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Treatment with antibiotic increases yields of declining pear trees

By John L. McIntyre, George H. Lacy, J. Allan Dodds, and Gerald S. Walton

The beautiful red foliage on some pear trees that develops in early to mid-August in Connecticut orchards is not, as some had believed, the first sign of fall. We now know that these reddened leaves are symptoms of a disease called pear decline.

Pear decline[1] is caused by a microorganism that looks like a mycoplasma. These are bacteria-like organisms that lack cell walls. These microorganisms cause restricted movement of the products of photosynthesis necessary for tree growth and fruit development.

The reddened leaves that typify this disease are leathery and curled (see Fig. 1). Severely affected trees may appear thin and spindly due to poor shoot and spur growth, reduced leaf size, and premature leaf drop. However, the effect of this disease on tree productivity and vigor has never been assessed because decline symptoms are vague and diseased trees produce fruit for years.

The microorganisms causing pear decline are transmitted by grafting or by the pear psylla, *Psylla pryicola*. Interestingly, this insect was introduced to North America via Connecticut in 1832. Pear decline, however, was not described in this state until 1978, although it was reported in Western North America over 30 years ago. This suggests that the microorganism causing pear decline was introduced recently to Connecticut and then spread to other trees. However, it is also possible, since symptoms are vague, that this disease has been unrecognized in Connecticut for a number of years.

Diagnosis of the disease requires indirect evidence since the microorganism that causes it has not been cultured. The studies that we performed to confirm that pear decline was in Connecticut were as follows: First, we looked for symptoms in pear orchards. Second, we used an electron microscope to see mycoplasma-like organisms in phloem sieve tubes. Next, collaborating with Dr. H. Schneider (University of California, Riverside, CA 92521), we transmitted symptoms of the disease by grafting budwood collected in Connecticut to indicator pear varieties. Finally, we found that postharvest treatment of diseased trees with oxytetracycline (OTC), an antibiotic used to treat many diseases caused by mycoplasma and related microorganisms, significantly reduced leaf symptoms the following year. These studies enabled us to verify that pear decline was in Connecticut.

An orchard survey showed that pear decline is widespread

An orchard survey showed that pear decline is widespread. We observed trees with symptoms of the disease in 18 orchards throughout the state (Table 1). The incidence per orchard ranged from 0.3% to 94%, and 33% of 5318 trees observed had symptoms. In these orchards, 22% of 2304 Bosc trees and 51% of 1980 Bartlett trees had symptoms. We also observed decline symptoms on other pear varieties including Devoe, Clapp's Favorite, D'Anjou, Seckle, Magness, and

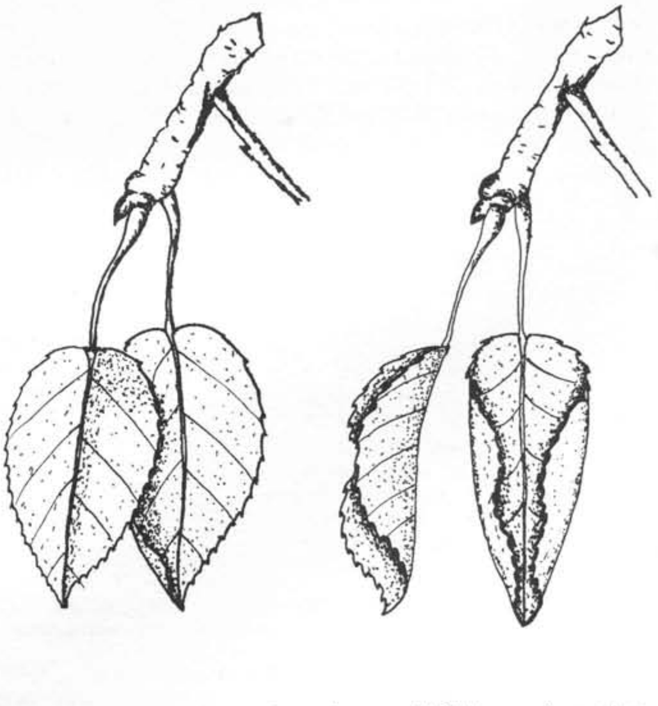

Fig. 1 A drawing of normal pear leaves at left. Leaves from a tree with pear decline would be reddened with a longitudinal upward curl as at the right.

[1] There are two types of pear decline. Tree decline is an insidious form of this disease that may occur on pear cultivars growing on *Pyrus communis* rootstock. When pear cultivars are grown on oriental rootstock, such as *P. usseriensis* or *P. serotina*, quick decline may occur, and affected trees die rapidly. Most pear cultivars are now propagated on *P. communis* rootstock, and in Connecticut we have observed only the tree decline type of pear decline.

Moonglow. No pear varieties are known to be resistant to this disease.

Pears with the highest incidence of pear decline symptoms were 2- to 10-years old. In contrast, trees more than 40 years in the orchard had the least severe and lowest incidence of symptoms. This again suggests that the disease may have been introduced recently into the state. However, it is also possible that young trees exhibit more intense symptoms than older trees.

Table 1. Location of orchards surveyed for pear decline and incidence of disease symptoms.

Town	Trees with Symptoms%
Berlin	40.7
Bethel	0.3
Cheshire	21.2
Easton	59.5
	37.8
Glastonbury	37.4
	3.3
Guilford	29.3
	7.5
Ledyard	1.8
Lisbon	3.1
	9.9
Litchfield	93.8
Middlefield	22.5
Roxbury	90.4
Southington	36.4
	17.0
Wallingford	33.2

In California, treatment of diseased trees with OTC after harvest greatly reduces the symptoms the following season. The treatments are either by high pressure injection or by infusion of large volumes of dilute antibiotic solution. However, these expensive and time-consuming methods of application are not appropriate for the small and diversified orchards in Connecticut because the peach, apple, and pear picking seasons overlap. Therefore, it was necessary to develop a new method.

The new method we developed uses a simple apparatus to treat diseased trees by infusion of small volumes of concentrated OTC into the tree trunk. We prepared the trees for infusion by drilling holes (¼" diameter, 1½" deep) on opposite sides of the trunk. A plastic 10 ml pipet (rigid tube) is filled with concentrated water solution of OTC (0.05, 0.25, 0.5, or 1.0 g active ingredient OTC/10 ml = 0.1, 0.5, 1.0, or 2.0 g OTC/tree), and firmly set into each of the holes with a twist. Trees take in the OTC solution within 30 minutes. Using this method, two persons can infuse 135 trees per hour. The pipets may be removed anytime. In 1978, the OTC (0.1 g/tree) cost less than 8¢ per tree and the reusable pipets cost about 14¢ each.

To ensure that the reduction in severity of foliage symptoms was not just cosmetic, we studied tree yield and response at two orchards. In 1976 and 1977, 20 diseased trees (12 years old) in orchard A were left untreated, and 20 diseased trees were treated after harvest with 0.1 g OTC/tree (Terramycin Tree Injection Formula 20% a.i., Pfizer Inc., New York, NY 10017). Twenty more trees were treated with 1.0 g OTC/tree in 1977. In orchard B, 32 trees (8 years old) were left untreated and 32 each were treated with 0.5, 1.0, or 2.0 g OTC/tree in 1977.

One year after treatment with OTC, leaf symptoms were reduced significantly. After two consecutive years of treatment with 0.1 g OTC/tree, the diseased trees were significantly more vigorous and productive.

The first effect of OTC treatment was visible 3 days after the trees were infused. Leaves on treated trees were yellowed and some were blackened. During the spring after treatment with 0.1 or 0.5 OTC/tree, we found some dead tissue on the trunks around treatment sites. This damage healed during the growing season. Rates of 1.0 g OTC/tree or more caused moderate to severe trunk damage, and therefore are unacceptable for treating trees of these ages. On trees treated with 0.5 g

Table 2. Response of trees with pear decline 1- and 2-years after infusion with oxytetracycline (OTC).[a]

	Year and Value			
	1977		1978	
	Untreated	0.1 g OTC/tree	Untreated	0.1 g OTC/tree
Disease rating[b]	1.7	0.7	1.1[c]	0.4
Weight/fruit (g)	94.0	130.0	87.0	114.0
Fruit weight/tree (kg/cm²)	0.2[d]	0.2	0.3	0.5
Fruit numbers/cm²/tree	2.2	2.0	4.1	4.9
Increased girth (cm)	2.4	2.1	1.6	2.2
Shoot growth (cm)	16.0	14.0[e]	17.0	24.0

[a] Trees were infused with 0.1 g OTC/tree after harvest in 1976 and 1977.

[b] Disease ratings were: 0 = no visible symptoms; 1 = 10%, 2 = 50%, and 3 = 90% of the leaves red and curled; and 4 = tree dead.

[c] The decreased disease rating from 1977 to 1978 for untreated trees was related to the normal rainfall during 1978 as compared to inadequate rainfall during 1977.

[d] Underlined values were not significantly different at $P \leq 0.05$.

[e] Note the 71% increase in shoot growth of treated trees from 1977 to 1978, with little difference in shoot growth of untreated trees between these 2 yrs.

OTC/tree or more, flower opening was delayed and blossom and leaf development was retarded on some fruit-bearing limbs. However, the leaves usually appeared normal by late June.

Tree vigor and productivity after 1- and 2-years of treatment with 0.1 g OTC/tree are presented in Table 2. We found a significant reduction in severity of foliar symptoms and that the individual fruit were heavier (g/fruit) after 1- and 2-years of treatment. After 2 years of treatment with 0.1 g OTC/tree, we observed significant increases in trunk girth and shoot growth, which are signs of increased vigor. Due to differences in tree size, values for tree productivity were standardized to the trunk area (cm^2) at 30 cm above the soil. The total weight of fruit per tree (kg/cm^2) increased by 47% with no significant change in the number of fruit per tree ($fruit/cm^2$).

In orchard B we observed similar increases in fruit weight without significant change in fruit numbers one year after treatment with 0.5 g OTC/tree. This rate may prove to be more desirable than the 0.1 g OTC/tree rate since it caused a greater decrease in disease symptoms with little tree damage.

Our analysis of fruit at harvest showed no OTC-like residues present, and all fruit from treated and untreated diseased trees were marketable. We asked staff members to taste fruit from both treated and untreated trees to see if they could detect a difference. In three of four tasting sessions, the staff preferred fruit from treated trees that were freed of decline symptoms over fruit from untreated diseased trees. Therefore, treatment of the trees does not impair fruit flavor.

There is, of course, no reason to think treatment of healthy trees would improve fruit taste or increase fruit productivity or vigor. Furthermore, there is no evidence that OTC treatment would protect healthy trees from decline symptoms.

OTC is approved for use in California for the control of pear decline and was registered for use in Connecticut in 1978. Thus, Connecticut orchardists can now increase tree productivity and vigor of diseased trees using this treatment.

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Brood II of periodical cicadas will be emerging this spring

By Chris T. Maier

Millions of periodical cicadas will soon appear in central Connecticut. On warm nights in late May and early June, the nymphs will emerge from the ground, shed their nymphal skins, and become adults. The adults survive only a few weeks, during which they will mate and females will lay eggs. Their large numbers and loud singing often arouse public interest and concern. Although adults can injure woody plants as they lay eggs in twigs, they pose no direct threat to human safety because they neither sting nor bite.

During the summer, the tiny nymphs will hatch from the eggs and will burrow into the soil. These nymphs will suck sap from roots as they slowly develop. In 1996, they will crawl to the surface to become adults and complete their 17-year life cycle.

Periodical cicadas emerge somewhere in the United States almost every year. Those that require the same period for development, either 13 or 17 years, and that reach adulthood in the same year are considered members of the same brood. Two broods have been reported in Connecticut. Brood II is the large brood due to emerge in 1979. The other, Brood XI, is apparently extinct because no adults were observed during its last scheduled emergence in 1971.

Their large numbers and loud singing often arouse public interest

Two biological characteristics distinguish periodical cicadas from other insects. They have the longest life cycle, 17 years in New England; and thousands of males sing synchronously to attract females for mating. Males of most other species of cicadas sing singly in the summer. Cicadas produce sound by vibrating tymbals, drum-like organs at the base of the abdomen.

The amount of damage caused by cicadas is proportional to the size of the population. Feeding of large populations of nymphs reduces the vigor and fruit pro-

Fig. 1 A periodical cicada nymph that was dug up during the winter surveying.

duction of apples for several years before the adults emerge. Adult females damage trees by cutting short longitudinal slits in small branches prior to laying eggs. Weakened branches often break, as the wind blows, and later die.

Most research on periodical cicadas has emphasized adult biology or control. By contrast, my study focuses on the development and the ecology of nymphs. A thorough understanding of the biology of nymphs may enable us to determine why cicadas thrive in some orchards and how the different broods of cicadas evolved. From September 1978 to April 1979, David Carlson, David Wagner, and I dug pits in forests and orchards in central Connecticut to observe nymphs. At each site, we collected data on the density and distribution of nymphs in the soil and on the diversity of tree species.

We found nymphs in the upper 15 inches of soil of apple orchards and in the upper 27 inches in forests. We found more nymphs where roots were concentrated. Nymphs in apple orchards were larger than those in adjacent forests. More research is required to determine why this is so, but nutritional differences in root fluids may be the reason.

Nymphs that we observed lived in chambers, 3- to 6 inches long and about ½ inch in diameter, feeding on rootlets that penetrated the chambers. The absence of tunneling and abandoned chambers indicated that nymphs do not move horizontally during their last several months in the soil.

A reduction in vigor and productivity of apple trees due to feeding of cicada nymphs was common several years before the last adult emergence. However, such apple decline was absent in the orchards that I inspected. The density of nymphs ranged from 0 to 48 per cubic yard in the seven orchards in which pits were dug. Thus, even 48 nymphs per cubic yard is not sufficient to cause apple decline. Cicada populations in many apple orchards were apparently decimated in 1962 by aerial and soil applications of carbaryl (Sevin).

Only orchards and forests in Southington had densities exceeding 5 nymphs per cubic yard. I estimated that the most heavily infested orchard had an average of 860 nymphs per apple tree or 36,000 nymphs per acre. The population in an adjacent oak-hickory forest was 71,000 nymphs per acre. Nymphs were more abundant at the edge than at the center of the orchard.

Although periodical cicadas once inhabited many of the forests in the Connecticut River Valley, my survey revealed that their major refuge now is the upland forest associated with trap rock ridges in central Connecticut. For example, sizeable populations occur in the woodlands around Totoket Mountain, Talcott Mountain, and the Hanging Hills of Meriden.

The diversity of tree species in upland forest was greater in areas with nymphs than in those without them. Both the pattern of egg-laying and differences in nymphal survival may be responsible for this outcome. Females prefer to lay eggs in the well-exposed branches of younger trees, which are usually more abundant in diverse forests. Nymphs in more diverse forests should be better able to withstand environmental changes, for example, selective cutting of trees, because they have more alternate food sources.

The disappearance of Brood XI in Connecticut may be a preview of the fate of many cicada populations. Since they must have unusually large populations to reproduce, they suffer severely from man-made disturbances. Their future is probably inextricably linked to their ability to exploit new habitats. During the upcoming emergence, I shall measure dispersal by marking, releasing, and recapturing adults. If they successfully colonize reforested areas, they will be seen and heard in our woodlands for generations to come.

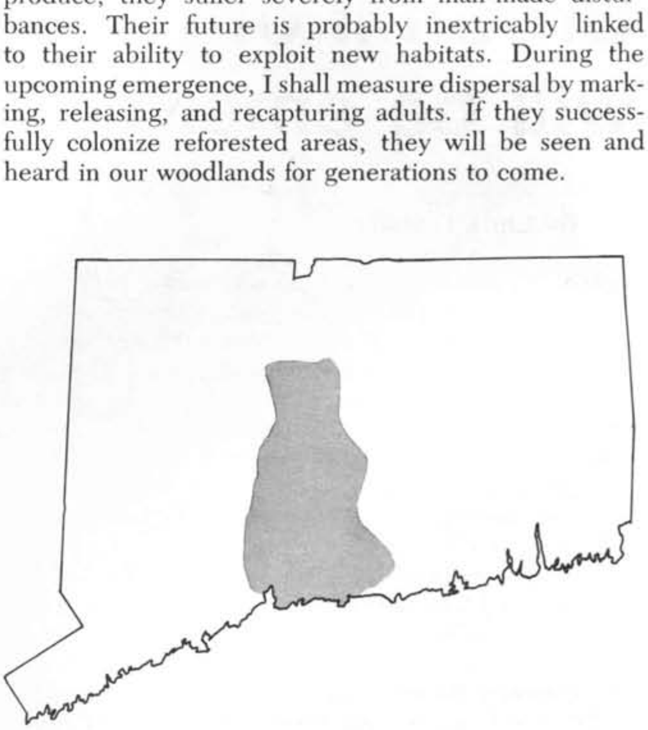

Fig. 2 Brood II periodical cicadas have been reported during previous emergences in the area outlined on the map.

Modelling the transport of chemicals in the Housatonic River system

By Donald E. Aylor and Charles R. Frink

Effective management of water quality in a river requires an understanding of the movement of water, including its ability to transport and to dilute pollutants. We are using the Housatonic River as an outdoor laboratory to develop a computer model of the movement of water and pollutants through a river system. This model should enable us to calculate changes in the quality of an identifiable volume of water as it passes through the river system, particularly in the impoundments known as Lake Lillinonah and Lake Zoar. The model is based on the physical principles of hydraulics, knowledge of channel geometry, and measurements of water flow and pollutant concentrations in major tributary streams. Using this information, we should be able to predict losses or gains of nutrients or other potential pollutants that may affect the quality of water in the river.

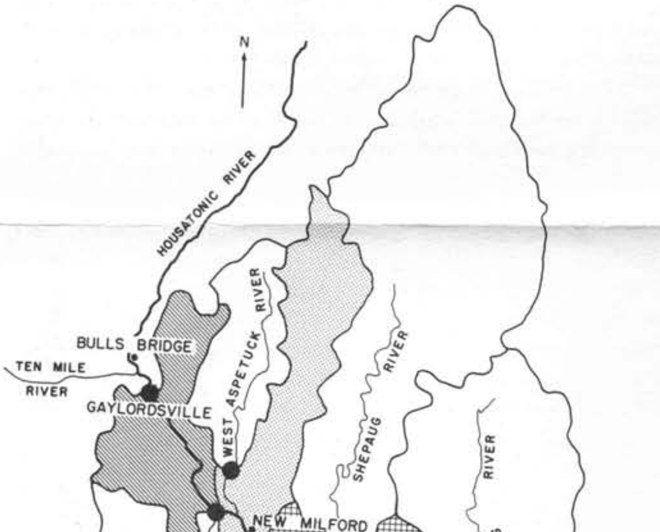

Fig. 1 A sketch of the Housatonic River and its major tributaries between Bulls Bridge and Stevenson Dam, CT. The solid line enclosing these tributaries represents their combined watershed boundaries. The watershed of the Ten Mile River, most of which is in New York State, is not shown.

We should be able to predict losses or gains of nutrients or other potential pollutants.

One problem in developing such a model is that the concentration of a chemical substance (*S*) is usually measured at fixed points. However, we learn little about gains or losses because the quality of different volumes of water at different locations in the river at the same time bear no direct relation to one another. But, if we could track a particular volume of water (*V*), say one entering Lake Zoar with a known amount of *S*, and then measure the amount of *S* in this same volume of water when it leaves the lake, we could tell whether *that* volume of water lost or gained *S* during its passage through the impoundment.

We are concentrating our study on the portion of the river between Bulls Bridge and Stevenson Dam (Fig. 2) where we previously had studied phosphorous and nitrogen concentrations and where PCBs have recently been discovered in sediments. Stevenson Dam creates Lake Zoar and is where Route 34 crosses the river; Shepaug Dam creates Lake Lillinonah. The major tributaries, which add both water and chemicals to the lakes, are shown schematically at the bottom of Fig. 2. The addition of one horizontal line downstream of each confluence, shown by a solid circle (•), is a reminder of the additional water and chemicals entering from that tributary.

We want to follow a volume of water *V* leaving Bulls Bridge and to account for changes in concentrations of particular chemicals as the volume travels downstream. Changes occur because of augmentation or dilution due to tributary inflows and by turbulent mixing. We expect to determine the net exchanges of pollutants, such as phosphorous or PCBs, with sediments in the lakes by comparing predictions of our model with actual measurements of these pollutants at the outlets of the lakes. Our model, if correct, will be able to calculate directly the concentration of a solute such as the chloride ion, which is not depleted by chemical or physical pro-

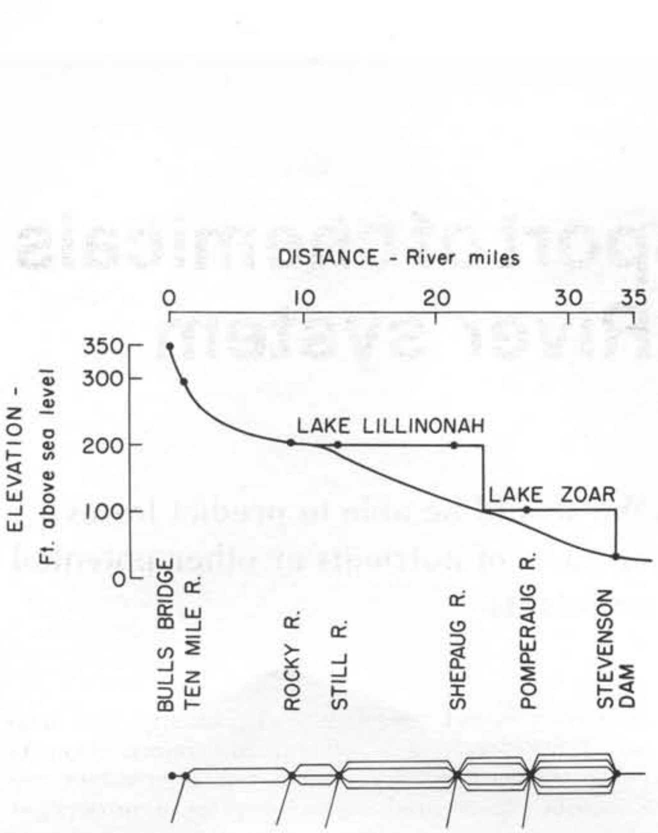

Fig. 2 A schematic of the elevation profile of the Housatonic vs. distance in river miles (top). The solid dots locate the confluences of the Housatonic with the tributaries shown at the bottom. The addition of a horizontal line downstream of a confluence is a reminder of the additional water and chemicals due to that inflow.

cesses in the river. Thus, measurements of chloride allow us to calibrate our model.

When the volume V reaches the confluence with a tributary, an additional amount (or load) of substance S is added; the load is the concentration of S times the flow in cubic feet per second (cfs) of the incoming stream.

If we ignore for the moment any changes in concentration along a section between tributaries, the concentration due to mixing the main stream and a tributary is now the sum of the two loads divided by the combined flow. These computations require us to know the time of arrival at each tributary. Thus, we must time the location of the starting volume as it moves downstream. Just as the distance travelled by an automobile can be determined from its speed and the time travelled at that speed, the location of our volume of water can be determined if its speed is known. The speed to use in the case of the river is not as obvious as for an automobile since the speed of the water varies considerably across a river at any particular location. The first problem, then, is to decide what speed to assign to our volume. This speed depends upon the way that this volume mixes with neighboring volumes as they move downstream. Therefore, we digress for a moment and consider this mixing.

When the flow speed is not uniform, but instead changes markedly, as it does from the bank toward the middle or from the top to the bottom in a stream, dilution is enhanced because parcels of water at the center race ahead of those nearer the bank and the distance between them tends to increase as time passes. This indefinite spreading out is checked by rapid cross-stream and vertical mixing, which tends to keep the material concentrated in a volume which moves downstream with a speed equal to the average velocity of the water in the stream cross-section. Therefore an important part of the model is the calculation of this average speed and thus of the position of the center of mass of substance S. The average speed is calculated from the known channel geometry and from gaged inflows.

The calculated location as a function of time for water volumes starting at Bulls Bridge in early fall and spring is shown in Fig. 3. A volume of water takes more than 10 times as long on the journey to Stevenson Dam in late summer and early fall due to differences in runoff.

When the travel time is short, dilution due to mixing along the length of the channel is relatively unimportant and downstream concentrations can be determined from upstream information. However, when the water is flowing at a slower pace, such as in late summer and early fall, we must account for the exchange of material with neighboring (both upstream and downstream) volumes due to velocity variations across the stream. Clearly, in this case, we must know the amount of S downstream of our beginning volume V.

The most straightforward way to obtain this information is to start a volume just before the one we are considering and calculate its concentration as we have de-

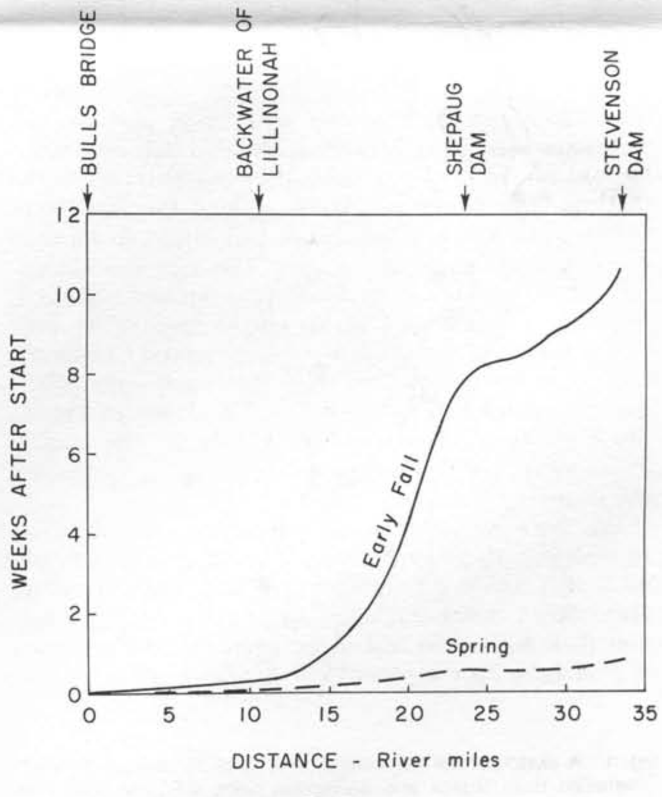

Fig. 3 The timing of the journey of the water volume V. The journey takes more than 10 times longer in late summer and early fall than in spring.

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scribed for volume *V*. Of course, this other volume is also exchanging material with the volume element in front of it and so on. Fortunately, the amount of this upstream transfer is small, and we can often obtain a reasonable approximation by considering only one or two downstream segments. The concentration of *S* in volume *V* is then just a weighted average of the amount of *S* in *V* and in its nearest upstream and downstream neighbors. The calculation of weighting factors depends in a rather complicated way on the flow and on the channel geometry.

The corrections for mixing, happily, are of secondary importance for much of the water year and we can make reasonable predictions of chloride (Cl) concentrations at Stevenson Dam using the time-of-travel model that we have described. We examined the agreement between 45 weeks of predicted and observed Cl concentrations by statistical analysis. The seasonal concentrations varied from 6 to 15 parts per million (ppm) Cl, providing a sufficient range to test the model. The analysis showed that the predicted and observed Cl concentrations at Stevenson Dam were not significantly different; the correlation between them is shown in Fig. 4. Much of the variation is accounted for by our model. Presumably, we will improve our model by including the dispersion process.

We have also compared predicted and observed phosphorus (P) concentrations. The analysis so far indicates that much P is retained by both lakes (totalling about 50%), that Lillinonah retains more P in the summer than during the rest of the year, but the retention of P in Lake Zoar appears to be independent of season. Thus, our goal of determining exchanges of pollutants within these lakes seems within reach.

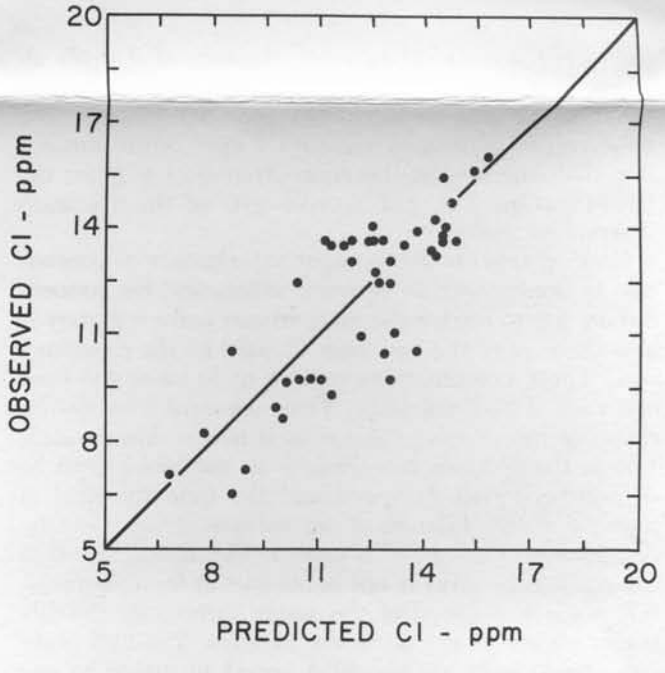

Fig. 4 Comparisons of observed and predicted chloride (Cl) at Stevenson Dam are shown by solid circles (•). The diagonal line with a slope of unity corresponds to perfect comparisons.

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