Muddying the Waters, Marissa Watson
High School Geometry
90 Minutes

This lesson unit is intended to help you assess how well students are able to:

Interpret data and evaluate statistical summaries.

Critique someone else's interpretations of data and evaluations of statistical summaries.

The lesson also introduces students to the dangers of misapplying simple statistics in real-world contexts and illustrates some of the common abuses of statistics and charts found in the media.

Common Core:
S-ID: Summarize, represent, and interpret data on two categorical and quantitative variables.
Interpret linear models.
S-IC: Understand and evaluate random processes underlying statistical experiments.
Make inferences and justify conclusions from sample surveys, experiments, and observational studies.

Materials:

Each small group of students will need a copy of Muddying the Waters and the Case Notes worksheet.

Teaspoon

Power Point

Introduction: (10 min)

Have students complete the Muddying the Waters Task in partners or a small group. Ask students to read through the task carefully. This task is concerned with the river pollution and its effect on the environment.

What do I mean by river pollution?

What does it mean when someone says that the level of pollution in a river is illegal?

Does anybody know of a river that is polluted? What was the source of the pollution?

How can you tell that a river is polluted?

In particular, explain how chemical pollution in a river is measured. Use a teaspoon to help illustrate this.

Chemical pollution is measured in milligrams per cubic meter of river water.

Does anyone know how much a milligram is?

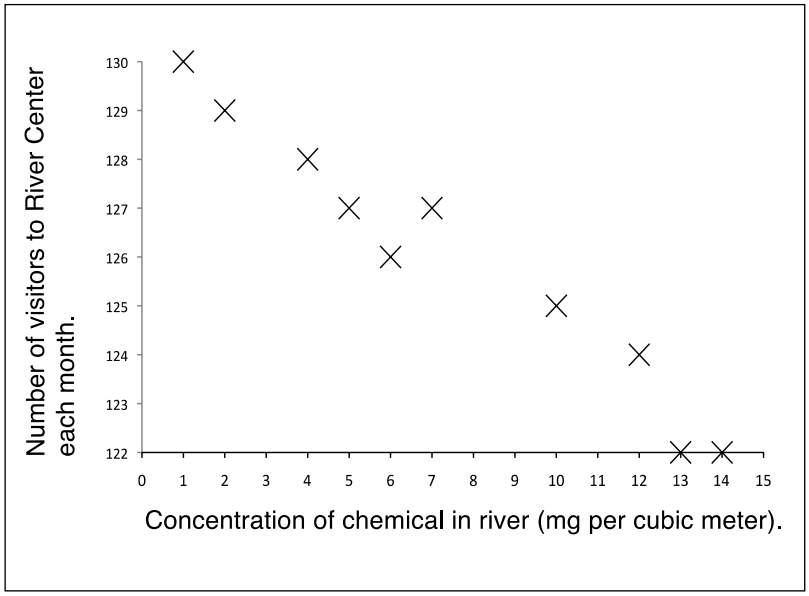
Does anyone know how much a cubic meter is?

A teaspoon of sugar is about 4,000 mg. This classroom is about 300 cubic meters.

Muddying The Waters

The manager of the Riverside Center is concerned about visitor numbers.
He is certain the Center's popularity has been badly affected by an increase in river pollution.
He feels the local Environmental Agency should do something about it.

To support his argument he measured the chemical concentration in the river each month.
He also counted the number of people visiting the Center over several months.
He used the results to draw this chart:

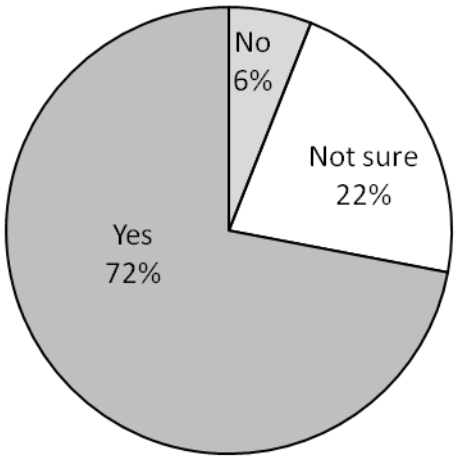


Scatter chart: Chemical concentration and number of visitors

At the same time the manager asked 18 visitors this question:

'The odor you can smell originates from the pollution in the river.
Is it spoiling your enjoyment of the Center?'

He displayed the results as a pie chart.



Pie chart showing the percentage of visitors whose enjoyment was spoiled.

The Center Manager writes to the Environmental Officer to try to get something done about the river pollution:

Dear Environmental Officer,

Please find enclosed two charts.

The scatter chart clearly shows that the increase in the concentration of the chemical in the river has caused a real drop-off in visitor numbers to the Center over the last year.

The pie chart proves that people (not surprisingly) don't like the acrid smell of pollution wafting up from the river.

The river needs to be cleaned up; it's not good for the environment and it's certainly not good for my business. Please let me know what action you intend to take.

Yours faithfully,

Manager, Riverside Center

Tasks

1. Describe in detail what you think the two charts show.

2. Do you think the Riverside Center Manager's argument is fair?
Explain your reasoning.

Activity: (30 min)

Organize students into groups of two or three. Provide each small group with a copy of the Case Notes worksheet. The Case Notes contain the map, information from the script, and arguments made in court by the Environmental Officer and the Factory Owner.

Sell the task and its context. Make it fun!

I'm giving you a copy of the arguments presented in court. Read through the information carefully. Write notes on what you think the data and statistics show. In particular, focus on critical analysis of the information presented. Explain why you agree or disagree with the arguments people made, using math. The important thing is to look critically at all of the information. Do not just accept what people say as fact.

At the end of the lesson, you will use your work to decide together whether the factory owner is guilty, or not guilty, of polluting the river.

While students are working in groups. Walk around to notice strengths and weaknesses in students' work:

Find out about students' current levels of understanding and the difficulties they encounter in the task. Students may be used to interpreting statistical diagrams, but may find it more difficult to analyze someone else's biased reading of information. Students may fail to notice a bias in a question, or may struggle to understand the issue of small sample size. You can use the information about common difficulties to focus the whole-class discussion towards the end of the lesson.

Support student thinking. Push students to help them move their thinking on.

You could strengthen your argument if you did some math on the data you've been given.

Is there another way to present this data?

Could you redraw that chart so it displays the important features of the data better?

A Case Of Muddying The Waters: Role-Play Scripts

Scene 1: Environmental Officer talking to the Assistant DA in the DA's office

Teacher	A year ago a small dam was built across the river to provide extra water for local domestic use. It was positioned just upstream of the Riverside Center and a factory [*show class **Exhibit 1** and point out the landmarks*]. This factory continually discharges a toxic chemical into the river. Prompted by the letter [*show class **Exhibit 2***] from the Manager of the Riverside Center, the local Environmental Officer [*indicate the student playing this role*] checks the concentration of the chemical in the river. Unhappy with the result he arranges to meet the Assistant DA at his office [*indicate the student playing this role*]. Here is how the meeting went *[show class the photograph of the DA's office*]:
Environmental Officer	Each year I test the river water for this toxic chemical and up until this year the concentration levels have been fine.
Assistant DA	But there's a problem now?
Environmental Officer	That's right. As you can see from this chart, [*show class **Exhibit 3***] the concentration of the chemical in the river is now disturbingly high.
Assistant DA	What can account for this change?
Environmental Officer	Well, downstream of the barrier the flow of the river has decreased from 20 to 4 cubic meters per second.
Assistant DA	Go on.
Environmental Officer	This decrease does affect the concentration of the chemical in the river. To calculate this concentration you divide the chemical discharge from the factory by the rate of flow of the river.
Assistant DA	Oh yeah, right [*not understanding a word*]. Have you noticed any other changes?
Environmental Officer	Yes, the number of diseased fish in the river. Two years ago we only found 6 diseased fish in the waters near the factory, but just last week we found 64. I'm sure you'll agree that's a massive increase.
Assistant DA	Mmm … I think I better take a ride out to the factory and see what the owner has to say about all this.

Scene 2: Assistant DA interviewing the Factory Owner in the Factory Owner's office

Show the photograph of the factory.

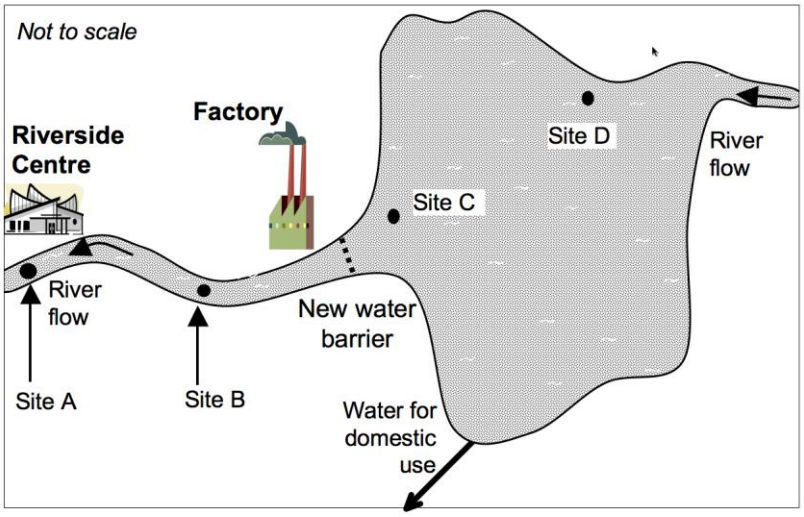
Teacher	So the assistant DA then drove out to the factory to interview its owner [*indicate the student playing this role to the class*].
Assistant DA	Do you know you are discharging a toxic chemical into the river?
Factory owner	Sure we know that, but we're only discharging it at the rate of 60 milligrams per second. When I first opened the factory some years ago, my manager checked that this was within the legal limits and this rate has not changed since then.
Assistant DA	I see. But the fact is, the concentration of the chemical in the river is now above the legal limit and you are the only factory in the area producing the stuff.
Factory owner	Well, it's a mystery to me. Something else must have caused the increase.
Assistant DA	I hear what you're saying, but I still think you're responsible.
Factory owner	Do you reckon – because I don't. What is important, though, is the health of the river. As you probably know, a good sign of a healthy river is the variety of the invertebrates in it. I've been keeping an eye on them in our river.
Assistant DA	What, you mean you've actually been counting the number of snails and water insects in the river?
Factory owner	Well yes, my people have counted all animals without a backbone. They've been counted at four different sites and the average number has barely changed in the last two years [*show class Exhibit 1 and point to the 4 sites*]. That's a good sign, don't you think?
Assistant DA	That is interesting. Have you checked anything else?
Factory owner	I've also kept a close watch on the number of birds around the factory and as you can see from the chart, there has been a dramatic increase [*show class Exhibit 4*]. Another sure sign of a healthy river.
Assistant DA	Well, I will get my experts to check all this. But from what I've heard, there is a case to answer. So I'll see you in court!

Case Notes

Background Information

Last year, a small dam was built across the river just upstream of the Riverside Center and the factory. The factory discharges a toxic chemical into the river.

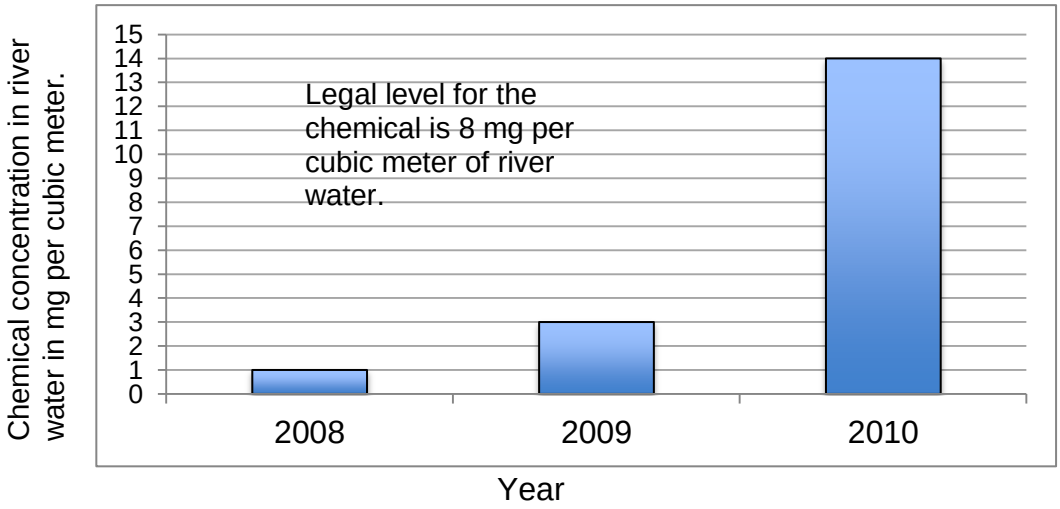
Exhibit 1: Map of the Riverside Area



Judge's notes:

Environmental Officer's Evidence

Exhibit 3: Bar chart showing level of chemical concentration in river water



“Each year, I test the river water for this toxic chemical and up until this year the concentration levels have been fine.

The chart shows that the concentration of the chemical in the river is now disturbingly high.

Downstream of the barrier, the flow of the river has decreased from 20 to 4 cubic meters per second.

This affects the concentration of the chemical in the river.

To calculate this concentration you divide the chemical discharge from the factory by the rate of flow of the river.”

Judge’s notes:

Factory Owner’s Evidence

“We are discharging a toxic chemical, but only at the rate of 60 milligrams per second.

When I first opened my factory the manager checked that this is within the legal limits.

The rate has not changed since then.

If the increase is now outside the legal limits, someone else must have caused the change.”

Judge’s notes:

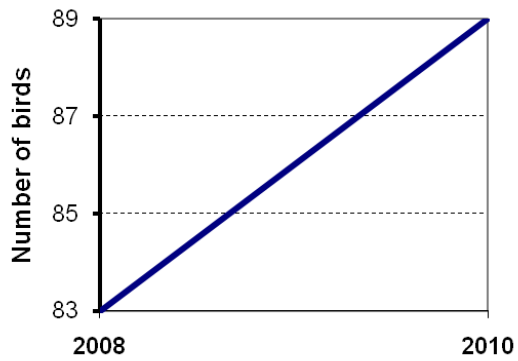
Factory Owner’s Evidence

“I’ve kept a close watch on the number of birds around the factory.

You can see from the chart that there has been a dramatic increase in the number of birds around here.

This is another sure sign of a healthy river.”

Exhibit 4: Survey of the number of birds seen next to the factory in one afternoon



Judge's notes:

Environmental Officer's Evidence

"There has been an increase in the number of diseased fish in the river."

Exhibit 5: Survey of diseased fish near site A

Both surveys covered a period of five days.

- Two years ago 6 fish out of 300 were diseased.
- Last week 64 fish out of 1,600 were diseased.

Judge's notes:

The Factory Owner's Evidence

"It's important to think about the health of the river.
A sign of a good healthy river is the variety of invertebrates in it.
I've been counting the number of animals without a backbone – things like snails and water insects."

Exhibit 6: Survey of numbers of invertebrates

	Two years ago	Now
Site A	20	15
Site B	22	9
Site C	19	23
Site D	23	29

"Invertebrates were counted at four different sites.
On the map (Exhibit 1), you can see where the sites are.
The average number of invertebrates has barely changed in the last two years - a good sign."

Judge's notes:

Judge's summing up:

After the groups have finished their activity have a class discussion: (20 min)
Choose a group to present their argument about one piece of evidence. Instruct the other groups to listen and write down questions about the group's argument.

Once the group has presented their case, other groups get a chance to challenge the details of their argument. If the challenge is not based on mathematics, you can rule it out of court.

> That is not a mathematical argument. As there is no good evidence, it can't be accepted in court.

Once you have modeled this process for students, give them responsibility for deciding whether there is an evidential base for each claim and challenge.

> Is that a mathematical argument? Is there good evidence for what [Shelley] has just said? Does the evidence support her conclusion?

Point out that an important message of this lesson is that it is easy to 'get it wrong' when interpreting statistics, especially in complicated real-world situations. In reality, most of the 'evidence' in this lesson is too vague to draw any firm scientific conclusions. A lot of questions are left unanswered.