Environmental Public Health Surveillance: Possible Estuary-Associated Syndrome

Lorraine C. Backer, Amanda Sue Niskar, Carol Rubin, Kim Blindauer, Dennis Christianson, Luke Naeher, and Helen Schurz Rogers

Centers for Disease Control and Prevention, National Center for Environmental Health, Atlanta, Georgia, USA

Public health surveillance involves the collection, analysis, and dissemination of data for use in public health practice. A surveillance system includes the capacity to collect and analyze data as well as the ability to disseminate the data to public health agencies that can undertake effective prevention and control activities. An emerging issue in environmental public health surveillance involves human exposure to the toxins produced by microorganisms present in oceans and estuaries. One of these organisms is *Pfiesteria piscicida* Steidinger & Burkholder, a dinoflagellate found in estuaries along the Atlantic and gulf coasts of the United States. There have been reports of both human illness associated with occupational exposures to concentrated laboratory cultures of *P. piscicida* and massive fill kills associated with the presence of the organism in rivers and estuaries. These reports, and anecdotal reports from people who worked on rivers where the organism has been found, generated concern that environmental exposures to *P. piscicida*, similar organisms, or perhaps a toxin or toxins produced by the organism(s), could cause adverse human health effects. To begin to evaluate the public health burden associated with *P. piscicida*, investigators from the National Center for Environmental Health at Centers for Disease Control and Prevention and health agencies from states along the Atlantic coast collaborated to develop a passive surveillance system for collecting, classifying, and tracking public inquiries about the organism. Specifically, the group developed exposure and symptom criteria and developed data collection and reporting capabilities to capture the human health parameters collectively referred to as possible estuary-associated syndrome (PEAS). The surveillance system was implemented in six states (Delaware, Florida, Maryland, North Carolina, South Carolina, Virginia) beginning in June 1998. From 1 June 1998 through 30 June 2001, the six state health agencies participating in the PEAS surveillance system received 3,859 calls: 3,768 callers requested information and 91 callers reported symptoms. Five individuals have been identified as meeting PEAS criteria. *Key words*: CDC, Centers for Control and Prevention, environmental public health, epidemiology, estuary, human health, PEAS, *Pfiesteria piscicida*, possible estuary-associated syndrome, surveillance. — *Environ Health Perspect* 109(suppl 5):797–801 (2001).

http://ehpnet1.niehs.nih.gov/docs/2001/suppl-5/797-801backer/abstract.html

Introduction

Public Health Surveillance

Public health surveillance involves the collection, analysis, and dissemination of data on specific health effects (e.g., disease, disability) for use in public health practice (*1*). A surveillance system includes the capacity to collect and analyze data as well as the ability to disseminate the data in a timely manner to public health agencies that can then undertake effective prevention and control activities.

Surveillance can be established to assess public health status, to establish public health priorities, to evaluate programs, and to conduct research (*2*). Surveillance data can be used to estimate the magnitude of a health problem in the population at risk, inform the population at risk of exposure or illness, inform persons and organizations responsible for immediate control measures and other interventions, understand the natural history of an illness or injury, detect outbreaks or epidemics, and document the distribution and spread of a health event. The data can also be used to test hypotheses about etiology, evaluate control strategies, monitor changes in exposure, identify research needs, facilitate epidemiological and laboratory research, facilitate planning, and provide information for decision making and policy (*2*).

Surveillance systems collecting primary data are classified as either passive or active (*2*). A passive system receives reports from physicians, individuals, or institutions, whereas an active system regularly contacts previously identified sources to elicit reports. Clearly, an active system results in more complete reporting; however, this type of surveillance is labor intensive and costly.

Surveillance systems prospectively identify the particular outcome of interest. Most surveillance systems also collect at least limited demographic information about the affected people, details about the health event, and the presence or absence of the appropriate risk factors (*3*).

Environmental Public Health Surveillance

In environmental public health, surveillance activities are applied not only to health outcomes but also to environmental hazards and exposures (*4*). For a surveillance system to be applicable to an environmental public health concern, the system must include measurements of specific hazards (e.g., water pollution), exposures (e.g., biomarkers for levels of an environmental contaminant in blood or other tissues), and/or health outcomes (*4*). The system must produce an ongoing data record rather than one-time surveys, and it must produce timely and representative data for use by agencies responsible for addressing environmental public health issues (*4*).

A number of special issues are associated with environmental public health surveillance (*4*), including a limited ability to identify the specific environmental causes of many adverse outcomes, particularly if the latency period is very long. In addition, we often attempt to conduct environmental public health surveillance using data collected for other purposes (e.g., vital records or drinking water quality monitoring) that do not contain adequate information to meet a case definition for an illness associated with an environmental exposure.

Another important issue to be addressed when conducting environmental public health surveillance is the need to involve a number of different constituencies in public health activities. Public alarm can influence a public health agenda by influencing not only funding decisions but also the directions of scientific research. Including input from specific interest and community activist groups, as well as the public health community, may improve the success of an environmental health surveillance program.

This article is based on a presentation at the CDC National Conference on *Pfiesteria*: From Biology to Public Health held 18–20 October 2000 in Stone Mountain, Georgia, USA.

Address correspondence to L.C. Backer, Centers for Disease Control and Prevention, National Center for Environmental Health, 1600 Clifton Rd, NE, MS E-23, Atlanta, GA 30333 USA. Telephone: (404) 498-1342. Fax: (404) 498-1355. E-mail: lfb9@cdc.gov

The authors acknowledge the contributions of officials from the collaborating state health agencies: A.L. Hathcock, C. Nace, Delaware Dept. of Health and Social Services; D. Johnson, R. Quimbo, Florida Dept. of Health; R. Venezia, A. Chapin, Maryland Dept. of Health and Mental Hygiene; J.S. Cline, K. Buckheit, P. Webb, North Carolina Dept. of Health and Human Services; R. Ball, N. Scruggs, South Carolina Dept. of Health and Environmental Control; S. Jenkins, L.A. Peipins, M. Monti, M. Brooks, Virginia Dept. of Health; A. Holmes, National Center for Environmental Health, Centers for Disease Control and Prevention.

Received 14 February 2001; accepted 7 August 2001.

Finally, an important scientific issue associated with surveillance in general, but which may be more important in environmental health surveillance, is biological markers (*4*). The ability to detect an environmental toxin in human tissues or verify a biological effect from such an exposure is critical to identifying and understanding environmental illnesses.

Pfiesteria piscicida

An emerging issue in environmental public health surveillance is human exposure to the microorganisms present in oceans and estuaries and to the toxins they may produce. One of these organisms is *Pfiesteria piscicida* Steidinger & Burkholder, a dinoflagellate that has been found in estuaries along the Atlantic and gulf coasts of the United States (*5*). There have been reports of human illness associated with occupational exposures to concentrated laboratory cultures of *P. piscicida* (*6*) as well as massive fill kills and the observation of fish with ulcerative lesions associated with the presence of the organism in rivers and estuaries (*7*).

In addition to the published reports, there were anecdotal reports that environmental exposure to this organism may impact human health. In 1997 a small group of people living and working near a river on the Eastern Shore of the Chesapeake Bay in Maryland reported to their health department that they were ill. Their symptoms included nonspecific complaints such as headaches and skin rashes and also included neurocognitive complaints such as problems with memory and concentration. Fishermen working on a local river that summer reported seeing a large fish kill comprising a number of fish with ulcerative lesions. *P. piscicida* was tentatively identified by light microscopy in water samples collected from the river. These reports generated concern that environmental exposures to *P. piscicida*, similar organisms, or perhaps a toxin or toxins produced by the organism(s), could cause adverse human health effects. To begin to evaluate the public health burden associated with exposure to *P. piscicida*, investigators and public health officials developed a passive surveillance system for collecting, classifying, and tracking public inquiries about the organism.

Methods

The public health officials from federal and state health agencies collaborated to develop the public health response to the presence of *P. piscicida* (and similar organisms, hereafter referred to as *Pfiesteria* spp.) in estuarine waters. Surveillance activities were supported by congressionally mandated funds through cooperative agreements with Centers for Disease Control and Prevention (CDC) (*8*). First, the group developed a number of working definitions for the illness, exposure, and symptoms. The aggregate of exposure and symptom criteria was called possible estuary-associated syndrome (PEAS) (*9,10*).

For surveillance purposes, people meet PEAS criteria if *a*) they report that their symptoms developed within 2 weeks after self-reported exposure to waters defined by the relevant state agency as estuarine; *b*) they report memory loss or confusion of any duration or three or more of the following symptoms: skin rash/sensation of burning skin at the site of water contact of any duration; or headache, eye irritation, upper respiratory irritation, muscle cramps, and gastrointestinal symptoms, any of which persist for more than 2 weeks; and *c*) a healthcare provider cannot identify another cause for the symptoms (*9,10*).

For the surveillance system we were specifically interested in trying to document human environmental exposure to *Pfiesteria* spp. However, at that time, there was no efficient way to evaluate exposure because no toxin had been identified and the identification of the organism itself was costly and time-consuming (involving long-term laboratory culturing and scanning electron microscopy) (*5*). The state and federal health agency representatives agreed to surmise the presence of *P. piscicida*, and thus assume human exposure, under certain circumstances such as the presence of fish kills for which there was no other explanation. For PEAS surveillance, exposure to estuarine water was considered an indicator of the potential for exposure to *Pfiesteria* spp. Thus, for the PEAS surveillance activities, exposure was defined as self-reported work or recreational activities in or on estuarine water within 2 weeks prior to onset of symptom(s), or self-reported laboratory or aquaculture work involving exposure to estuarine water or organisms from estuarine waters within 2 weeks prior to symptom onset (*9,10*).

Each state participating in the PEAS surveillance system established a toll-free telephone hotline to provide information to callers about *P. piscicida* and similar organisms, exposure to estuarine water, and symptoms of PEAS. CDC and the state health agencies jointly developed questionnaires, a core data dictionary, and a database program for state PEAS data collection (*11*). Some state health agencies elected to collect additional information based on circumstances in their state or to address particular research interests. To facilitate data entry, the screens for entering data into the database program reflected the format of the paper form used when responding to callers.

The surveillance system was designed to passively collect information to assess the public health burden of exposure and illness associated with *Pfiesteria* spp. The telephone hotlines provided an entry point to the data collection system. CDC epidemiologists worked closely with state health agency representatives to provide training and technical assistance in implementing the surveillance system.

On 1 June 1998 CDC and the state health agencies of Delaware, Florida, Maryland, North Carolina, South Carolina, and Virginia initiated the passive surveillance system for PEAS. Callers are triaged through a complex decision system (Figure 1). People who call for information are provided with brochures and other education materials developed by their state health agencies. People calling to report symptoms are administered an interview that includes questions on demographics, exposure, symptoms, and related medical care. The purpose of the interview is to determine, based on exposure and symptoms, whether an individual should be referred for further medical evaluation and to provide a disposition. As part of their surveillance programs, some state health agencies refer callers to their personal primary health care providers for any further medical care. Other state health agencies identified a group of physicians interested in assessing the health symptoms reported by people who may have been exposed to *Pfiesteria* spp. and provided funding for the follow-up medical evaluations.

All calls from people requesting information or reporting symptoms that may be related to *Pfiesteria* spp. are recorded in the database. If symptoms are reported, exposure is assessed by using the established exposure criteria. If symptoms are reported but exposure to estuarine water is not, the symptomatic person receives information about PEAS and *Pfiesteria* spp., and based on state-specific protocols, may be referred to a healthcare provider.

If the caller reports symptoms and exposure to estuarine water, the state representative administers a telephone questionnaire to determine if the caller meets symptom criteria. If a person does not meet symptom criteria, the state representative provides the caller with information about PEAS and *Pfiesteria* spp., refers the person to his/her primary health care provider, and requests that the person call back if symptoms change or persist. When a person meets PEAS symptom criteria, the state health agency representative may (depending on state-specific protocols) refer the caller to or assist the caller in making appointments with medical specialists.

Subsequent physician reports may provide an explanation for the person's symptoms. When no alternative explanation can be given for an exposed individual's symptoms, the state health agency representative refers him or her to the appropriate medical specialists, according to the state protocol. A representative from

the state health agency conducts follow-up by telephone to obtain medical reports and assign a final disposition based on the PEAS symptom and exposure criteria. If the state health agency is unable to obtain the relevant medical reports from physicians, the symptomatic person is considered lost to follow-up.

Surveillance information for the core data variables is periodically transferred to CDC for data aggregation and dissemination to the public in the form of periodic reports in the *Morbidity and Mortality Weekly Review* (*12*).

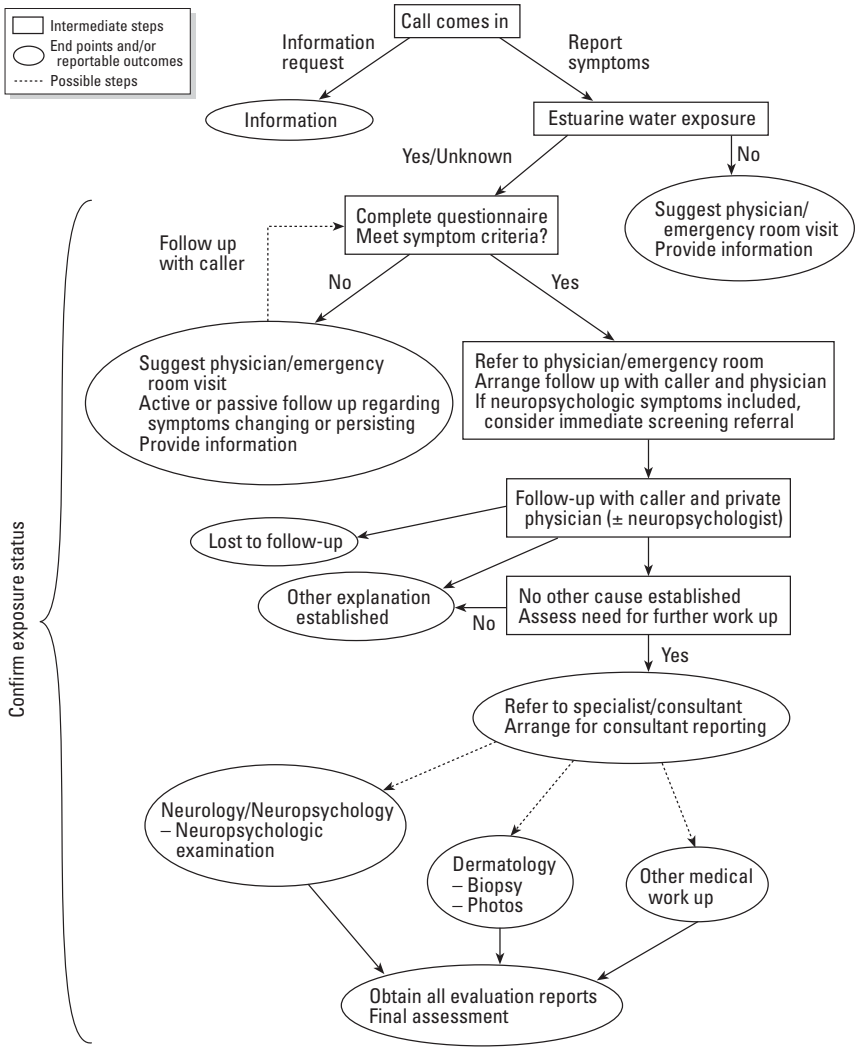

Figure 1. Flow of calls in surveillance system.

Table 1. PEAS surveillance results: 1 June 1998–30 June 2001.

Calls to PEAS surveillance system	1998[a]	1999	2000	2001	Total
Number requesting information only	939	962	1615	252	3,768
Number reporting symptoms	41	33	15	2	91
Total calls	980	995	1,630	254	3,859
Number reporting symptoms and potential estuarine water exposure	27	23	14	2	66
Number seen by or referred to a healthcare provider	23	18	13	1	55
Number for whom another cause of illness was identified and reported by a healthcare provider	8	7	3	0	18
Number with final results pending	0	2	2	1	5
Total number of callers meeting PEAS criteria[b]	1	1	3	0	5

[a]1 June through 31 December 1998. [b]For surveillance purposes, people meet PEAS criteria if *a*) they report that their symptoms developed within 2 weeks after self-reported exposure to waters defined by the relevant state agency as estuarine; *b*) they report memory loss or confusion of any duration or three or more of the following symptoms: skin rash/sensation of burning skin at the site of water contact of any duration; or headache, eye irritation, upper respiratory irritation, muscle cramps, and gastrointestinal symptoms, any of which persist for more than 2 weeks; and *c*) a healthcare provider cannot identify another cause for the symptoms (*9,10*).

Results

From 1 June 1998, through 30 June 2001, the six state health agencies participating in the PEAS surveillance system received 3,859 calls to request information about *P. piscicida* or similar organisms or to report symptoms (Table 1). Almost all (97.6%) the calls were requests for information about *P. piscicida*, similar organisms, or PEAS. Ninety-one calls concerned symptomatic people; 66 (73%) of these people had possible exposure to estuarine water. Of these 66 people, 55 were seen by or referred to a healthcare provider and five chose not to seek medical care. Of the 54 people who did contact a healthcare provider, 18 had another cause identified for their symptoms [e.g., physician-diagnosed insect bites, impetigo, foliculitis (*13*)], and four have environmental and medical results still pending.

Five individuals have been identified as meeting PEAS criteria (see "Materials and Methods" for criteria). The time of exposure, reported activities, date of symptom onset, and environmental sampling data for these five people are presented in Table 2. Because most of the fish and water sampling and analysis was done as part of routine monitoring programs, it is difficult to establish a temporal association between finding fish with lesions or identifying *Pfiesteria* in water samples and the reported onset of symptoms for these individuals. For example, for subject 1, menhaden with lesions were found in the same general area where the subject had been engaged in recreational activities. *Pfiesteria* was identified in water samples from the Pocomoke, but the samples were collected 2 months after the reported exposure. For subject 2, *Pfiesteria* was identified in the water samples collected soon after the reported exposure; however, less than 0.5% of the collected menhaden had lesions. For subject 3, fish and water were sampled at times that overlapped the reported exposures, but very few menhaden had lesions, and *Pfiesteria* was not found in the water samples. For subject 4, sampling was conducted 2 months after the reported exposure and onset of symptoms; thus, we do not know if the exposure involved water containing *Pfiesteria* or fish with lesions. Finally, for subject 5, no fish sampling was done, and few samples were taken in the rivers where exposure was reported to occur. *Pfiesteria* was not identified in the two water samples collected.

Discussion

The development of the PEAS surveillance system represented a unique challenge to the public health agencies involved because the health outcome was a nonspecific constellation

Table 2. Date and description of activities conducted on estuarine waters in Maryland, date of symptoms onset, and date and results from environmental sampling in the geographic area of the exposure to estuarine waters for individuals meeting PEAS criteria as of 31 January 2001.

Subject	Activities	Area of activities	Date of activities	Date of symptoms onset	Fish monitoring[a]	Water monitoring[b]
1	Recreation	Pokomoke River	Summer 1998	Aug 1998[c]	Lower Pocomoke 15 Jul–15 Aug 1998 2/4 4,307 fish, 43 anomalies	Lower Pocomoke Oct 1998 4/28
2	Kayaking	Back Creek	9 August 1999	9 Aug 1999	Back Creek 11 Aug–14 Sept 1999 2/2,002	Back Creek 11–26 Aug 1999 6/9
3	Hobby fishing, crabbing, clamming	Tangier Sound, Back Creek, Rumbly Point	Oct & Nov 1999 May & June 2000	Oct 1999[c]	Tangier Sound No sampling Back Creek May–Jun 2000 2/2,135 Rumbly Point No samples	Tangier Sound Apr–Oct 2000 0/30 Back Creek Jun 2000 0/2 Rumbly Point 8 Apr–19 Oct 1999 0/7
4	Water sampling	St. Martins Smith Island	23 June 2000 26 June 2000	24 June 2000[c]	Bishopville Prong 6–10 Aug 2000 3/13 Smith Island No samples	Bishopville Prong 4 & 10 Aug 2000 0/2 Tangier Sound, 5 miles south of Smith Island Apr–Oct 2000 0/10
5	Summer boating	Miles River, Severn River	Apr–Aug 1998, 1999, 2000	1 May 2000	Miles River No samples Severn River No samples	Miles River No samples Severn River Sept–Oct 1999 0/2

[a]Number of menhaden with lesions/number of menhaden examined, unless other species of fish listed. [b]Number of water samples positive for *Pfiesteria*/number of water samples analyzed. [c]These individuals were exposed to estuarine water and reported various symptoms in 1997. Their symptoms had resolved (completely or incompletely) over time, and they were again symptomatic on the dates shown in this table.

of health complaints based on self-reports from a small group of people. In addition, exposure could only be surmised from reports of unexplained fish kills or fish with lesions or the identification of *P. piscicida* in water samples taken after the fact. Finally, the hazard was ill-defined as the presence in the water of *P. piscicida* itself or of toxin(s) produced by the organism, similar organisms, or, possibly, of bacteria or other pathogens that might be found in association with *P. piscicida*.

While PEAS surveillance activities were being planned and implemented, a considerable amount of research effort was simultaneously devoted to investigating the biology and ecology of *P. piscicida*, whether and under what circumstances the organism might produce a toxin or toxins, and what the human health effects from exposure to the organism actually were. We expected to revise PEAS surveillance exposure and symptom criteria as the scientific work on *Pfiesteria* spp. evolved.

Our ability to detect and identify *P. piscicida* and similar organisms improved from 1997 to 2001. New assays included a polymerase chain reaction–based assay (*14*) and a reporter gene assay for toxic activity associated with the organism (*15*). However, there were few improvements in defining human exposure and symptoms. For example, in 1998 Grattan et al. (*16*) reported that the original group of people who may have been exposed during the late summer of 1997 experienced symptoms that included skin lesions and measurable neurocognitive difficulties. However, even for this original group that reported symptoms and potential exposure, a temporal association between symptom onset and the presence of *P. piscicida* in the river has not been confirmed.

Efforts to identify a toxin or toxins elaborated by *P. piscicida* have not yet been successful; without something to measure, it is not possible to confirm that an environmental exposure has occurred. In addition, without an identifiable toxin, we cannot develop markers of either exposure or biological effect in people. Thus, the anticipated improvements in defining exposure and symptoms have not yet occurred.

Despite the difficulties associated with PEAS surveillance, the surveillance system has accomplished the important public health goal of identifying the public health burden of *Pfiesteria* spp. on the state health agencies that were responsible for responding to *Pfiesteria* spp.–related phone calls over a 37-month period. The PEAS surveillance system provides information about estuarine events that state health agencies can use to make decisions related to potential *Pfiesteria* spp.–related illness and public health. This information can then be quickly disseminated to the public. It is interesting to note that from 1998 through 2000, the number of calls requesting information increased, while the number of calls reporting symptoms decreased. Although these changes probably reflected the decrease in *P. piscicida*–related environmental events (i.e., fish kills, fish with lesions), they probably also reflect the efforts of local health agencies to educate the public. We anticipate that PEAS surveillance activities will continue minimally through 2002.

During the period from 1 June 1998 through 30 June 2001(Table 1), only five of the individuals who were captured by the surveillance system received a final disposition of PEAS. Five people are still undergoing medical tests, others were lost to follow-up, and other symptomatic people may have provided incomplete information (particularly information about medical follow-up)or never reported to the system.

Of the five individuals who met PEAS criteria, three were in the original group that reported exposure during the summer of 1997. We attempted to use primarily routine monitoring data to verify that these individuals were exposed to estuarine waters during fish kills or at times when *Pfiesteria* was found in the water. However, except for subjects 2 and 3, the monitoring data were not collected

during the reported exposure period(s). For subject 2, the fish and water sampling data did not identify either a large number of fish with lesions or the presence of *Pfiesteria* in the water at the time of their reported exposure. *Pfiesteria* was identified in samples taken in Back Creek in Maryland at about the same time subject 2 reported being there. However, even in this example, there were only two lesioned fish among over 2,000 examined. Thus, it remains difficult to conclude that the symptoms reported by those meeting PEAS criteria are related to the presence of *Pfiesteria*. If ongoing research indicates that the definitions of PEAS or that symptom or exposure criteria should be modified, the disposition of some of the people in the surveillance system may change.

The identification of people with PEAS is certainly dependent upon the existence of the appropriate environmental and ecological circumstances. During the *P. piscicida* "seasons" (from midsummer through late fall) since the initiation of PEAS surveillance (June 1998), there have been few adverse impacts on fish populations that could be attributed to *P. piscicida* and very few indications of *P. piscicida* blooms (periods of exuberant growth). Although the reasons for this lack of *P. piscicida* activity are unclear, it is possible that upon more careful observation, fish kills and the presence of lesions on fish are being attributed to other causes, including environmental stressors such as suboptimal water quality (*17*) or fungal infections (*18,19*). In addition, runoff from the massive hurricane-related flooding in the North Carolina piedmont area may have created suboptimal habitat for this organism, limiting its ability to impact fish and/or human health.

Characteristics of the PEAS surveillance system that may limit its usefulness have been discussed. The definitions of PEAS and the criteria for symptoms and exposure are nonspecific and impossible to confirm. In addition, the system is passive and relies on public awareness of the system, and the public obtaining access and providing information to the system. It is likely that there is underreporting of exposures and symptoms that meet our surveillance definitions. It is important also to emphasize that the surveillance system was designed to assess the burden to the public health agencies responding to inquiries about the organism. It was not designed to determine the human health risk from exposure to estuarine waters, *P. piscicida*, or similar organisms.

Despite these limitations, the PEAS system was successful in contributing to the field of environmental public health surveillance. The PEAS surveillance system provided valuable information about the extent of the burden for state health agencies from public concern about *Pfiesteria* spp. Through the development of the PEAS surveillance system, several state health agencies have created an infrastructure allowing them to rapidly respond to public health events associated with estuarine exposure that includes multidisciplinary teams, a tracking system, and data collection capacity. Finally, the PEAS surveillance system is a model for conducting public health surveillance for other environmental health issues, including the human health impact from other harmful algal blooms.

References and Notes

1. Thacker SB, Berkelman RL. Public health surveillance in the United States. Epidemiol Rev 10:164–190 (1988).
2. Teutsch SM. Considerations in planning a surveillance system. In: Principles and Practice of Public Health Surveillance (Teutsch SM, Churchill RE, eds). Oxford:Oxford University Press, 1994;18–28.
3. Klaucke DN. Evaluating public health surveillance. In: Principles and Practice of Public Health Surveillance (Teutsch SM, Churchill RE, eds). Oxford:Oxford University Press, 1994;158–174.
4. Thacker SB, Troup DF, Parrish RG, Anderson HA. Surveillance in environmental public health: issues, systems, and sources. Am J Public Health 86(5):633–641 (1996).
5. Steidinger KA, Burkholder JM, Glasgow HB, Hobbs CW, Garrett JK, Truby EW, Noga EJ, Smith SA. *Pfiesteria piscicida* gen. et sp. nov. Pfiesteriaceae fam. nov.), a new toxic dinoflagellate with a complex life cycle and behavior. J Phycol 32:157–164 (1996).
6. Glasgow HB Jr, Burkholder JM, Schmechel DE, Tester PA, Rublee PA. Insidious effects of a toxic estuarine dinoflagellate on fish survival and human health. J Toxicol Environ Health 46:501–522 (1995).
7. Burkholder JM, Noga EJ, Hobbs CW, Glasgow HB Jr. New "phantom" dinoflagellate is the causative agent of major estuarine fish kills. Nature 358:401–410; 360:768 (1992).
8. Centers for Disease Control and Prevention. Fiscal year 1998 *Pfiesteria*-related illness surveillance and prevention. Fed Reg 63(13):3138–3141 (1998).
9. Centers for Disease Control and Prevention. Results of the Public Health Response to *Pfiesteria* Workshop—Atlanta, Georgia, September 29-30, 1997. Mor Mortal Wkly Rep 46:951–952 (1999).
10. Centers for Disease Control and Prevention. Possible estuary associated syndrome. Mor Mortal Wkly Rep 48:381–382 (1999).
11. Centers for Disease Control and Prevention, Delaware Department of Health and Social Services, Florida Department of Health, Maryland Department of Health and Mental Hygiene, North Carolina Department of Health and Human Services, South Carolina Department of Health and Environmental Control, Virginia Department of Health. Possible Estuary Associated Syndrome (PEAS) Surveillance Software, Version 2.0. (June 2000).
12. Centers for Disease Control and Prevention. Surveillance for possible estuary associated syndrome–six states, 1998-1999. Mor Mortal Wkly Rep 49:372–373 (2000).
13. Rowan A. (Harmful Algal Blooms Coordinator, Florida Department of Health) and Buckheit K. (Harmful Algal Blooms Coordinator, North Carolina Department of Health). Personal communication.
14. Oldach DW, Delwiche CF, Jakobsen KS, Tengs T, Brown EG, Kempton JW, Schaefer EF, Bowers HA, Glasgow HB Jr, Burkholder JM, et al. Heteroduplex mobility assay-guided sequence discovery: elucidation of the small subunit (18S) rDNA sequences of *Pfiesteria piscicida* and related dinoflagellates from complex algal culture and environmental sample DNA pools. Proc Natl Acad Sci U S A 97(8):4303–4308 (2000).
15. Fairey ER, Edmunds JS, Deamer-Meila NJ, Glasgow HB Jr, Johnson FM, Moeller PR, Burkholder JM, Ramsdell JS. Reporter gene assay for fish-killing activity produced by Pfiesteria piscicida. Environ Health Perspect 107(9):711–714 (1999).
16. Grattan LM, Oldach D, Perl TM, Lowitt MH, Matuszak DL, Dickson C, Parrott C, Shoemaker RC, Kauffman CL, Wasserman MP, et al. Learning and memory difficulties after environmental exposure to waterways containing toxin-producing *Pfiesteria* or *Pfiesteria*-like dinoflagellates. Lancet 352:532–539 (1998).
17. Kane AS, Oldach D, Reimschuessel R. Fish lesions in the Chesapeake Bay: *Pfiesteria*-like dinoflagellates and other etiologies. Md Med J 47(3):106–112 (1998).
18. Levine JF, Hawkins JH, Dykstra MJ, Noga EJ, Moye DW, Cone RS. Epidemiology of ulcerative mycosis in Atlantic menhaden in the Tar-Pamlico River estuary, North Carolina. J Aquat Anim Health 2:162–171 (1990).
19. Kane AS, Dykstra MJ, Noga EJ, Reimschuessel R, Baya A, Driscoll C, Pearl HW, Landsberg J. Etiologies, observations and reporting of estuarine fish lesions. Mar Environ Res 50:473–477 (2000).