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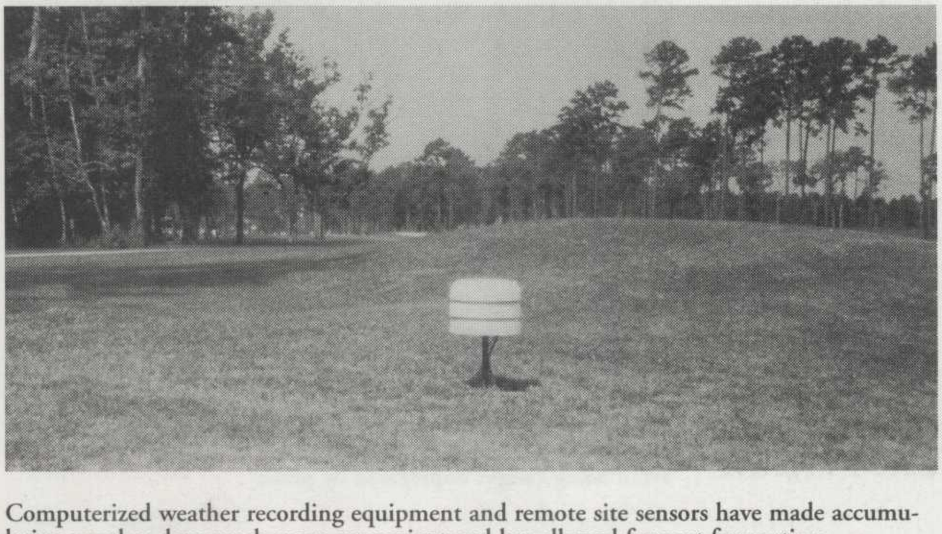
Intuitive Forecasting of Turfgrass Insect Pests

by R. L. Brandenburg

One of the most frustrating moments in turfgrass pest management comes when a pest catches you by surprise and causes significant turf damage before you can respond. This may not only be embarrassing; it can also be expensive in terms of lost clients and the cost of remedial measures. Insects are notorious for surprising us and creating a serious problem in a relatively short period of time.

Some insects such as chinch bugs and armyworms usually catch us by surprise as it is. Others such as white grubs may be a little more predictable in time of occurrence, but not necessarily in location. Since they are underground pests, and go about their business unseen to the casual observer, they too can catch us by surprise. With this in mind, one can assume that the most valuable tool a turfgrass manager could have to aid insect management (other than the products used to control the pests) would be a means of predicting their occurrence.

The ability to predict insect pest occurrence isn't necessarily a distant dream. Current research at several universities is providing insight into the making of such forecasts. In this article I'll attempt point out that you may already be doing some predicting of pest outbreaks. Even if you aren't, this article contains guidelines on how to take advantage of our knowledge of insect development and put it to use in your turfgrass business.



Computerized weather recording equipment and remote site sensors have made accumulating weather data much more convenient and has allowed for pest forecasting.

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Insect modelling

First, let's look at a bit of the history behind insect forecasting and prediction. Back in the 1970's, an area in the study of insects (entomology) that received a great deal of interest was insect modelling. Insect modelling wasn't the assembly of plastic or wooden parts into some facsimile of an insect. It was the collection and fitting together of information on insects that gave us a better understanding of their lives and their relations with their environments (ecology).

These models were often quite elaborate, encompassing variables such as egg-laying rates, growth rates, migration, dispersal, and mortality factors like predation. It should come as no surprise that these models were often complicated and required a lot of data collection and input to make them operate.

Many times these models were quite successful in enlightening us about a particular pest. It is a fact that the more we know about an insect, the greater the likelihood that we will be able to manage it in the most efficient manner. Knowing how various predators, parasites, or weather patterns impact various insect populations is very useful to both scientists and pest managers.

The benefits of the models have been many and their development has become a science in itself within entomology. A lot of time and energy has been invested in them over the last 25 years. They have a negative side though: they tend to require not only a lot of funding, but also many years to develop.

This long period of development has frustrated many of those involved in the development of pest management strategies for turfgrass managers. Improvements are needed today. A model that can't be used until 10 years from now is liable to be too late. In addition, the turfgrass industry has shown such growth in recent years that it has outstripped the small group of entomologists working on turfgrass. Regardless of how good and effective some of the original turfgrass entomologists were, the industry has expanded far beyond what a few individuals can effectively address.

Fortunately, universities have seen the value of shifting more research and teaching resources into turfgrass. We now have more entomologists working on turf (although there is certainly not a surplus) and this has allowed us to expand our research efforts. While modelling to enhance our understanding of insect lives continues, some entomologists have begun to take a slightly different approach.

Forecasting can be most useful in determining when to scout for hard-to-detect pests such as soil insects; it can also help you avoid being caught unprepared by pests.

Half the battle in protecting high quality turf, such as this golf course, from insect pests is knowing when to expect certain problems.

"Intuitive modelling" defined

This new approach is commonly referred to as "intuitive modelling." What is "intuitive modelling"? As the name would imply, it is basically what your intuition tells you is going to happen, backed up with a little bit of science. Turfgrass managers in the northeast United States have known for years that the annual bluegrass weevil begins egg-laying when the flowering dogwood blooms. In many areas, preemergence herbicides for crabgrass are applied using the same cue. Intuitive modelling is simply using temperature and growth to tell us when something should be done.

A brief review of the concept behind intuitive modelling makes it more understandable. First, all insects are cold-blooded creatures. That is, for the most part, their body temperature is regulated by the temperature of the environment around them, whether that is air, soil, plant, or water. Many insects have ways to manage their body temperature a little, but by and large they are at the mercy of their environments. If it is hot, then they are hot. If it is cold, then they are cold.

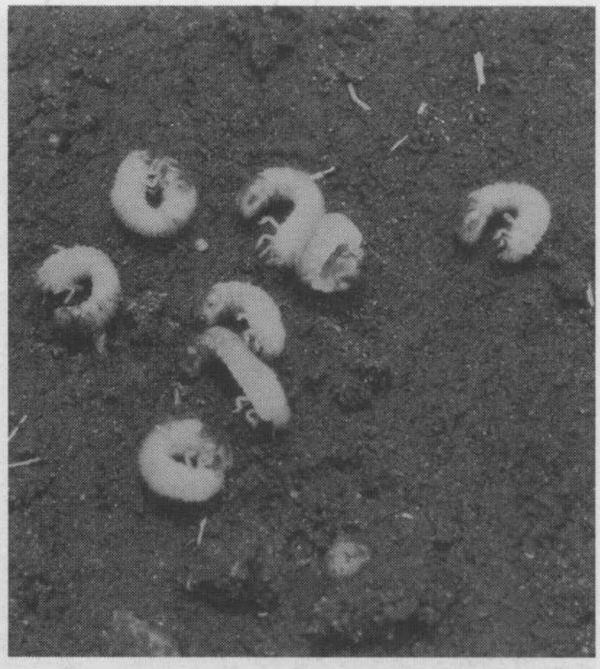
Second, this same cold-blooded insect's growth is very much regulated by the temperature of its environment. It if is warm, the insect develops faster. If it is cool, then the insect develops more slowly. There are upper and lower limits to this, however. If it gets too cold, the insect may stop growing altogether, or die. The same is true for many insects if it becomes too hot.

So an intuitive model would tell you "if the spring has been warmer than normal, then the insect should show up earlier than usual." This is the basis of intuitive modelling. "If something changes, then these are the consequences" is another way to state this modelling philosophy. The "if-then" relationship is the key to understanding how the model works.

Intuitive modelling applies to more than just insect pests. Diseases are controlled, in large part, by temperature and humidity. Germination of numerous weed seeds is determined by soil temperature. And there are factors other than temperature that may play a role in regulating pest presence and activity. Sometimes all these factors interact in a straightforward manner; at other times their interaction is very complicated and difficult to understand.

In intuitive modelling we seek trends that are associated with parameters that can be monitored easily. In other words, we look for straightforward guidance from measurements such as temperature, relative humidity, and precipitation. Prediction is usually much easier if there is a straightforward relationship, but interactions of temperature and rainfall, for example, don't prevent the use of a model. Some immature insects may develop to a pupal stage, but not emerge as adults until rain occurs. While development to this preadult stage may be dependent on temperature, no matter how warm it becomes, no adults will be observed until it rains.

Intuitive models can still play a role in providing insight into insects. If you know that the below-ground larvae have progressed to the pupal stage, then you know that the next substantial rain or irrigation will probably result in adults emerging. If the adult is a species that feeds on ornamentals, then this information may even be more important than knowing what the root feeding larval stage pest is doing in the turf.



White grub development and the emergence of adults is closely related to temperature.

These interactions are often more common and more important with turfgrass diseases. Temperature and relative humidity and/or leaf wetness or dewpoints often work together to determine disease incidence.

Monitoring equipment and services

The ability to monitor such factors is critical. In this age of computerized weather stations, almost every environmental factor can be monitored and recorded. The cost tends to be reasonable. In fact, many insects can be forecast based solely on monitoring air or soil temperature. In some areas, such data can be obtained from local papers, phone services, or satellite dish weather services.

Many pests can be forecast with wide-area environmental information. In other words, the temperature from a site several miles away may be sufficient to accurately predict insects over a wide area. There will be exceptions to this: areas that have a southern slope or exposure, for example, will warm more rapidly in the spring and see accelerated insect development.

Tracking some pests, particularly diseases, may require more specific microclimate data. Sensors and monitoring equipment may be necessary in numerous locations throughout an area (i.e: in subdivisions, at golf courses, even at various locations within a single golf course). Another option is to monitor environmental conditions at the site considered most likely to experience pest problems. By monitoring environmental factors in this one location, advance warning is supplied for surrounding areas.

Dramatic advances in environmental monitoring technology have brought the equipment needed to model insect pests within everyone's reach. Not only has the capability of the equipment been enhanced, but the price has dropped significantly over the past few years. Equipment varies from the most basic, simply displaying current temperature, humidity and rainfall, to complex systems that monitor and record a wide range of environmental factors. Some have built-in computers, or are linked to a computer that accumulates a data base. Others have programs that record degree-day accumulations. Degree accumulations, as we will discuss shortly, form the backbone of intuitive modelling.

Other advances in environmental monitoring technology include the ability to monitor remote sites without hard-wired connectors. In the past, if you wanted information from a particular location, it was necessary to run a cable from your computer or data collection unit to the monitors or sensors in the field. That often limited flexibility in site selection. Now, however, we can rely on wireless communication.

The use of radio telemetry, cellular phones, and infrared signals allows the field sensors to communicate directly with your equipment in the office. This permits the placement of the sensors in those critical locations where environmental monitoring is essential, and your work station wherever you prefer.

Some sensor-recorder packages are "stand alone" units. Their sole function is to collect environmental data. Other systems may perform additional functions, such as controlling an irrigation system. More recently, still other information sources have been made available through satellite down-link. The latter, while relatively inexpensive and offering a wide range of services, may not provide sufficiently specific or localized information for pest forecasting. They are useful, however, for tracking general trends and detecting variations from the normal.

"Intuitive modelling" in action

Let's look at a specific example of intuitive modelling and its many levels of use. Mole crickets have become a serious pest of turfgrass throughout the southeastern United States. Management of this pest is difficult at best. Many turfgrass managers spend thousands of dollars attempting to control mole crickets and end up with less than satisfactory results.

One of the key elements in effective control of this pest is the timing of insecticide application. Control measures against mole crickets are most efficacious when about 50% of the eggs have hatched. This may sound relatively straightforward, but the underground habits of the mole cricket make it difficult.

Mole crickets spend virtually their whole lives underground, feeding on the roots of turfgrass. When egg hatch is occurring, June through July, warm-season turf looks very healthy. The severe damage caused by mole crickets only becomes apparent late in the summer and early fall. At that point, however, the mole crickets are large and chemical controls are much less effective against them.

Detection of the very small crickets right after hatching is consequently very important. A soap flush—a mixture of 2 tablespoons of liquid dishwashing detergent in 2 gallons of water, applied to an area a yard square—can be an effective technique for bringing small mole crickets to the surface. This procedure is very time-consuming and labor intensive, however. Add to that the fact that, since there are no obvious above-ground symptoms, large areas of turf must be inspected.* Most importantly, mole cricket egg hatch can vary as much as a month from one year to the next. This means turfgrass managers relying only on soap flushes to track the hatch must keep at it for weeks before discovering when to take control measures. They would be a lot better off if they had some guidance on when egg hatch is most likely to occur.

Work at North Carolina State over the past several years has monitored mole cricket egg-laying, egg hatch, and nymph (or immature cricket) development. At the same time, air temperature, soil temperature, and rainfall have been recorded at 15 minute intervals by a computerized weather station.

After several years, a clear pattern has begun to emerge. Above-average soil temperature during April, May, or June means the eggs will hatch earlier than normal. A cool month during that same period will have the opposite effect. By monitoring and recording soil temperatures, we can determine when the egg hatch is likely to occur: earlier than usual, or later. For the turfgrass manager with consistent mole cricket problems, this is invaluable information.

It's important to note that with a soil insect such as a mole cricket, monitoring the soil temperature, not the air temperature, is what's important. Air temperatures in southeastern North Carolina during 1991 and 1992 were almost identical. However, the mole crickets hatched 2 to 3 weeks earlier during 1991 (see figure 5). The reason for this was that, while the air temperature was about the same during the month of May in both years, May of 1992 was much cloudier and overcast.

*See the August 1995 *TurfGrass TRENDS* issue for in-depth discussions of scouting techniques that would be helpful here.

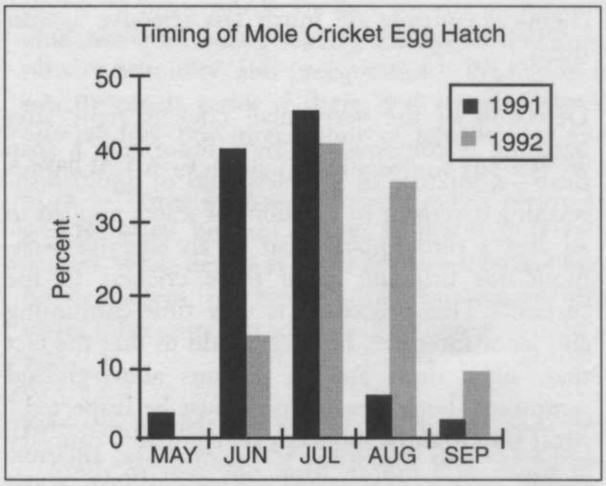


Figure 5. Mole cricket development (differences in egg hatch in two successive years).

As a result, the amount of solar radiation (sunlight) reaching the soil was much less. The soil didn't warm as quickly, and the crickets developed more slowly. Monitoring only the air temperature would have produced an inaccurate forecast of mole cricket development.

The end result of this work at North Carolina State University is that, through several years of monitoring soil temperatures and cricket development, we have constructed an intuitive model. Each year, we begin monitoring soil temperatures on January 1. We compare the degree-day accumulations for the current year with records of degree-day accumulations and cricket development from past years. This gives us a basis for predicting whether the crickets are going to be ahead of schedule, or behind.

"Degree-day" modelling

The term "degree-days" has been mentioned a couple of times. Degree-days are simply an accounting tool for recording how warm it has been. Most living organisms have a threshold or a minimum temperature for development. For insects, a common threshold is 50°F. Temperatures below this usually mean development does not take place; temperatures above 50°F usually mean development occurs. The higher the temperature above 50°F, the more rapid the development (within limits—insects can be cooked).

A simple way of calculating degree-days is to record the maximum and minimum temperature for the day, then add the two together and divide by 2 to get an "average temperature." From this "average" temperature, we then subtract 50°F, since this is our insect development threshold temperature. The resulting sum is the number of degree-days for that day. A negative number isn't used since it simply means no development occurred. If the minimum temperature for a day was 60°F and the maximum temperature was 80°F, then the average would be 70°F (80 + 60 = 140/2 = 70). Subtracting the 50°F threshold would yield 20. This is the number of degree-days recorded for that day.

Developmental models have cumulative degree-day targets that indicate when an important event is likely to happen (see table 1). For example, if mole cricket egg hatch is predicted to occur at 2,000 degree-days, and this usually occurs around June 17 here in Raleigh, then we base our current prediction on that model. Should we have 1,900 degree-days by June 1, and be accumulating about 30 additional degree-days each day thereafter, then we can estimate that egg hatch is going to occur earlier than the usual June 17. With this information in hand, we then know when to begin our all important soap flushes to verify the egg hatching. Once hatching has been verified, we can begin control measures in a timely and effective manner.

Similar intuitive pest models are already in use or under development in many states. These include models for sod webworms, masked chafers and Japanese beetles. The prediction of these pests includes both the appearance of the first and second generations (sod webworm) and appearance of the adults (masked chafers and Japanese beetles).

Of course, the real value of such predictions is dependent on the accuracy and completeness of the environmental information collected, and how specific the information is to the location of interest. Using a base 50°F, we see our first Japanese beetle adults in North Carolina at about 1,100 degree-days, which is the same for Ohio or New York. Only the time of year that target is reached is different for the different states.

As we look to the future of turfgrass pest management, intuitive modelling will likely take on an increasingly important role. One reason will be increasing regulations and legislation that will limit the amount of preventive pesticide application.

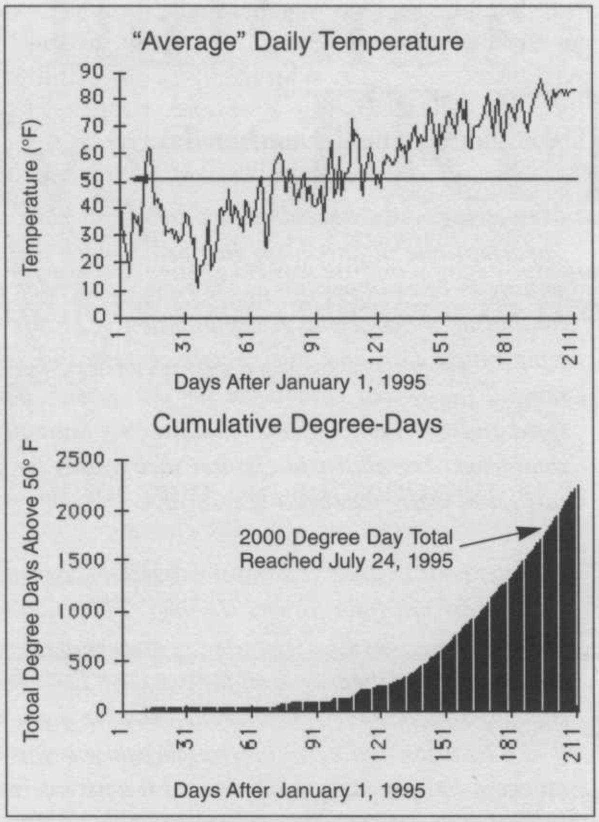


Figure 6. Degree-day accumulation at a representative site. (Data supplied by J. Michael Bailey, Automated Weather Source, Gaithersburg, MD.)

Future applications must be based more on the presence of a threatening pest population. Models that tell when the pest is most likely to appear will prove quite useful in helping meet those guidelines.

Additionally, we are seeing the production of more "biorational" or biological types of insecticides. Many of these must be targeted against a specific stage in the insect's development. Intuitive models can provide insight into the insect's growth patterns and help provide guidelines for the use of such products.

Suppose you have an interest in monitoring pest development, but aren't aware of any specific models for your area. How can you use the concept of intuitive modelling? The immediate answer is that you probably already are. Remember the flowering dogwoods mentioned earlier? In addition, with a little more record keeping, you can probably use it a lot more.

We have just reviewed intuitive modelling in making common sense decisions based on good information. If you have kept good records on the occurrence of a pest for several years, then you definitely have a good start on doing your own intuitive modelling. Should a certain pest typically occur in your area in early June, then you have a baseline from which to judge other years. If the weather in the spring is unusually warm, or cool, then record how this affects the occurrence of the pest.

Should you have access to weather data, be it from your own computerized system or simply by checking the daily newspaper, then the whole process can be quantified a bit more. You can even record your degree-days by hand. The bottom line is you can put as much time and effort into the recording of weather information and pest occurrence as you want. The more time you spend, the greater the likelihood of accurately determining if a pest going to show up earlier or later than usual.

It is important to note that not all pests need specific degree-day accumulations before they appear. In other words, it really doesn't matter how warm or cool it has been in the spring. Some pests may migrate in from other areas while others (and some diseases) may simply respond to the appropriate conditions of temperature, relative humidity and plant stress. The occurrence of many of the insects, however, can be predicted based primarily on temperature.

Intuitive modelling is continually being refined and models for additional pests are being developed. The real advantage to intuitive modelling is that it is straight-forward, simple, and useful. As turfgrass managers become more familiar with it,

Table 1. Degree-Day Targets of Various Species.

Species, Developmental Stage, Extent of Hatch	
Larger Sod Webworm (1st gen)	1050-1950
Larger Sod Webworm (2nd gen)	2600-3010
Bluegrass Sod Webworm (1st gen)	1250-1290
Bluegrass Sod Webworm (2nd gen)	2550-3010
Cranberry Girdler	1700-2750
N. Masked Chafer 1st adults	898-905
N. Masked Chafer 90% adults	1377-1579
S. Masked Chafer 1st adults	1000-1109
S. Masked Chafer 90% adults	1526-1679
Japanese Beetle 1st adults	1050-1180
Japanese Beetle 90% adults	1590-1925

Modelling tips

1. Always keep good records of the timing and location of each pest occurrence.

2. Keep or have access to good weather data.

3. Review the records and look for trends in insect occurrence.

4. Contact local or state turfgrass experts for existing models to predict turfgrass pests.

5. Always verify the occurrence of the pest with a careful scouting/sampling program—especially before taking control actions.

6. NEVER assume a pest isn't going to occur just because it doesn't show up on time. Other factors may be at work.

they are able to customize it to fit their needs. This is because intuitive modelling is based more than anything else on common sense. Intuitive modelling is a tool of the future that can be integrated into your turfgrass programs today.

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Some useful references:

- Brandenburg, R.L. and M. G. Villani (eds.), *Handbook of Turfgrass Insect Pests*, Lanham, MD: Entomological Society of America, 1995 $30 (ISBN:0-614-05664-0) [telephone (301) 731-4535 to order].

- Watschke, T.L., P. H. Dernoeden, and D.J. Shetlar, *Managing Turfgrass Pests (Advances in Turfgrass Science)*, Ann Arbor, MI: Lewis Publishing, 1994 $69.95 (ISBN: 0-87371-999-9) [telephone (800) 272-7737 to order]

Collecting local weather data

Monitoring your immediate environment plays an important role in forecasting turf pests, which is itself coming to be as important as the plan you develop for controlling the problem. A combination of factors — temperature (air and soil), moisture (air and soil), rainfall (daily and cumulative for the season), wind speed and direction, and solar radiation — must all be considered. The ability to monitor their values for the turf stand you're managing is critical.

To date, most weather information available commercially is derived from airport readings. This "canned" data can be misleading. How many airports have you been to that had shade trees on the runway? Data from regional or national vendors can be valuable if you use it as a basis for your overall meteorological monitoring program, but you have to supplement it with information on your immediate environment.

There are many weather stations on the market today that you can use to obtain local data. They range in cost from $400 to $50,000. Of course, the more you pay, the more you receive. A soil temperature and moisture probe can easily be integrated into most of the sensor suites in low cost weather stations, however, so you can get by with less than the most expensive. A weather station that periodically logs a complete set of environmental data, and records daily minimum and maximum values, provides all the capability you need to monitor and predict the onset of many pests. The additional benefits of real time reporting and PC-based tracking and modelling can be acquired for an additional $2,000 to $4,000, depending on the sensors, communications links and computer you choose. And any number of programs are available that permit users to tailor data reporting, aggregation and analysis functions to their particular requirements.

Contributed by J. Michael Bailey, Automated Weather Source, Gaithersburg, Maryland