Problem Based Inquiry Series in Mathematics

Sustainability of Ocean Fisheries

Fish populations in the world's oceans are currently under great stress as a result of increased human population, more efficient fishing methods, and pollution. Today nearly 1/3 of all fish species are threatened with extinction. Fish harvests have actually declined over the past several years for the first time.

Context:

The World Trade Organization (WTO) is a group of industrialized nations that deals with the rules of trade between nations on a global scale. When this group makes policies it needs to be very clear on specific needs of nations, corporations and people to be effective and fair. Suppose you are the head of the WTO and YOUR responsibility is ensure the well being of all the fishing companies, the people and nations they serve, while supporting a sustainable global fishery. In order to accomplish this, what kind of information will you need about the needs of the various stakeholders? The stake holders include: citizens--health and social well being, the fishing companies and their economic well being, and of course, the environment and the well being of the ecosystem.

Note: This mathematical inquiry is designed to highlight quantitative relationships and process. The exact values used are chosen for ease of use in an educational context, they do not reflect exact values of any specific fishery. They are do however, closely resemble dynamics generally in ocean fisheries. Students are invited to do independent research of specific fisheries and apply the problems.

Analysis

For a fish population to be "sustainable", the total amount caught each year by all the companies must equal the total amount that the fish will reproduce from the remaining fish population to replace their numbers. If the annual catch is larger than the numbers that they reproduce, the fish population will eventually reach zero, and the fish will be extinct.

Part 1 - Specific Problem Scenarios

1. Suppose there are five companies fishing in an ocean. The ocean has 20 million fish (carrying capacity), and after each year the fish grow back by 25% of what is left in the ocean after all the companies have fished. **What is the maximum number of fish each company can catch each year that will be sustainable?** Let h represent the annual catch for each company.

Discuss/reflect:

- What factors will determine if this solution is possible in reality?

2. If each company says it needs to harvest at least 3 million fish each year to make a profit and stay in business, **what is the maximum number of companies that can be allowed to fish** in the ocean to ensure sustainability AND meet the minimum harvest needs of the companies? Let n equal the number of companies. As in problem #1, assume there are 20 million fish in the ocean and that they grow back by 25% each year.

Discuss/reflect:

- *If all of the companies want to fish but it cannot be done sustainably, what would be a fair way to solve this problem?*
- *How is this problem solved in real life?*

3. Suppose all companies must operate harvesting 3 million fish per year to stay in business, and that ALL companies must be allowed to do this to avoid serious conflict, **what would the carrying capacity of the ocean (fishery) need to be** for this to be sustainable?

Discuss/reflect:

- *Could the carrying capacity of the ocean be changed this much?*
- *What else could change? How could the carrying capacity of the ocean be changed?*

4. In order for all companies to fish at their desired harvest levels (3 million per year) and keep within the carrying capacity of the ocean (20 million) **what would the replenishment rate need to be?**

Discuss/reflect:

- *What factors can affect the replenishment rate?*
- *What can be done to increase the replenishment rate?*

Part II. - Generalizing

In real life, each ocean scenario is different and has many parameters. These include the number of companies fishing, the carrying capacity (maximum stock level) of the ocean, the rate of replenishment of fish at each round, the harvest level each round needed to stay in business. These are listed below:

r=rate of replenishment (percent the stock grows after fishing each year)
h=annual harvest (number of fish taken each year)
m=number of companies fishing in the ocean
a=quantity of fish in the ocean before a year of fishing
A=quantity of fish in the ocean after a year of fishing
S= stock level for the ocean (carrying capacity)

Use the variables for the parameters above to create the following general formulas:

1. The amount of fish in the ocean after each round (a formula for A in terms of all the other parameters).

2. The stock level necessary for sustainability.

3. The number of companies for the fishery to be sustainable at the stock level, S.

4. The rate of replenishment necessary for sustainability.

5. Create a function between two specific parameters when others are given. For example if the carrying capacity is 20 million fish, replenishment is 25% per year, find a function for the amount of fish that individual companies can harvest each year (h) in terms of the number of companies fishing (m). What kind of function is this? What type of graph is it?

Part III

In doing part I you might find that in the effort to reach sustainability the results of the given scenarios (the values for h, n, S and r) yield unacceptable or unrealistic values, either for the economics of the companies or the ecosystem.

Your mission: Play with the numbers and find values for these parameters that could yield sustainability in a way that is realistic for all concerned. Your scenario might include government subsidies, combined with some companies being paid NOT to fish in alternate years, etc. The possibilities are endless, and in the real world, the solution that works will depend on the circumstances specific to the fishery and the fishing needs of humanity. The fact is, it will require creative compromise, in all cases. There is no exact correct answer here, and what is realistic for this exercise can be determined by your own judgement.