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TURTLES

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ABSTRACT. Juvenile turtles have the capacity to eat more than 500 3rd and 4th instar mosquitos per day. Keeping one turtle in each water-storage tank during field trials for a dengue-control project in Honduras eliminated all mosquito production from the tanks. In Louisiana, keeping turtles in residential roadside ditches polluted by septic-tank effluent reduced *Culex quinquefasciatus* larvae and pupae by more than 99%. Turtles can serve as alternate hosts for *Salmonella* when kept in small pet containers, but the available evidence indicates that turtles create no *Salmonella* hazard in water-storage tanks or other mosquito-breeding habitats. Although turtles would probably not be practical for mosquito control in roadside ditches, they could be effective in storm-water catch basins or holding ponds.

INTRODUCTION

Most aquatic turtles are general predators, eating a diversity of animals including mosquito larvae. Experiments with red-eared slider turtles *(Trachemys scripta,* Fig. 1) revealed their enormous capacity to consume mosquito larvae (Borjas et al. 1993). The turtles, which were less than a year old, came from a Louisiana turtle farm that supplies the international pet trade. They ignored 1st instars, preyed to some extent on 2nd instars, and preyed intensively on 3rd and 4th instars and pupae. When 500 3rd and 4th instar *Ae. aegypti* were placed day after day in cement tanks (several hundred liters capacity), each containing a single turtle, no larvae survived to the adult stage. The turtles frequently ate as many as 1,000 larvae within a few hours if that many were available.

The turtles displayed the same predation intensity during months of laboratory observation as long as the temperature remained above 20°C (Marten [NOMCB] October 1993 p 5-6, November 1993 p 4-5, February 1994 p 5-6). Turtles less than a year old generally consumed 400-1000 4th instars/day. Turtles between 1 and 2 years old consumed 1000—2000 larvae/day. Although *T. scripta* in nature are primarily carnivorous when young, becoming more omnivorous (consuming more plants) as they grow older (Gibbons 1990), older turtles also ate large numbers of mosquito larvae in the laboratory. Predation ceased at temperatures below 18°C.

WATER-STORAGE TANKS IN HONDURAS

Field trials in a community-based dengue control project in Honduras revealed how effective turtles can be for mosquito control (Marten et al. 1992, Borjas et al. 1993). A single *T. scripta* (6-12 months old) was introduced to each of 50 cement water-storage tanks, known locally as *pilas.* The tanks have a capacity of 100-500 liters and are open at the top for dipping water to hand-wash clothes immediately adjacent to the tank. The water is also used for household cleaning but not for drinking. *Pilas* are major sources of *Ae. aegypti* production, and when dirty, they can produce large numbers of *Culex.*

Turtles were employed because other methods of *Ae. aegypti* control had failed. Educational campaigns advising housewives to scrub *Ae. aegypti* eggs off the sides of their tanks or remove larvae by changing the water once a week had not worked. Other biological methods such as fish and copepods were tested in the tanks, but fish and copepod survival was poor (Marten et al. 1994). Fish were stressed by the continual use of the tanks. Copepods were washed down the drain when tanks were cleaned and were sometimes killed by bleach or other household chemicals that got into the tanks when women were washing clothes. Turtles were not noticeably disturbed by human activity. They were too large to go down the drain, and small quantities of household chemicals did not bother them.

During 2 years of observation, no mosquito larvae were known to emerge from a water storage tank that contained a turtle. Families welcomed the turtles as pets. The supply of mosquito larvae or other natural food was not enough to sustain the turtles, but kitchen scraps maintained them in excellent health. A small floating platform in the tanks provided turtles an opportunity to sun themselves, but proved unnecessary for health and survival. Turtles in tanks without a platform showed no signs of skin disorders or other health problems. Mortality was less than 5% per year. Turtles have a natural life span of more than 30 years.

The tanks were used to store water that flowed from the tap only a few hours a week. The main hazard with the turtles was escape if the tank was filled to the top. This sometimes happened if

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Fig. 1. Red-eared slider turtle (*Trachemys scripta*). Photo by Chris Brown.

a housewife turned on the tap to fill the tank and left it until it overflowed. Turtle escape could be prevented by drilling a small overflow hole 4 cm below the top of the tank.

RESIDENTIAL ROADSIDE DITCHES IN LOUISIANA

Culex quinquefasciatus breeds in the roadside drainage ditches of residential neighborhoods in small towns in Louisiana. The larvae are particularly dense in the vicinity of septic-tank outlets, where organic pollution generates an abundant supply of bacterial food for the larvae. Chemical pollution near septic-tank outlets excludes fish and copepods that provide natural control of *Cx. quinquefasciatus* larvae in unpolluted segments of the ditches (Marten et al. 2000). When turtles in the laboratory were kept for months in ditch water collected at septic-tank outlets, they appeared unaffected by the pollution. Moreover, they showed no preference between clean and polluted water when kept in cages with dishes containing both kinds of water (Marten [NOMCB] October 1994 p 7–9).

Nine-month-old *T. scripta* from a turtle farm were introduced in April to an experimental enclosure, 6 m in length, in the polluted portion of a ditch in Slidell, LA (Marten [NOMCB] May 1994 p 6–8). The stocking rate was one turtle per meter of ditch. Natural populations of *Cx. quinquefasciatus* larvae and pupae were extremely high before turtle introduction – typically 400–500 larvae/dip and 25–60 pupae/dip. The turtles reduced the numbers of 1st and 2nd instars only slightly, but by the 5th week after turtle introduction, the number of 3rd and 4th instars and pupae in the enclosure with turtles was less than 1% of the number in the adjacent control enclosure, and remained equally low during the subsequent month of observation (Fig. 2).

Although these results showed that turtles will readily eat older instars of *Cx. quinquefasciatus* in ditches, there are practical difficulties using them for biological control in these habitats. It would be necessary to maintain a much larger number of turtles than a drainage ditch could sustain without supplemental feeding, and it would be difficult to confine the turtles to the ditches. Even if there were enough turtles, they might not be distributed evenly enough to provide reliable control if they were free to move at will.

However, turtles might be practical for use in isolated water bodies such as storm-water catch basins and holding ponds. It is likely they would have little motivation to leave, and it would be practical to provide them supplemental food if necessary.

THE SALMONELLA *ISSUE*

There has been a reluctance to use turtles for mosquito control because turtles can serve as alternate hosts for non-typhoidal human *Salmonella* (Izadjoo et al. 1987, D'Aoust et al. 1990). However, the following laboratory and field observations strongly suggest that there is no practical risk.

The 50 turtles in water storage tanks in Honduras came from a turtle farm that certified

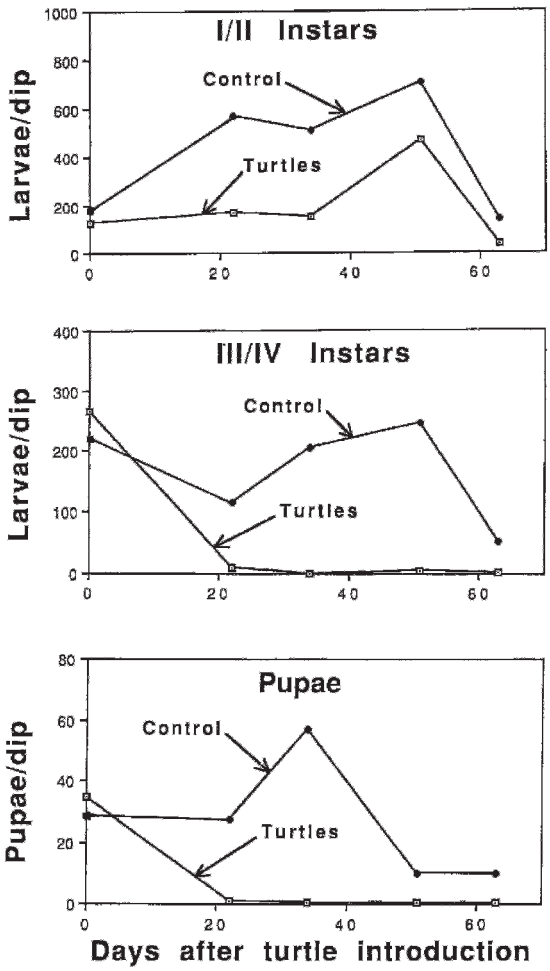

Fig. 2. Numbers of *Cx. quinquefasciatus* larvae and pupae after introducing juvenile *Trachemys scripta* turtles to a residential roadside-ditch enclosure.

them to be *Salmonella*-free (Siebeling et al. 1984). During 2 years of monitoring turtle feces for *Salmonella*, none of the turtles tested positive, although the tap water used to fill the tanks seldom contained chlorine (Borjas et al. 1993). None of the families with a turtle was known to have a *Salmonella* infection.

Pet turtles in a small dish of water can definitely pose a public health hazard. Tap water heavily polluted with turtle feces is an ideal *Salmonella* culture medium, capable of sustaining a high concentration of the bacteria (Brown 1978). Because turtles that live in such water are continually reinfected, they maintain *Salmonella* in their guts.

In the laboratory, *Salmonella enteritidis* was introduced directly into the water in shallow dishes containing juvenile *T. scripta* (Marten [NOMCB] July 1994 p 6–8). Other turtles in dishes were exposed to *Salmonella* by feeding them fish or chicken laced with the bacteria. *Salmonella enteritidis* is the species that infects turtles in Louisiana turtle farms. It is also one of the two main species responsible for clinical human infections. The feces of all turtles in the dishes tested positive for *Salmonella* within a week and remained positive after that. Quantitative estimates based on culturing serial dilutions of the turtles' feces indicated that the infected turtles released at most a few hundred viable *Salmonella* cells per day (Marten [NOMCB] August 1994 p 6–8, October 1994 p 7–9).

Experiments with turtles held singly in 500-liter water-storage tanks in the laboratory demonstrated that tank conditions are very different from those in a small dish (Marten [NOMCB] October 1994 p 7–9). Although the tanks contained chlorine-free water that was not changed for months, the water did not support *Salmonella* growth. The feces of turtles in the tanks, one turtle to a tank, never tested positive after turtles were fed *Salmonella*-laced fish or chicken. Nor was *Salmonella* detected in the water. When a small quantity of *Salmonella* was introduced directly into the tank water, the turtles never displayed infected feces, and all traces of *Salmonella* disappeared from the tank water within a week.

To examine a "worst case" scenario, an experiment was conducted to see what would happen if a turtle already infected with *Salmonella* was introduced to a tank. Turtles infected with *Salmonella* in small dishes (as described above) were placed in 500-liter tanks, 1 turtle to a tank (Marten [NOMCB] July 1994 p 6–8). *Salmonella* concentrations in the water during the first few days after introducing infected turtles were less than 0.1 bacteria/ml and diminished after that. *Salmonella* disappeared from the turtle feces within 4–8 weeks, and *Salmonella* disappeared from the water at the same time.

Experience with turtles in roadside ditches polluted with septic-tank effluent revealed no health hazard from turtles in that habitat (Marten [NOMCB] April 1995 p 7–9). *Salmonella* was never detected in water samples from ditches, whether there were turtles in the ditch or not. In the laboratory, when *S. enteritidis* was introduced to water samples from polluted ditches, the *S. enteritidis* concentration in the water dropped to <1 cell/ml within a week, and *S. enteritidis* usually disappeared entirely within a month. *Salmonella enteritidis* thrived when introduced into ditch water after the water was boiled and cooled, suggesting that natural bacterial flora in ditch water may suppress *Salmonella*. It appears unlikely that turtles would significantly augment *Salmonella* in ditches. Turtles released no *S. enteritidis* (or at most trace quantities) in their feces when held in ditch water to which *S. enteritidis* had been introduced.

Would the very small quantities of *Salmonella* from turtles in "worst case" scenarios create a health hazard? Probably not, but the answer is not completely clear. People are exposed to small doses of *Salmonella* on a regular basis because small numbers of the bacteria are common throughout our environment. Normally, only turtles certified *Salmonella*-free at the outset would be used for mosquito control, and only in water that is intended for bathing and household cleaning, not for drinking. Even if some of the water in the "worst case" were ingested, the dose would be at most a few *Salmonella* cells.

The minimum dose necessary for clinical infection appears to be highly variable, depending on the strain of *Salmonella* and the susceptibility of individual people. Although analysis of *Salmonella* outbreaks has led some epidemiologists to conclude that ingesting even a few viable *Salmonella* cells could conceivably lead to infection (Blaser and Newman 1982), the prevailing view seems to be that it is necessary, particularly for healthy people, to ingest thousands or even millions of *Salmonella* cells (Barrali 2006). In light of the limited experience using turtles for mosquito control, and until further experience shows them to be completely safe, it will be prudent to monitor *Salmonella* when using turtles in water-storage tanks.

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