Issue 2 Pacific Salmon

> This river is remarkably clear and crouded with salmon in maney places, I observe in assending great numbers of salmon dead on the shores, floating on the water and in the Bottom which can be seen at the debth of 20 feet, the cause of the emence numbers of dead salmon I can't account for so it is ... The number of dead Salmon on the Shores & floating in the river is incrediable to say -- and at this Season they have only to collect the fish Split them open and dry them on their Scaffolds on which they have great numbers ... great quants. of Salmon on scaffolds drying.
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> Journal of William Clark
> October 17, 1805
> Lewis and Clark Expedition

When Lewis and Clark arrived at the Columbia in 1805, they found, as described in the journal excerpt above, a river teeming with fish and a native American culture that both celebrated and depended on the salmon. How plentiful were the fish? In *Undaunted Courage*, his chronicle of the Lewis and Clark Expedition, Stephen Ambrose reports that, "The Columbia and Snake River system ... produced more salmon than any other river in the world. Their catches were incredible; one man could kill a hundred salmon on a good day, a full ton or more of fish." Salmon were woven into the fabric of the native Americans' lives. The fish figured in their mythology, and their rituals and celebrations. The annual salmon runs provided a rhythm to the year. And the salmon were their primary source of sustenance; fish caught during the salmon runs were dried, and then eaten throughout the year.

The salmon run observed by Lewis and Clark was not unique to the Columbia River. Every west coast river from San Francisco north to British Columbia supported a flourishing salmon population, and the salmon were central to the native American cultures up and down the coast. Over the last century, however, the number of salmon that return to west coast rivers has greatly diminished. How serious is this problem? Should anything be done in response to this situation? We will investigate such questions in this assignment.

The life cycle of Pacific salmon begins with birth, upstream in coastal rivers. The fingerlings (small salmon) travel downstream to the ocean, where they remain for two to five years, growing into adult fish. They end their life by returning to the stream where they were born. Upon arrival, the females spawn (lay eggs), and then die. The eggs will hatch, beginning the life cycle again. Salmon return to a stream when conditions are right, and they return, en masse; this migration is called a salmon run. Clearly, the health of a salmon population is dependent upon the health of the salmon run. It is essential that enough salmon return to spawn successfully to produce the next generation of fish.

When we begin to look at the health of the west coast Pacific salmon population, we soon see that we must examine this issue on a river by river basis. Salmon are already extinct in many west coast rivers; in others, the salmon runs are quite healthy. For this assignment, we will work with data about the Klamath River in Northern California and Southern Oregon. The Klamath River begins near Klamath Falls, an Oregon city that lies in an agricultural valley. The river flows southwest from Klamath Falls into California, running through through a very remote, mountainous region in the northernmost part of the state. The river then passes through both the Hoopa Valley Indian Reservation and the Yurok Indian Reservation on the way to the Pacific Ocean. At the Hoopa Valley

Indian Reservation, the Klamath waters are joined with waters from the Trinity River, a tributary which has its source in the Trinity Mountains. Total length of the Klamath River is about 250 miles; by the time it reaches the ocean, it is a big, powerful river, and, historically, it supported a large salmon run.

The politics surrounding Klamath River water have been fierce. The farmers of Southern Oregon use Klamath River water to irrigate their cropland. Dams on the upper Klamath store the water for irrigation use, but pose a major impediment to the salmon run. In the 1960's the State of California constructed a massive engineering project to divert Trinity River water into the Sacramento Valley, where it joined other waters in the state for use irrigating vast California farmlands in the Central Valley, and for supplying water to the Los Angeles area. Flow in the Trinity River was drastically reduced, which consequently had a major effect on the Klamath. The native Americans (Hupa and Yurok) claimed tribal rights to the water in the Klamath in order to support the salmon, a fish that is central to their history, their culture, their way of life. And ocean fisherman, as well, depend on a healthy flow of water in the Klamath; their livelihood depends on the salmon. In the face of these competing demands for Klamath River water, how are the salmon doing?

Our data are from the Pacific Fisheries Management Council, which was formed to implement the Magnuson-Stevens Fishery Conservation and Management Act, an act of Congress originally passed in 1976. The Pacific Fisheries Management Council is responsible for managing ocean fisheries off the coasts of California, Oregon, and Washington. Among other things, the Council monitors the return of salmon to many of the west coast rivers. We will examine data for the Klamath River over the last few years. The table below gives the total inriver run of adult salmon from the year 2000 to 2006 for the Klamath River. The total inriver run is a count of the number of adult salmon that return to the mouth of the Klamath River from the ocean. As such, this number is a measure of the health of the salmon population. Of course, only a fraction of these fish survive the upriver journey to successfully spawn, producing another generation of salmon.

Inriver Salmon Run, Klamath River	
year	count
2000	218,077
2001	187,333
2002	160,788
2003	191,949
2004	79,191
2005	65,227
2006	61,630

Overview of the assignment:

Your task for this paper is to investigate the health of the salmon population on the Klamath River. Construct a mathematical model to fit the data, expressing the size of the inriver run as a function of time. Help the reader understand the implications of the model by presenting it algebraically, numerically, and visually. Interpret the model by describing it, and by making projections. In

particular, use all three representations of the model (equation, table, and graph) to make the following two projections:

- predict the size of the inriver run in 2007
- predict the year in which the inriver run count will reach zero
  (that is, the year in which the Klamath salmon will become extinct)

In addition to the knowledge you gain from working with the mathematical model, you may also consider other factors that influence the health of the salmon population. Salmon are very dependent on the particulars of the environment (water quantity, water clarity, water temperature) which can vary greatly from year to year. For this reason there is generally a lot of natural fluctuation in the size of any particular salmon run. But beyond the natural fluctuations in the size of the salmon population, much of the cause of the diminishing salmon stocks is a consequence of human activities. The silting of the streams caused by extensive logging in salmon country, water pollution caused by agricultural and urban runoff, low water flow caused by the diversion of water for irrigation and other purposes, rising water temperatures caused by the removal of protective vegetation from the stream banks and by low, sluggish water flow, and overfishing: all of these have acted to depress the size of the salmon stocks. As you think about the implications of the data, one thing to consider is whether or not there are possible actions we should take to have a positive impact on the health of the Klamath River salmon population. If so, what would be required to take such actions? Are there impediments to the actions you think are necessary or desirable?

Your task for this paper is to understand and explain the current state of the salmon population of the Klamath River, and to make projections for the future. Use your understanding of the current state and your projections to make recommendations for actions that should be taken. Discuss the barriers in the way of such actions, and explain why you think the steps should be taken. Or, perhaps, you think no action is required; then state this and give your reasoning to support this position.

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Preliminary work:

- Start by defining variables.
- Enter the data into an Excel spreadsheet, and then use Excel to graph the data.
- Construct a mathematical model that expresses the size of the inriver salmon run as a function of time. To do this, carefully select two data points from the graph; the goal is to select two points that will lead to a linear model that offers a good fit to the data. Use these two points, along with pencil and paper, to find an equation for the model.
- Use the equation for the linear model to add a model column to the Excel spreadsheet. Then graph both data and model. Spend some time making your graph look nice by providing a title for the graph, labeling the axes, constructing a helpful legend, and choosing pleasing shapes and colors. Save this work in Excel.
- Work with all three representations of your model (the equation, table, and graph) to make the projections given above. Make a note of each with pencil and paper.
- What is the slope of the model? What does the slope tell you about the relationship between the size of the salmon run and time?
- Note any thoughts you may have about the implications of the data, implications you may have found while working with the data. What are the data telling you about the relationship between size of the salmon run and time?

Writing your paper:

You are now ready to begin to write your paper. Use what you have learned from your work with the mathematical model and any background information you have learned about the situation on the Klamath as the basis for your analysis.

Your essay will, of course, have an introduction, the presentation of your model (as an equation, table, and graph), three or four (or more) nicely developed body paragraphs, and a conclusion. You will also attach an appendix, showing the details of your mathematical work. More specifically:

- **The introduction**: In this essay, your introduction can be utilitarian, but it can also be descriptive or personal. Have you ever gone fishing, bought fresh salmon at the market, or enjoyed a great salmon barbecue? Don't be afraid to make a personal connection to the topic. Then make a transition to the general topic and your analysis.

- **First body paragraph**: Here you should examine your data on the Klamath inriver salmon run and present the mathematical model you have developed. Explain where the data came from, how you developed your model (mathematical details in the Appendix) and (very importantly) what the model definitely tells you. A table of the data and model, and a graph showing both data and model, all carefully labeled, should be included. You should also discuss, qualifying your statements carefully, what the model seems to indicate.

- **Further body paragraphs**: Devote one paragraph to a discussion of the predictions of your mathematical model with regard to the salmon population. In another paragraph, discuss possible limitations of your model. Do you expect it to be an accurate forecast of the future? Or do you think the model might break down in some fashion? If you expect that your model might break down, discuss the factors that you think will cause the model to break down and the ways in which this will affect your predictions. Devote at least a paragraph to your recommendations about what should be done (if anything) in view of the trends in the salmon run that your model describes.

- **Conclusion:** Finally, for your conclusion, consider returning, in some fresh way, to your introductory strategy. This technique can bring a satisfying closure to the essay. You could also discuss the ecological, social, or economic significance of the issue.

  After the conclusion to your paper, be sure to include an appendix in which you show the algebraic work you did to support the derivation of the mathematical model and the projections that you made. Be sure to use correct mathematical notation when you write the mathematics in the appendix.

Sources: Ambrose, Stephen E. *Undaunted Courage*. New York, NY: Simon and Schuster, 1996. p. 303
Lewis and Clark Journals: www.ccrh.org/comm/river/docs/lcww.htm
www.pbs.org/lewisandclark/archive/idx_jou.html

Data Source: http://www.pcouncil.org/salmon/salbluebook/salbluebook.html

Recommended Reading: *Salmon Nation: People, Fish, and Our Common Home*. Portland, Oregon. Ecotrust. 2003

Note: This assignment was developed in collaboration with Jean Mach at the College of San Mateo.