Fishing Simulation Game

Over-harvesting and the Fishing Banks simulation game.

To prepare my students to better appreciate the amazing ability of mathematics to explain and predict population crashes, I want them to first experience for themselves how seemingly reasonable human behavior can lead to over-harvesting. After having read the Easter Island chapter, and before we start looking at the mathematics in class, We then have a special three-hour evening meeting of the class in which we play the simulation game Fishing Banks, Ltd created by Dennis Meadows. In this game, teams of students manage their own fishing fleets with the goal of maximizing profit. Over time, what invariably happens is that the teams build up large fishing fleets to maximize their short-term profit, over-harvest the fish population and cause the fish stock to crash to extinction. At this point, with no more fish to catch, the fish companies go bankrupt and hence fail to meet their goal of maximizing profit. The population crash happens even though the teams get feedback after each round on the amount of fish they have caught. By the time they notice that the stocks are decreasing, the corrections they make are too little and too late to stop the extinction. As we debrief this experience, the students realize that they have fallen into the same trap as the Easter Islanders: by over-harvesting a valuable resource, they have driven it to extinction.

Now that the students have a visceral understanding of the over-harvesting phenomena, in class I introduce the differential equation $dP/dt = kP(1 - P/N) - \lambda$ that models the situation, and we undertake its mathematical analysis. The mathematics involves the notion of bifurcation points and critical harvesting levels. If the harvesting levels are too high, then the population will crash towards extinction; new births will not be enough to offset the harvesting. A study of the solutions of this equation for various harvesting levels shows the existence of a critical fishing level; technically, it is called the bifurcation value. If the fishing level is increased beyond this critical value, even very slightly, then the model predicts that there will be a drastic crash in the fish population, potentially leading to extinction or near extinction.

The moral of the story is that, if one happens to be unlucky enough to be close to the critical harvesting value, then even a small additional increase in the harvesting level can have cataclysmic implications for the population. Thus great care needs to be taken when increasing harvesting levels even by small amounts, least we inadvertently cause a population crash. Here is an example where mathematics provides us with a key insight that runs counter to our natural intuition.

Sadly, the implications of a critical harvesting level have not been well understood and acted upon: there are numerous examples in the world of fisheries that have been over-fished leading to a precipitous decline in the fish stock. Such situations continue today and are regularly in the news.

Students learn that mathematical modeling can be used to predict and explain the population crash phenomena and can thereby serve as a counter-weight to the many pressures encouraging over-harvesting of resources.

We finish the unit with a discussion of the interplay between mathematical modeling and government and business policy making. Why is it that even though modeling can predict negative consequences, as with over-fishing or climate change, it is so hard to get society to take preventative action? Society might better served by leaders with a firm understanding of mathematics in the context of policy making. By including in our math courses components that link mathematics to issues of social relevance, we can prepare and inspire our students to become these future leaders.