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ECONOMIC IMPACT OF BLACK FLIES (DIPTERA: SIMULIIDAE) IN SOUTH CAROLINA AND DEVELOPMENT OF A LOCALIZED SUPPRESSION PROGRAM

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ABSTRACT. The membership of a private golf club in South Carolina's Piedmont Physiographic Region was surveyed to determine perceptions regarding local black fly populations and the effects of these populations on golfing habits. The economic impact of black fly annoyance at this club was estimated to be $27,202. Adult monitoring indicated that the pest species were members of the *Simulium jenningsi* group; larval monitoring identified the Enoree River, Laurens County, as the primary source of the pest species. A localized suppression program was initiated during the late summer of 1994 and continued through the fall of 1995. Four larvicide applications were conducted in 1994 and 11 in 1995, using the biological insecticide Vectobac®. Larval mortalities of 94.5 and 97% were produced during 1994 and 1995, respectively. Adult black fly populations were reduced 92 and 88% during 1994 and 1995, respectively, from pre-program populations. Improvements for future suppression programs are proposed.

INTRODUCTION

Black flies are important pests in many parts of North America, yet actual data on their economic impact are scarce. Calculated losses almost exclusively involve black fly attacks on livestock: *Cnephia pecuarum* (Riley) in the Mississippi River Valley (Tucker 1920, Bradley 1935), the *Simulium arcticum* complex in Alberta (Fredeen 1969), *S. luggeri* Nicholson and Mickel in Saskatchewan (Fredeen 1985), and *S. defoliarti* Stone and Peterson in southern British Columbia (Curtis 1954). Information on economic losses to recreation industries are virtually nonexistent, despite a real need to evaluate these losses in light of increasing interest in outdoor recreation and burgeoning black fly populations associated with improved water quality. Golf clubs in South Carolina represent one segment of the recreation industry that is being impacted by black flies.

In this study, we evaluated the black fly problem at one golf club in South Carolina. Specifically, we determined: 1) the pest species and their breeding grounds, 2) the membership's perception of the problem, 3) the economic impact of black flies on the economy of the state, and 4) the efficacy of a pilot control program. Musgrove Mill Golf Club is a private club located in northern Laurens County in the heart of the state's Piedmont Physiographic Region. The golf course has approximately 2,235 m of river frontage on the Enoree River (flow rate 5–11 m^3/sec). It is within 1 km of Cedar Shoals Creek (0.18–0.32 m^3/sec), 6 km of Duncan Creek (0.16–0.55 m^3/sec), 6 km of Warrior Creek (0.79 m^3/sec) and has an unnamed stream (0.01–0.04 m^3/sec) flowing past holes 2–4. The club has reported a nuisance problem since its first season of operation in 1989.

MATERIALS AND METHODS

Our investigation was conducted from May 6 to October 6, 1994 and from April 26 to October 23, 1995. Adult black fly activity was monitored between 1500 and 1900 h EDST at 6 sites on and around the perimeter of the golf course during 1994. Adult activity during 1995 was monitored at 4 sites, 3 of which were continued from 1994 and a 4th site which was located central to the club. One individual stood at each site for 5 minutes before making 10 figure-eight sweeps above the head and shoulders with an insect net (38 cm diam); after the first 5 sweeps, a 15-second pause was inserted to permit the flies to regroup. The same individual (E.G.), dressed in navy blue shirt and pants, performed all sweeps.

Larval samples were collected in acetic ethanol (1:3) for subsequent morphological and chromosomal identification. Larval collections were made at 22 sites on the 6 watercourses during 1994 and 1995. One larval sample was collected at each of the 22 sites. Each larval sample contained approximately 25 larvae, which were collected from accessible, colonized substrate. Late-instar larvae were removed with forceps from the substrate and placed in vials containing acetic ethanol.

On September 1, 1994, survey forms were mailed to the 315 members of the club. The survey consisted of 11 questions and an introductory paragraph stating the purpose of the survey. The initial 2 questions addressed the membership's perception of the black fly problem; remaining questions addressed economic aspects.

A treatment program, using the biological insecticide *Bacillus thuringiensis israelensis* was initiated on August 13, 1994. Treatments were conducted with Vectobac® 12AS (Abbott Laboratories, N. Chicago, IL), following recommendations of Horosko and Noblet (1986). Because no informa-

tion existed regarding downstream carry in piedmont streams, the highest label rate (25 ppm) was used first. The 1994 treatment program encompassed an area within a 6.1-km radius of the club. It included 6 sites on the Enoree River, 4 on Duncan Creek, 2 on Cedar Shoals Creek, and several (depending on larval populations) on the unnamed creek, requiring 255.5 liters of Vectobac 12AS. Applications were made on August 13 and 31, September 14, and October 6. The 1995 treatment program was conducted in a similar manner, with treatment rates being reduced and treatment sites being changed as larval mortality evaluations were conducted and evaluated. Eleven applications were made from April 26 to October 23, requiring 450 liters of Vectobac 12AS.

On each treatment date, selected sites were chosen to evaluate downstream carry and larval mortality. In 1994, when the highest label rates were being used and treatment sites were closer together, larval mortality was evaluated the same day as the treatment. On these dates, larval mortality was monitored above the next downstream treatment site, thereby determining whether or not mortality was produced throughout that treatment zone. All evaluations of larval mortality were conducted after sufficient time had been allowed for the insecticide to pass the monitoring site. Mortality was determined by visual observation of a minimum of 30 larvae/site. Larvae failing to respond to physical contact were classified as dead.

In 1995, when lower treatment rates were used and greater distance was allowed between treatment sites, same-day and 24-hour evaluations were conducted. When 24-hour evaluations were conducted, larvae were collected on pieces of substrate and placed in 0.946-liter containers with river water. Larval samples were immediately stored in coolers on ice. Airstones operating on aquarium air pumps were placed in these containers and run overnight. Mortality was evaluated the next morning, approximately 24 hours posttreatment. When 24-hour evaluations were conducted, control samples from untreated areas were handled in the aforementioned manner.

RESULTS AND DISCUSSION

Adult monitoring: Of 378 adults captured in 1994, all were members of the *Simulium jenningsi* species group, and included *S. anchistinum* Moulton and Adler, *S. confusum* Moulton and Adler, *S. fibrinflatum* Twinn, *S. jonesi* Stone and Snoddy, and *S. notiale* Stone and Snoddy, the biologies of which were described by Moulton and Adler (1995). In 1995, 236 adults were captured, and again all identified specimens (65%) were members of the *Simulium jenningsi* species group. Adult monitoring in 1994 yielded 0–114 adults captured with a mean (±SE) of 8.6 ± 3.7 per sample (n = 36 samples), but no bites were incurred. During adult monitoring in 1995, 0 to 42 adults were captured with a mean of 5.4 ± 14 per sample (n = 44); again, no biting occurred. Members of the *S. jenningsi* species group have been documented as serious nuisance and biting pests in other parts of the country, particularly *S. jenningsi s. s.* Malloch in Pennsylvania (Adler and Kim 1986) and West Virginia (Amrine 1982) and *S. penobscotense* Snoddy and Bauer in Maine (May et al. 1977).

Breeding sites: Larval identifications indicated that the primary larval habitat for all pest species was the Enoree River. Smaller populations of *S. confusum* occurred in Duncan Creek and of *S. notiale* in Cedar Shoals Creek. The unnamed creek contained *S. tuberosum* (Lundstroem) cytotype A, *S. vittatum* Zetterstedt cytospecies IIIL-1, and *S. verecundum* Stone and Jamnback, with less than 1% *S. jonesi* (n = 137). Warrior Creek contained substantial populations of *S. notiale.* The Tyger River contained populations of *S. confusum* (64%) and lower levels of *S. anchistinum* and *S. fibrinflatum.*

Perceptions and economic losses: Of the 315 surveys mailed, 145 (46%) were returned with the following results: 1) 75% of respondents considered the black flies very annoying or annoying, 18% considered them slightly annoying, 7% considered them minor to very minor; 2) 81% felt the club should implement a suppression program, whereas 19% felt it should not; 3) 58% would pay higher membership fees or contribute to a black fly suppression fund; 4) of the 58% that were willing to provide financial support, $8.08 was the average monthly increase in membership fees that respondents would be willing to pay, whereas $72.87 represented the average contribution to a suppression fund; 5) 20% of respondents did not play golf at the club because of black flies, with an average of 5.2 days/person not played; 6) 30% of respondents stopped for at least one meal (mean = $8.37) on the way to or from the club; 7) members drove an average of 110 miles round trip to the club.

If 20% of the club members each do not play 5.2 days per year because of annoyance from black flies, 328 days of golf are missed and 36,080 miles are not driven. At $0.31 per mile, $11,185 is lost to the South Carolina economy. If 30% of the 328 days of golf not played included a meal at $8.37, then $824 are lost to the state's economy. In addition, the management of this club estimates the associated costs (cart fees, guest greens fees, pro shop revenues, and bar and grill expenses) per day of golf to be $46.32. If 328 days of golf are missed per year due to black fly annoyance, then $15,193 in these associated expenses are lost. Thus, approximately $27,202 are lost to the economy of South Carolina as a result of black fly annoyance at Musgrove Mill Golf Club. Considering that South Carolina has approximately 350 golf courses (T. Whitwell, unpublished data), and the entire state is inhabited by pestiferous members of the *Simulium*

jenningsi group, it is reasonable to assume that the economic effects of black flies on the golfing industry in South Carolina are much greater than this figure. We know of at least 3 other courses with black fly annoyance problems.

Although Musgrove Mill members may have engaged in other activities on days they did not golf because of black flies, and thus contributed to other segments of the economy, our figure is nonetheless the first documented economic loss associated with black flies and a recreational industry. In addition, unsolicited comments on the surveys suggested that membership in the club is being adversely affected by black flies.

Treatment program: In an effort to evaluate the effectiveness of larvicide treatments, selected sites were chosen to evaluate downstream carry and larval mortality. During 1994, 2,848 larvae were sampled with a mean (±SE) mortality of 94.5 ± 3.1% (n = 30 samples). During 1995, 3,475 larvae were sampled, with a mean mortality of 97.0 ± 1.9% (n = 44). Control mortality ranged from 4.0 to 8.0%.

In 1994, the average number of adults captured over 4 monitoring periods was 92% lower than the pre-program high of 28.5 flies per site. In 1995, the average reduction in adult numbers from the pre-program high of 27.3 flies per site was 88% for 9 monitoring periods. These results were achieved at a cost of approximately $12,500 per year. The lowest levels of adult reduction were 62 and 66%. These lower levels of reduction were recorded after August 28, 1995 when a flood occurred in the Enoree River drainage basin. The flooding, which created ideal larval habitat in all waterways around the golf club by cleaning the substrate, probably contributed to the lower levels of suppression during the following 2 months. The 1994 peak of adult activity also occurred immediately following a flood period of August 16–22.

Workers at this club indicated that adult monitoring levels over an average of 5–7 flies/10 sweeps/site would constitute a nuisance level. This threshold is lower than that used by the Pennsylvania Department of Environmental Resources, which proposes a level of 10 flies per monitoring session as warranting concern and 5 flies per session as being acceptable (D. Arbegast, unpublished data). This lower level of black fly tolerance is indicative of the high standards demanded by the golfing industry.

While satisfactory adult suppression was observed throughout most of 1995, improvements are being considered. These include: 1) eliminating treatment of the unnamed stream, which harbors a negligible pest population; 2) expanding the treatment program to a 12-km radius; and 3) reducing the time between treatments. This program should be applicable to other golf clubs in the southeastern USA that are experiencing similar problems.

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