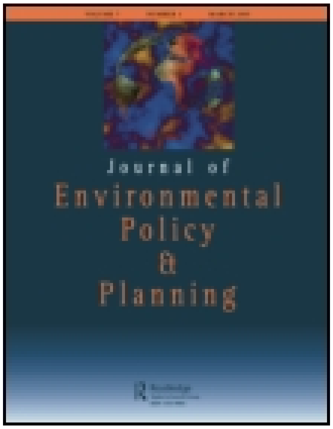

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Insects and Institutions: Managing Emergent Hazards in the U.S. Southwest

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ABSTRACT *A range of institutional systems exist to manage and mitigate environmental problems, yet the quickly changing, ecologically surprising, and spatially complex qualities of ecological problems create new challenges for institutional learning. The rapid and nearly uncontrolled recent outbreak of West Nile Virus in the U.S. Southwest, and the associated risk of other mosquito-borne diseases, typifies these sorts of challenges. How are management authorities adapting to the changing conditions presented by mosquito-borne diseases? What bureaucratic structures condition and limit their responses? Using archival research and interviews, this paper analyzes the recent track record of mosquito management in southern Arizona, specifically examining county health programs and municipal water authorities in Pima County and Tucson. Results suggest that bureaucracies develop fundamentally different practices. While health officials collect data and manage problems based largely on citizen complaints, water management authorities are occupied with managing emerging problems in artificial wetland environments. Both bureaucracies are encumbered by disciplinary specializations that fragment learning, thwart interagency interaction, and decrease response times. These differing systems of management and understanding also lead to spotty and inconsistent data collection and abatement. By addressing the fundamental analogies and metaphors that lie at the heart of persistent institutions, adaptation might be better facilitated.*

KEY WORDS: Mosquito, institutional geographies, West Nile Virus, political ecology

Introduction

As a result of increasingly complex interactions between humans and environments, the risks associated with managing environmental systems are commonly thought to be increasing rather than decreasing (Beck, 1992). Government and civil institutions struggle with emergent and often unforeseen problems that are simultaneously human/technological and environmental/biogenic, some of which have no precedent. Sea level rise, aquifer depletion, avian influenza viruses, and invasive species are but a few examples of such complex, 'hybrid,'

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and difficult-to-govern transformations. From a geographic perspective, these problems cross borders, have sources at locations separate from their effects, and include drivers that are both human and non-human, with serious and ongoing implications for communities, economies, and livelihoods, as well as ecosystem resilience, degradation, and diversity.

A vast range of institutional systems currently exist to manage and mitigate environmental problems, yet the quickly changing, ecologically surprising, and spatially complex qualities of new problems may create a serious mismatch for institutions formed in earlier times—that is, for organizations created with (a) less complex and more clearly delineated substantive roles and (b) simpler, jurisdictionally bound geographies of responsibility. What remains unclear, therefore, is the degree to which and the way in which already existing bureaucracies and structures of governance, often operating across different jurisdictional spaces and drawing on different forms of information, are organized to address emergent problems, assign causation, carry out surveillance, and choose mitigation alternatives.

The recent outbreak of West Nile Virus in southern Arizona and the associated risk of other mosquito-borne diseases, including dengue fever and a range of related encephalitis diseases, is an acute example of just such a problem. This rapid and nearly uncontrolled set of outbreaks underline the importance of understanding and governing emerging disease risks in complex, highly humanized landscapes, where multiple authorities (and the public at large) operate with varying geographical and substantive capacities and knowledge regimes. We should therefore not be surprised if state agencies and other organizations prove to be greatly constrained by their specific geographical practices and boundary limits, as well as by the distinctive training, education, competences, and governance capacities they bring to mosquitoes. This presents a pressing question: How do traditional bureaucracies and agencies adapt, adjust, and learn when faced with this new hazard? For southern Arizona more immediately, where no coherent and unified agency is charged with managing the risk of mosquitoes and mosquito-borne disease, how do health and water agencies re-gear their operations, re-think their logics, and re-direct their budgets, as mosquitoes are found to proliferate?

This paper addresses these questions by empirically surveying two public agencies in Pima County, Arizona—the Pima County Department of Health and the Tucson Water (TW) department—to compare their emerging strategies and commitments in adapting to mosquitoes. By reviewing historical records, recent and contemporary agency practices, organizational structures and job descriptions, and through interviews with key agency personnel, the work seeks to determine whether the differing institutional geographies and regulatory authorities of health and water agencies match, overlap, or diverge from one another, and whether their emerging strategies bring them closer to a coordinated response or, rather, farther away.

We conclude that the responses of these agencies are seriously hampered by the disciplinary knowledges and jurisdictional geographies each has inherited. Our results suggest more practically that, relative to the problem of mosquitoes, agencies are capable of adapting to unprecedented problems, but slow at learning and re-institutionalizing these responses. This is so since, following the work of Mary Douglas (1986), deeply rooted analogies, categories, and metaphors lie at the heart of persistent institutions. More than this, we anticipate that these persistent knowledge habits are in part formed by the problematic gaps in the geographies of control and management, rather than being inherited passively from the state of disciplinary knowledge (following Mitchell, 2002). The outcomes of our research suggest a need for better theoretical understanding of the state/nature divide, but also improvement of our understanding of institutions, agencies, and other high-order actors in complex political ecologies.

A Brief History of the Mosquito in Arizona

The case of the arid U.S. Southwest is potentially paradigmatic in this regard, since it represents a place where new insect problems are rapidly confronting traditional management institutions. Despite the aridity of southern Arizona and Sonora, the region has long been a center of mosquito-borne insect problems and epidemics. The more intermittent but formerly more consistently riparian river flats of the region have provided breeding grounds for insects since the time of the earliest recorded histories of missionaries in the region in the 16th century. Settlers did not yet recognize mosquitoes as carriers of malaria, but did recognize the 'unhealthful' nature of living close to swamps or *cienegas*. In his description of the Sonora province, the Jesuit priest Ignacio Pfefferkorn (1725–1793) describes *mosquiteros*, or mosquito nets, in use by Spanish settlers to avoid insects (Pfefferkorn, 1949).

In the Tucson area in the 1750s, serious illness from what were most likely insect-borne diseases, as well as complaints of mosquito nuisance, were prevalent throughout the rainy season (Dobyns, 1976). Early friars and missionaries in the territory reported suffering from malarial fever and periodic epidemics of the disease devastated tribes living in mission districts (Kessell, 1976). Mormon settlements in the 1870s experienced constant malarial threats and were on occasion abandoned in the face of disease. The population of these communities only stabilized after the surrounding wetlands were fully drained towards the end of the 19th century (McClintock, 1921, p. 234). The first settlers in the Gila valley were also constantly beset by malaria, and possibly some forms of encephalitis, with a high rate of attrition in pioneer families to fever (Teeples, 1929). Several U.S. Army camps, including two major forts, were abandoned in the face of malaria (Fink, 1998). These insect problems, especially mosquitoes, were made worse by the construction techniques of Anglo settlers, which included windows and doors without screens (Boehringer, 1930).

The geography of mosquitoes and disease in this era was highly uneven, however. Gila valley residents report constant sickness in the 1800s, while the Salt River Valley remained relatively free of fever (Alsap, 1936). This reflects the historic and ongoing sensitivity of mosquitoes to microclimatological conditions and the availability of breeding sites and blood resources, even in an era before large-scale human modification of the ecosystem.

Though little intentional disease-control drainage occurred in the U.S. Southwest, the arrival of the cattle economy coincided with the lowering of water tables and the loss of wetlands. Chemical controls further reduced mosquito populations. Pioneering tests of the 'wonder insecticide' DDT were conducted in Arizona and, as part of an experiment to test the newest modes of insecticide application, the U.S. Navy sent two 'highly secret fog generators' to the state in

1945 (Russell, 2001, p. 154). This was to usher in an aggressive campaign that, coupled with wetland draining, dramatically reduced the mosquito hazard for several decades. Even so, these early chemical-based management efforts ran up against the problem of acquired resistance in fast-breeding nuisance species, including mosquitoes, which began to resist DDT and its relatives (e.g., dieldrin) by 1952. Efforts at insect control in Phoenix as early as 1950 reported diminished returns and lack of chemical potency (Russell, 2001).

Although a precise date is difficult to determine to any degree of accuracy, the nadir of mosquito populations in the region probably occurred in the 1960s. A combination of land transformation and chemical control, coupled with a still relatively low human population, meant that mosquitoes and mosquito-borne diseases were far from the policy agenda of water mangers, planners, and development officials in urban or rural areas.

By 2005, this set of conditions was overthrown entirely. Specifically, the region has seen the arrival of several specific pest and nuisance species of mosquito, including *Culex pipiens, Aedes aegypti, Culiseta melanura*, and the female *Anopheles* mosquito (Table 1), many of which are capable of over-wintering in the region. Surveys in Pima County, Arizona, the southernmost county of the state bordering on Mexico, have revealed that *Ae. aegypti*, the mosquito responsible for transmitting dengue, has colonized many cities and towns throughout the region (Merrill *et al.*, 2005), while eggs of *Ae. aegypti* have been found in and around 46% of surveyed residences (Botz, 2002). *Culex quinquefasciatus*, found in both wetland and residential areas, continues to feed extensively on humans and birds in the region, presenting a serious West Nile risk (Zinser, 2004; Zinser *et al.*, 2004).

The drivers behind these changes are several. New land uses have increasingly been favorable for mosquito growth and development. Heavily irrigated agriculture, especially pecan production involving flood irrigation with standing water, has become an important fixture of the southernmost part of the state, including 7000 acres of irrigated pecans in the region (Herrera, 1995; 2005). Urban land use changes are even more influential, including an increase in backyard habitats like neglected swimming pools, unmaintained ponds and fountains, and in certain forms of solid waste (i.e., abandoned tires). For *quinquefasciatus*, a rise in the number and density of urban dairies outside of Phoenix and other municipalities further creates breeding habitat in large ponds for wastewater purification and flushing.

The cessation of large scale fogging efforts and the ban on DDT in the late 1960s also curtailed some of the most dramatic checks on mosquito populations,

Table 1. Diseases and mosquito vectors in Southern Arizona

Potential disease	Mosquito vector (currently present in the region)	Disease currently present
West Nile Virus	*Culex quinquefasciatus* and others	✓
Malaria	Female *Anopheles*	✗
Dengue	*Aedes aegypti* and *Ae. albopictus*	✗
Yellow fever	*Aedes aegypti* and *Ae. albopictus*	✗
St. Louis encephalitis	*Culex* species and *Culiseta melanura*	✓
Equine encephalitis	*Culex* species and *Culiseta melanura*	✓

although some populations (*Ae. aegypti*) had never been seriously affected by pesticides (Reiter & Gubler, 1997). These changes have been compounded by the deliberate restoration of previously drained wetlands (for amenity and ecosystem services) as well as the construction of manmade wetlands (for water treatment) throughout southern Arizona in the last two decades. Controlled studies at constructed wetland sites, including those that incorporate mosquito population control designs, show increases in mosquito populations, often by several orders of magnitude, shortly after their establishment (Karpiscak, *et al.*, 2004; Willott, 2004; 2006). In sum, the nature of economic and technological development and urban growth in the region has resulted in a dramatic resurgence of mosquito populations, bringing with it a significantly increased risk of disease transmission, with historically demonstrated reasons for concern.

The rapid emergence of the current problem presents unusual challenges for citizens and managers. Long accustomed to an arid environment free of mosquito hazards, a huge range of agencies—including health services, water delivery utilities, municipal and county managers, and wildlife management agencies—have all quite suddenly been confronted with a new set of uncertainties and responsibilities.

With few historically established protocols, differing agencies and groups must devise strategies that fit their expertise, responsibilities, and organizational capacity. Individual managers, many of them migrants from other regions, must assemble their disparate knowledges, weigh and establish risks, and devise behaviors and often-non-obligatory measures to pass along to citizens. The mosquito population, moreover, continues to expand and adapt to these changing circumstances, colonizing new areas and exploiting changes in the physical and political landscape.

Anticipating the Agency/Environment Mismatch

The institutional capacity of a state agency to address and govern spatially complex problems like mosquito emergence is dependent, in part, on the flexibility of its surveillance mechanisms for addressing, managing, and coping with nature. Yet as Scott (1998) has demonstrated, inherent in any state's mandate to control, protect, and manage environments and populations, is the necessity to render complex ecological contexts legible and simplified, in the sense that they are measured in a way that they can be coded and recorded. Through practices of standardization of measures, categories, and practices of mapping and accounting, the state is better able to take a census of problems, and rationally parcel out the elements of governance: 'The great advantage of such tunnel vision is that it brings into sharp focus certain limited aspects of an otherwise far more complex and unwieldy reality' (Scott, 1998, p. 12). Such standardization is inherently geographic, as Scott observes, since it implies a selective mapping of the distribution and classification of objects of state concern; it is explicitly optical.

But in rendering problems legible, state metrics used in mapping and categorizing nature both limit and create perverse incentives for state agents and institutions, with the often pernicious effect of grossly mismanaging ecologies that are far more complex than the systems simplified to manage them. Environmental patterns often are written into the natural world in this way in an attempt to make them fit the categories, measures, and organization of state optics. In this way, landscapes are 'reverse engineered' from the simplified categories used in their description (Veregin, 1995; Winner, 1977). At the same time, deep, practical, and local knowledge of integrated systems (*metis*) is discarded in favor of thinner, more universal schematics (*techne*).

Although Scott's critique of state capacity and behavior is directed at high modernist authoritarianism (e.g., Stalinist Soviet Union) certain elements of it might be predicted to operate in the management of the mosquito-borne illnesses in southern Arizona. With some agencies collecting data on standing water while others count avian vectors or map cases, governance is likely organized around discrete and simplified controls and tasks that, while central to the problem, overlook complex ecological processes and linkages. Moreover, these segmented controls are precisely what keep agencies from conversing between themselves—sharing information among interoperable data systems, for example—whether or not they share jurisdictional boundaries.

This portrait of environmental governance is rendered even more problematic by two facets of the real regulatory environment. First, the state is an agent that operates under disjointed cultures and political economic circumstances, from regulatory mechanisms in powerful urban centers geared towards protecting consumption, to local service delivery bureaucracies in rural and smaller urban areas seeking to simply maintain access. While some bureaucracies protect large budgets, others operate through interstitial cooperation between small entities. It is increasingly clear, therefore, that the geographic capacities, knowledges, and tendencies of state institutions are both enabled and restricted by their specific context of governance, rather than by any general or universal logic. Bureaucracies, institutions, and state scientists at different locations (central urban cores versus resource peripheries in particular) are often steeped in deep, practical, and unique local knowledges and practices, rooted in always contextual politics and local cultures (Robbins, 2000; 2003). They also embed and reproduce space in their daily practices: strategizing locations, dividing territories, and discursively constructing places and environments are all but a few of the many ways in which organizations are inherently geographic (del Casino *et al.*, 2000).

Second, state ecological geographies are further cleft along the lines of the domain of their responsibility (e.g., health, environment, vertebrate species of concern, or wastewater management). This is true for the relatively obvious reason that agencies and actors charged with a single portion of a complex problem imagine, record, and act on information in way that is inevitably distinct from those with totally differing goals, even within the same encompassing problem. But more subtly, it is also increasingly well understood that differing state agencies come to reflect the disciplinary tendencies of their constituent academic practices and trainings. Despite the interdisciplinary nature of public environmental and health management problems, some agencies and organizations have historically come to be dominated by the cultures of specific disciplinary groups, whether it is biologists in wildlife management agencies or range scientists in the Bureau of Land Management. Moreover, the explanatory habits, systems of classification, and preference of data to confirm or deny claims differ between cultures of differing disciplines (Becher, 1989; Biglan, 1973; Braxton & Hargens, 1996), including those of scientists (e.g., botanists and geomorphologists: Latour, 1999, p. 27) or professional practitioners (e.g., nurses and doctors: Bowker & Star, 1999).

So while expertise to deal with emerging health problems historically has always created problems to which new forms of expertise must be amassed and legitimized (see specifically Mitchell, 2002 for the case of mosquito-borne illness), the specific character and conditions of these new forms of knowledge and expertise will inevitably be cleaved in changing ways, as complex political and disciplinary conditions evolve. Thus, it might be postulated that understandings of complex, abstract, and mobile problems like that of mosquito-borne illness may come to differ between state agencies occupying differing domains (e.g., health or environment), and populated by differing practitioners (e.g., immunologists, entomologists, or conservation biologists).

In sum, to understand the geographic capacities and limits for state management of mosquito-borne illness, it is essential to untangle the influence of institutional contexts and cultures on actual agency knowledge and practice. How do these cultures and domains activate different activities in actual institutions? To ask such questions is neither to deny the porosity of bureaucracies to even larger contextual environments within which they operate, including among other things the various control points (e.g., the Center for Disease Control) that coalesce in a federalized system. Nor equally is it permissible to overlook the role of key actors in adapting institutions to changing circumstances. Indeed, as elements of the state apparatus, it is valuable to conceive of the bureaucracies charged with management of the mosquito hazard through the lens of state theory more generally (e.g., Jessop, 1990), which suggests a dialectical approach to both the institutional–contextual interface and the institutional–individual one. Nevertheless, in actual research practice these intersecting influences cannot all be held constant at any one time. In the research reported here, we focus on the impact of disciplinary domain knowledges and the distinct objects—disease and water—as they influence the two most important agencies dealing with the mosquito in southern Arizona.

Methodology

As noted previously, Pima County is paradigmatic insofar as mosquito-related hazards, though having a long history in the region, have not until very recently been a source of state management concern, being driven out of public consciousness during the early and mid-twentieth century. So too, high levels of population increase and radical urban growth make the area typical for much of the urban Southwest. Finally, the region is notable for the relative autonomy of county and municipal government in the planning and execution of health and environment policy. In this way, the actions and adaptations of Pima County and southern Arizona municipal agencies represent conditions and experiences that will likely recur elsewhere as mosquito hazards promulgate through the region.

The first portion of research, therefore, focused on establishing the historical background of vector control in Arizona and the degree of management by local agencies in the region. This included review of policies of the Arizona Department of Health Services and current state-oriented research conducted at Arizona state universities and extension services. This phase disclosed that the sole regional agencies with directed mandates for coping with changing mosquito populations and health risks in Pima County are the Pima County Health Department (PCHD), specifically its Consumer Health & Food Safety Services branch, and TW.

We then began a detailed exploration of policies and planning by the PCHD, beginning with archival research at the Arizona State Historical Society, especially in Health Department Monthly Reports from 1963 to 1987. Supplemental text sources included contemporary PCHD websites and annual reports, along with limited archives maintained by departmental staff. Interviews were conducted with managers of the vector control division at the Department. At the same time, a review of policy at City of TW focused primarily on interviews and office visits with key staff, specifically those directly involved with vector control programs at TW's Sweetwater Wetlands. This was supplemented with the department's internet sites and library sources concerning agency structure and fiscal arrangements.

From Nuisance to Hazard: The Experience of County Health

The Consumer Health & Food Safety Services branch of the PCHD is the primary agency to oversee and manage the risk of mosquito-borne illness in the region. As its name suggests, the agency is simultaneously charged with an enormous range of other tasks, including certification of swimming pools and testing of food vendors. In FY 2002–2003, for example, while its 21 full-time staff members investigated 300 vector-related complaints, they also performed 7600 food service inspections and 3800 pool safety inspections (Pima County Health Department, 2004).

The vector control program at PCHD is at least 20 years old, but the department has maintained no consistent archive of its activities related to vector control over the long term. This is because mosquito-related problems have only slowly emerged to be understood as a health problem, rather than merely a nuisance. This fact is punctuated in part by record keeping: the primary data of department activity relative to mosquitoes comes in the form of citizen complaints received by the department and maintained as part of the public record. These are recorded in monthly reports, the latest of which is made available online. Issues from the past few years are stored at PCHD. Though the evaluation of trends (both temporal and spatial) requires the archiving of past copies of this report, there is no comprehensive collection at any county or state office. The University of Arizona library contains copies of the report from 1963 to 1987, and staff members at County Clinics have opted to save more recent reports (1997–2005). Yet there is no system of compilation, review, or storage, and a 10-year data gap persists. Moreover, current staff could provide no knowledge of what control measures were taken in the past or how mosquito control has evolved within the department. Vector control agents were unable to provide information regarding many basic organizational facts, including when formal and official 'vector control' first began at PCHD.

Review of the existing records suggests, however, that there has been a distinct trend away from understanding the mosquito as a nuisance towards treating it as a potentially dangerous disease vector, even while the sampling and reporting procedures of the department have remained primarily nuisance-oriented. The acknowledgment of monitoring mosquito populations for disease only first emerges in 1969; prior to this date, mosquitoes were an irritant. The predominant method for sampling and ameliorating the problem in the period prior to 1970, therefore, was an established protocol for complaint management. All mosquito-related complaints were recorded, and once an unspecified 'critical mass' was reached, spraying or other vector controls procedures (e.g., site visits) would be undertaken.

With the rise of West Nile Virus and related encephalitis cases and concern about other diseases on the increase in the 1980s, the mission of PCHD relative to mosquitoes changed markedly. It is unclear when vector control became a formal part of the structured tasks of the agency, but these tasks currently control their own dedicated but fluctuating budget line. Yearly costs for monitoring mosquito activity in the Department exceed $50,000. The budget for this effort is a small proportion of the total Consumer Health and Food Safety budget, which is itself about 6% of the total public health budget in Pima County ($244M in FY 2004/05). This budgeting is pursuant to goals laid out in Arizona State Legislature Bill 36-601, which designates mosquitoes to be a 'Public nuisance dangerous to public health . . . capable of carrying and transmitting disease-causing organisms to any person or persons.'

The resulting budget expands information campaigns, which focus primarily on providing information for residents on avoiding mosquitoes, and pays for control activities. Where controls are initiated, a range of adulticides and larvicides are used by PCHD, including petroleum Larviciding Oil, which simply drowns larvae and pupae by increasing water surface tension at breeding sites, as well as more active Altocid Briquettes and *Bacillus thuringiensis* cultures.

Even with this rise of attention, modest dedication of funds and activities, and improvement in control technologies, the primary data collection methods and territorial strategies of the department have remained largely unchanged from the 1960s, and continue to depend on recording and treating the 'hotspot' sites of citizen complaint. Most data available on mosquito distributions at the municipal scale, and all sites for abatement and treatment, are therefore delimited by areas of human habitation (as opposed to known conditions for mosquito breeding, drainage, moisture, or temperature), and then only sampled where multiple complaints are lodged. So too, complaints in recent years are considerably fewer than their peak in the 1970s (see Figure 1, showing complaints to PCHD, for years available), suggesting even sparser information sampling.

Some active mosquito surveillance and trapping is conducted by PCHD from March through October. The Mosquito-Borne Virus Surveillance Program tests adult female mosquitoes for Western Equine Encephalitis, St. Louis Encephalitis, and West Nile virus. The Department's recent 'Fight the Bite' initiative has also extended efforts to testing of dead birds for West Nile Virus. Even so, the presence of mosquitoes is recorded and control technologies are implemented primarily where there are significant numbers of citizen complaints, while the number of trapped sites in the last decade is comparable to the mid-1960s and is considerably lower than in the 1970s, long before the shift in agency attention to mosquitoes as a health hazard, rather than mere nuisance (Figure 2). The overall rate and coverage of direct monitoring by staff (outside of complaint-related investigation and intervention) has declined exactly coincident with the period of increased risk of vector-borne diseases. Fewer resources spread over more tasks have diluted some of the agency's efforts. Moreover, the historical orientation of the PCHD as a provider of services and information for people, rather than as an environmental management agency, provides a strong inertia against maintaining a mosquito-centered monitoring system. This extends to the training and

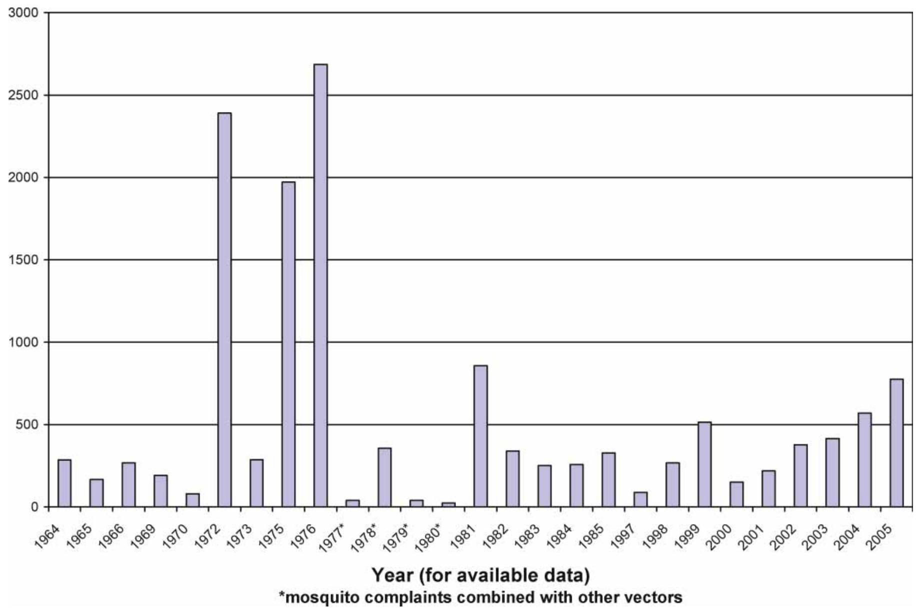

Figure 1. Mosquito complaints to Pima County Health Department: 1964–2005.

disciplinary background of the department's personnel. The 21 specialists in Consumer Health are primarily trained in public health disciplines, with job descriptions ranging from sanitarian to epidemiologist. No entomologist has been employed by PCHD since the 1960s.

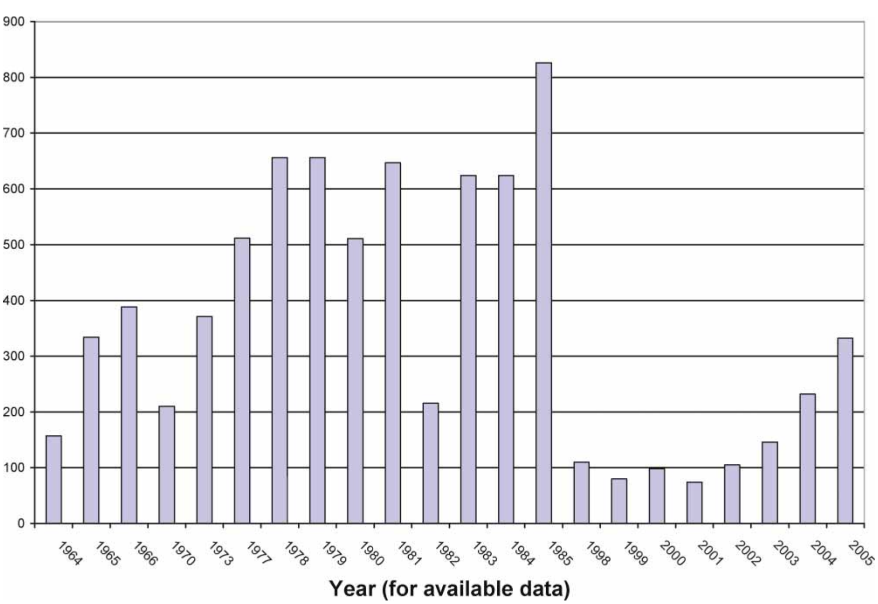

Figure 2. Number of trapped sites by Pima County Health Department: 1964–2005.

To equip themselves for vector control, PCHD employees are now trained annually by entomology and chemistry experts from the University of Arizona, the Arizona Department of Health Services, and pesticide companies that supply the county. This means that all employees of the Consumer Health and Food Safety Division are now trained in vector control and some form of vector control is listed in most job descriptions in the division. Simply being able to spray for insects and check for larval activity does not, however, necessarily translate into an understanding of mosquito habits and population dynamics (especially as these change), and no staff members exclusively manage insect-related data or map and monitor the direction and rate of insect population growth. As a result, PCHD has no internal capacity or expertise for anticipating areas of potential outbreaks, modeling or managing risk, or forestalling environmental interactions that may create new threats. The department relies heavily on outside sources not only for training, but also for basic research.

In sum, a review of Pima County Health's efforts to adapt to changing health management conditions created by increasing mosquito-borne disease suggests the following: (a) poor institutional memory born of limited precedent; (b) an extremely limited budget in an agency with multiple unrelated objectives; (c) sampling and management biased towards the Department's traditional mission of public health information and services; (d) a territorial focus largely circumscribed by public complaints; and (e) a disciplinary orientation that forces outsourcing of training and science. The experience of Municipal Water is comparable, but with some notable distinctions.

From Solution to Problem: the Experience of Municipal Water

TW is an 'Enterprise Fund' of the City of Tucson, meaning that it is a municipal authority but one that covers all costs of doing business with revenues from operations. The agency provides water service to 710,000 people, or approximately 85% of the total number of people in Pima County, many of whom live outside the city of Tucson (Tucson Water, 2006). Unlike the jurisdictional simplicity of the PCHD, TW's boundaries coincide neither with the City's nor County's. It is bound, rather, by a Long-Range Planning Area established in the late 1980s. Much unmodified today, it resembles a gerrymandered congressional seat, and within it there are several independent water providers, including the towns of Marana and Oro Valley, the Flowing Wells Irrigation District, and Davis-Monthan Air Force Base (Tucson Water, 2004). These and other areas not within the projected service area leave a jurisdictional patchwork of water responsibility that spills over into the management of mosquitoes.

TW's responsibility for mosquito-related illnesses emerges from the fact that some of their operations have inadvertently created conditions that foster potential vectors. Specifically, its artificial Sweetwater Wetlands project has become a major breeding site. The Sweetwater Wetlands project, an artificial riparian area, arose from a suit successfully filed by the Arizona Department of Environmental Quality that found the City of Tucson in violation of drinking water monitoring and reporting requirements. In lieu of a fine, an experimental wetland/recharge facility was proposed, one that would enhance public education, restore a riparian area, and provide opportunities for research. The Department of Environmental Quality approved the plan and initiated development of the wetland. The Public Notification and Participation Plan for the project was approved by the City Mayor and Council in October 1994, and subsequently a Citizen's Advisory Committee on the wetlands was formed. Other organizations, such as the U.S. Fish and Wildlife Service, Game and Fish, Parks and Recreation, and the University of Arizona, also joined the committee. Ten meetings were held from December 1994 to September 1995 to help design the wetlands. Construction began in 1996 (Gelt, 1997).

The central role of the wetlands is as a facility for cleaning reclaimed water previously used to backwash filters deployed in wastewater treatment. Three hundred acre-feet of backwash water is treated annually. At a total cost of $1.7 million, the completed facility houses 17.5 acres of constructed wetlands, 14 acres of recharge basins, and no shortage of mosquitoes, which find it an ideal breeding environment.

The central mosquito issue facing TW is the design and implementation of control measures associated with the wetland. The city has undertaken vector control programs to manage the population and TW staff monitor mosquito numbers weekly. In addition, samples are sent to the entomology department at the University of Arizona where they are analyzed for species identification and diseases. As in the case of County Health, the current responsibility for insect-related knowledge and practice was largely unanticipated. The original plan for mosquitoes in the wetland called for their control through natural predation, especially by bats. On the completion of the wetland, however, monitoring showed daily counts in excess of 8000 mosquitoes per trap, rendering this control mechanism unrealistic. Mechanical removal of plant biomass was also attempted, but was largely unsuccessful as little municipal heavy equipment in the greater Southwest is designed for riparian work. Controlled burning by area fire departments has been initiated in lieu of direct biomass removal. One-third of the wetland is burned annually.

Spraying, however, has proven far more effective, both in killing adult mosquitoes and in preventing the growth of larvae. Successful management has meant, however, a far more dedicated and hands-on regime than was anticipated by TW in its original planning, and necessitated a massive and ongoing effort in experimentation. In deference to the lessons learned from the use of chemicals like DDT in the past and under a mandate to keep the wetlands as natural a preserve as possible, TW has gone to lengths to develop environmentally-friendly vector control techniques. Species-specific larvicide (e.g., *Bacillus thuringiensis*, or BTI, a bacterium that once ingested breaks up the cells of the gut wall, stopping the insect from feeding) is designed to dissolve at the pH of mosquito larvae stomachs and is therefore safe for other animal and insect life in the wetlands. Methoprene and other biological larvicides made from chrysanthemums have also been used.

Yet, delivery of insecticides remains a problem. BTI is used from February to November and is distributed weekly by aerial dispersal from a remote-controlled Yamaha helicopter, the only one of its kind in the nation. In 2003, some distribution shifted to ground-based hydroseed spraying using high-pressure water cannon. Unable to reach central areas of the wetland with the cannon, TW then contracted for a Kawasaki ARGO tracked aquatic watercraft to distribute larvicide centrally. In periods of high mosquito activity, the city further contracts to spray by a truck-mounted aerial fogger twice a week. Adulticide fogging with a plant-based product is used when deemed necessary, either when monitoring trap numbers are high or when West Nile Virus is prevalent.

Overall, the system is directed to prevent the wetlands from generating more than a minimum of mosquitoes (agency-defined as less than 20/trap every night). The average annual population is 82% lower than in 1998–1999 when management was initiated. TW representatives complain that the successful reductions experienced at Sweetwater remain largely unacknowledged and that Tucson residents continue to associate the wetland as the sole and largest source of mosquitoes in the region.

These apparently successful adaptations have come at cost, however. As an 'Enterprise Fund,' TW receives all of its revenue from the payments of citizen water bills. Before the wetlands, annual treatment of backwash water came at an annual cost of $100,000, with backwash waste pumped into the sewer system. The wetland now treats this backwash water at a yearly operational cost of slightly less than $100,000, which suggests that, as intended, the wetland pays for itself (minus the significant front-loaded capital expenditure). The aggressive mosquito abatement program increases the operating budget of the wetland by more than $60,000/year, making the investment far less than cost-effective, while the mandate and structure of the agency's operational funding has not been able to incorporate the additional cost burdens associated with managing the mosquito hazard.

Meanwhile, the training problems associated with the unanticipated addition of mosquito management to municipal water have also broken with the agency's traditional practices. TW personnel in charge of managing the Sweetwater Wetland are hydrologists, and respondents report that there was a 'huge learning curve' in coming to understand and implement mosquito abatement. The officer in charge of the mosquito abatement program is a hydrologist, as is the head of operations of the wetlands, as is the agent in charge of public information. Facing a City of Tucson hiring cap on the agency, there remains no plan to hire an entomologist. Like County Health, therefore, TW has worked through resources including the state university and indirectly through state health agencies and private pesticide companies in order to obtain additional training for staff.

Extension of efforts to other waste water treatment areas that may be sources of vector hazards are not so far a part of TW's planning, despite the presence of eleven wastewater treatment facilities in the agency's uneven jurisdiction across the county. In part, agency personnel explain, this is simply because these facilities maintain flow rates high enough to retard mosquito development, unlike standing water in wetlands. In this sense, the already-limited geographic and territorial mandate of TW is further constrained by the agency's understanding of, and responsibility for, sites of breeding. Nevertheless, it is clear that there is little institutional capacity or budgeting to expand mosquito management in any case, much less adapt to any further mosquito hazards, given that current management efforts already involve negative fiscal balances. In short, the origin and management of the wetland has resulted in a hybrid hazard that has extended agency management practices well beyond their traditional mandate.

As a result, municipal water, like county health, does not have the resources or the responsibility to predict what insect populations might do in the face of future urban growth or in the implementation of other new water treatment technologies. Arguably, the 'unforeseeable' growth in mosquito populations at the wetlands in the first place reflects the relative unimportance of entomology and other biotic sciences in the decision-making and planning arrangements of the agency. Spatially, moreover, all agency efforts are now directed at managing the problems created with the wetland and not to other management territories including, for the moment, any other treatment facilities.

The record of TW in adapting to the emergent problem of mosquito-borne disease in the region suggests the difficulty of: (a) adapting an agency to a management role with absolutely no precedent; (b) budgeting for growing mandates in a 'zero-sum' fiscal system; (c) confining management territory to that established by the unintended impacts of agency mission and jurisdictional reach; and (d) disciplinary orientation that forces outsourcing of training and science. Together with the experience of PCHD, therefore, some key patterns are clear, and are summarized in Table 2.

Discussion: Institutions Think, but Can They Learn?

In her book *How Institutions Think*, Mary Douglas (1986) explains that institutions are founded on common naturalized principles (or analogies) that allow their participant members to share a model for behavior and action. In this way of thinking, institutions do much of the categorization of problems or situations for people, allowing their constituents to share a common identity, and to get things done. Fully rational decisions are made by people within their institutionalized context, but always only rational within the terms and conditions of the institution's internal logic. As a result, institutions can also remember and forget for us, actually coming to make important (indeed 'life and death' in Douglas' terms) decisions *for* their constituent members.

The problem of mosquito management in the U.S. Southwest is one that shows the potentialities and limits of agencies within the logics elaborated by Douglas. Both the PCHD and TW find themselves operating to solve tasks for which their governing analogies, categories, and identities have no set precedent, and for which there is no institutional memory. The directed resources of each, one set in the narrow confines of scarce state budgets and the other trapped within a 'zero sum' self-funding mandate, both pose difficulties for accessing funds for

Table 2. Memory, resources, territory, and training in institutional learning

	County Health—PCHD	Municipal Water—TW
Institutional memory	Poor historical record of efforts and techniques; little capacity to learn or experiment	Unprecedented growth of responsibility to mosquito control
Directed resources	Extremely limited budget in an agency with multiple unrelated objectives	Self-funding mandate of 'enterprise fund' makes vector control an unanticipated operating cost
Management territory/geography	Nuisance mandate directs areas of control	Water treatment mandate (artificial wetland) creates 'unforeseen' mosquito hazard at site
Discipline/training	Sanitarian, Public Health, and Epidemiology; no entomologists on staff	Hydrology & Geophysics; no entomologists on staff

tasks historically not within their purview. The historical territorial ranges of each circumscribe not only management jurisdictions but even the spatial and temporal data sets from which their decisions are made. The training, disciplinary habits, and even identity of participants and agents, though adapting to changing responsibilities, remain rooted in the traditional assumptions about what each institution is and does.

To be clear, this by no means suggests that these (somewhat beleaguered) bureaucracies have in any way failed in their new responsibilities for managing mosquitoes and containing insect disease vectors. To be sure, PCHD has successfully adapted and retrained its personnel and begun realigning its management, shifting from an understanding of mosquitoes from being a nuisance to being a more urgent health threat. So too, TW has effectively adopted and adapted an enormous range of technological capabilities in addressing the 'unintended' mosquito problems created in their attempts to solve water treatment problems inherent in urban growth. And not insignificantly, both agencies have comprehensive and extensively distributed public information campaigns, including outreach efforts. Institutions can think.

At the same time, however, the new practices, methods, and ideas that these agencies extend and propose must necessarily always reflect some of the often limiting elements of their historical configurations. The data development needs for surveying the highly mobile and complex geography of mosquitoes is poorly matched to the metaphor of 'nuisance'—a mosquito control relict from the 1960s. The very planning of a wetland that underestimates mosquitoes reflects the range of 'hydraulic' concepts available to TW in the mid-1990s. Though the constituent members of these institutions have admirably and rapidly retrained at great effort, the analogies that naturalize certain ways of thinking within these institutions remain undisturbed; have these institutions really learned?

This raises troubling questions about the inherent capacities of agencies more generally, as they face the increasingly rapid transformations of landscape and climate, inevitably part of future urban growth and the concomitant and unintended interactions that follow between human and non-human systems. It does go further, however, towards identifying the root causes of inertia, beyond the trite conclusion that bureaucracies are slow to change. Beyond this, it suggests that the site of control lies in the fundamental principles and metaphors that necessarily lay at the heart of coherent institutions. Sitting at the core of organizations are governing first concepts and analogies—unwritten, unacknowledged, and buried. As documented here, these are themselves not without history, however, and so it stands that they can be challenged, questioned, and changed. A proactive approach to environmental management suggests that they must be.

Conclusion

What then might constitute some elements of a proactive approach to mosquito management? One avenue might be to create a more spatially comprehensive agency to deal with the mosquito in Pima County. While the PCHD's jurisdictional area conforms to the county's boundaries, their method of data collection—based on citizen complaints—means that mosquito reporting has more to do with population distributions than with the geography of the insect or its ecological drivers. (What is more, even citizen reports can be untrustworthy.

Tucson has a significant Hispanic population, much of which has good reason to be wary of contacting government agencies.) Epidemiologically speaking, we do know that the 2006 summer outbreak of West Nile Virus in Tucson, which affected 47 people and claimed several lives, was concentrated in a few neighborhoods. These areas were dubbed and mapped as West Nile 'hotspots' in the local newspaper, an event that unfortunately led some eventual victims living outside the neighborhoods to have taken on a false sense of security (Rathbun, 2007). Meanwhile, the gaps in TW's surveillance are due to the facts that: (a) the agency's service area boundary conforms to no other official jurisdiction, which would seem to be a limit condition for full inter-agency coordination; (b) inside the service area's main boundary there are spatial islands that are not served at all or are served by other water agencies, further complicating coordination; and (c) TW has focused its limited resources on the Sweetwater Wetlands facility. Taken together, these uneven geographies of response suggest the need for a new agency with county-wide responsibilities and the resources for trapping and management in both populated and non-populated areas. The latter is especially important in the face of avian transport of the West Nile virus.

Even in the absence of a new coordinating body, modification of existing institutions is possible. There is, first, the need for improved inter-agency collaboration wherein institutional procedures, habits, and languages can be jointly examined. At present, staff members of PCHD meet with those of TW only annually. They of necessity tend to bring their own perspectives to the table, and in any case those of the discipline of entomology are not at all represented. Reflecting on these meetings, one research confidant remarked that anecdotal information can be re-coded as truth and passed through the organizations, while some issues are not broached or challenged. Thus popular beliefs among some members of both the public and agency staffs that the Sweetwater facility is the primary non-human agent behind the rise of West Nile cases remain, despite the fact that neighborhoods that saw the most activity in 2006 are far removed from the wetlands. A more direct collaborative strategy might allow more issues to arrive at the table for discussion and contestation.

In addition to new forms of collaboration, these agencies may profit by reworking some of their institutional structures from the ground up. In the case of the PCHD, mosquito control was attached onto an existing organizational arm, while in TW's case insect management arose only in response to pubic concerns over the construction of the wetlands. Thus both agencies have seen their organizations respond in only haphazard ways as the mosquito has shifted from a nuisance to a vector.

In sum, the mosquito threat in southern Arizona—as elsewhere—has now exceeded both the knowledge regimes and jurisdictional capacities necessary to manage it. The new West Nile-carrying mosquito is a public health hazard quite different from the mosquitoes of the past, and, equally, there is no reason to expect that our institutions' geographies conform to the rhizomatic and punctured spaces of the bugs they are charged with detecting.

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