy vessels which then have annual maintenance and operating expenses. Each vessel may operate in both international waters and the local waters of its own country. Harvest rate on the high seas is a saturating function of the total effort; thus the economics of high seas operations depend on both the abundance of fish and the amount of effort. It is quite common for stocks to become so depressed that a high seas fishery is not profitable. Catch in the local waters of each country is proportional to effort, so that it is always immediatly profitable to fish until all the fish are gone. The result is that the high seas fishery cannot ever totally wipe out a stock, but too much effort in the local fishery can. These assumptions roughly correspond to the economics of harvesting of salmon; in particular, the local fisheries at river mouths are so efficient that it would actually be profitable to catch nearly all the migrating fish if there were no concern for future production.

Economics assume an important role in Fish Wars since the purpose of the game is to make money. There are costs associated with every aspect of operation or purchase of vessels or hatcheries. Income is derived from catching fish. Each player starts without any money in the bank; he can borrow at 10% per annum and once he has money in the bank, he receives interest of 10% per annum. This rather unrealistic assumption is used to convince players that the computer is intrinsically benevolent.

Visual displays

Each year, two major steps take place: the players enter their decisions, then the computer calculates resulting catches, stock sizes and bank balance. During the decision entry stage, each player in turn is asked how many vessels he will buy, where he will operate them, and how many hatcheries he will build and operate. There are a number of internal checking procedures to assure that a player does

Fish Wars, on the other hand, involves complex competition and development of fleets and hatchery stocks. It takes considerable time to play, and permits the players to contemplate changes that occur while the game develops.

The Skeena Management game takes about half an hour or an hour to play and we believe that this is a little too long. The game does not have the strategic complexity of Fish Wars, and it would probably be more effective if it could proceed faster. However, in all games the speed is largely determined by the individual players, and thus the games are somewhat self-timing.

Each of these games has undergone considerable evolution in response to experience in training session. Most of our early problems stemmed from inappropriate display of information, and from not anticipating some of the players' responses. We found that our programs had to be very robust to input error so as not to frustrate players with error messages and aborted runs. For example, an early version of the Skeena Management game would abort when running one specific historical year in which a strike occurred, and this made some key players most unhappy. Thus Fish Wars is totally protected by using diskette dumps of the system state at each year, so that it can be recovered from any point. We have not taken the time to provide this level of protection for Stock and Recruitment or the Skeena Management game. Protection is obviously less important for a fast game like Stock and Recruitment, since the player has invested only few minutes and will not be too frustrated if he has to begin again. In the end, though, it is only our own laziness that has prevented us from permitting complete recovery from errors, and we do recommend to others building management training games to allow for total recovery.

We discovered that the biggest educational benefits came from discussion before and after the playing of the games. While the games themselves are educational, players who have not participated in these discussions will miss many of the general patterns and outcomes that are often not encountered in a few plays. Stock and Recruitment is designed primarily to illustrate lessons from lectures, thus pre-game lectures and a follow-up serve as a reminder of what went on and to show players interesting situations that occurred to others. With Fish Wars it is more important to conduct extensive discussions and give problem assignments after the game is finished. The level of these before and after discussions will obviously vary from game to game, but there should always be a thorough discussion after each game.

None of our experiences are totally new, Greenblat and Duke [10], Duke [11], Cocatis and Atkinson [12], Van Sickle [13], and Konczal [14] mention the same lessons to some extent. Our experience is somewhat unique in that we had well over a hundred players whose job was natural resource management play the games repeatedly. Certainly some problems, such as flight simulators, have much more extensive experience, but in resource management large numbers of participants with actual management responsibility is rare.

When designing any management training game, decisions have to be made about what to include. All real resource management problems are complex enough to make it difficult to decide what to put into a game. As a general rule, we have found that it is better to err on the simple side when there are many choices. Set some (no more than 5) points you wish to illustrate and build the game around them. The game should not be built as a realistic mimic of the world, but rather as a simplified world with a few pedagogical foci. Thus, it would have been more realistic to include natural variation in stock production and catchability coefficients in Fish Wars, but this would make it more difficult for players to "see" the underlying structure of the stock response and estimation problems. On the other hand, natural variation was included in Stock and Recruitment because it is an essential element of that game.

If management training games are to be effective, the players must enjoy playing them. In the course of developing our games, we have learned about the length of time required to play each game, the user interface, and simplicity. We also found that providing some form of scoring, along with a little levity (messages from fishermen) makes it more fun and keeps up motivation. Thus, there is a score associated with the non-competitive as well as the competitive games. Players with a poor score almost always want to play again to try to do better. Also, all our games incorporate some form of unexpected response from the computer. In Stock and Recruitment the computer will complain if there is to be no catch in a given year, and there are simulated telephone messages. In Fish Wars, if a player catches all his fish, a nasty message appears on the screen telling him he has just wiped out his stocks. We look forward to innovations in computer synthesized voice generation, which we will use in the next generation of training games to add even more interest.

While the three games we have discussed in this paper were designed for specific purposes in training salmon biologists, managers, and fishermen, we have used all of them with non-salmon biologists and managers in such widely divergent locations as Ontario and Australia. Players in these contexts appeared to find the games as informative and useful as the salmon managers.

The games are intrinsically simple to build. Our first working prototypes of each game were programmed in a few hours. Naturally, much more time is then spent on the development of the user interface, but this has to be done through experience with players. But since this additional time is spent as part of the educational process for which the games are intended, it does not add much to the cost (in time) of developing and implementing the games.

We learn by experience, and computer based management simulations provide the opportunity to give fisheries managers experience in managing stocks without some real world costs of mismanagement. We have found that such teaching tools are effective and reasonably easy to develop. We hope that the lessons we learned will be useful to many others.