Insecticidal Wound Treatment of Livestock on Isla de la Juventud, Cuba: an Efficient Suppression Method of New World Screwworm *Cochliomyia hominivorax* Prior to the Release of Sterile Insects

R. GARCIA[1], L. MENDEZ[2], E. SERRANO[2], T. GIL MORALES[2] and M. J. B. VREYSEN[3]

[1]*Av. Presa Penitas no. 277, Colonia Electricistas Fraccionamiento, Las Palmas, CP 29040, Tuxtla Gutièrrez, Chiapas, Mexico*
[2]*Instituto de Medicina Veterinaria,Calle 12 Nro. 355 entre 15 y 17 Plaza, CP 10400, La Habana, Cuba*
[3]*Insect Pest Control Sub-Programme, Joint FAO/IAEA Programme of Nuclear Techniques in Food and Agriculture, IAEA, Wagramerstrasse 5, A-1400 Vienna, Austria*

ABSTRACT A two-year pilot trial was conducted on the Isla de la Juventud, Cuba to assess the effect of insecticidal treatment of wounds of livestock on the wild New World screwworm *Cochliomyia hominivorax* (Coquerel) population. On average, 338 921 and 369 622 animals were inspected every month in 2001 and 2002, respectively out of a total livestock population of 86 000. The average monthly infestation rate (number of positive screwworm myiasis cases as a proportion of total animals inspected) declined from 0.058 during the first quarter of the programme to 0.005 in the last quarter, i.e. a statistically significant reduction of 92%. The trial demonstrated that a systematic animal inspection programme coupled with insecticidal wound treatment can effectively suppress New World screwworm. The impact of the suppression programme on the adult fly population, sampled using vertical sticky traps, was less clear. Fly sampling data from the southern part of the island – an area with very few livestock – indicated little impact and the dynamics of the fly population showed a seasonal pattern. In the north, the fly population remained stable and fairly low in 2001 due to the insecticidal treatment of wounds, but increased in 2002, possibly as a result of migration from the south in the aftermath of a hurricane that created unfavourable conditions in the south. The paper argues that a systematic wound treatment programme, possibly combined with a dense adult fly trapping network should be implemented in screwworm area-wide integrated pest management (AW-IPM) programmes well before the release of sterile insects. This will enable the sterile males to compete effectively with the wild males and exploit the inverse-density dependence of the sterile insect technique (SIT). In countries with low labour costs, this strategy will make AW-IPM programmes with an SIT component more cost-effective.

KEY WORDS New World screwworm, *Cochliomyia hominivorax*, insecticides, wound treatment, vertical sticky trap, myiasis, Isla de la Juventud, Cuba

1. Introduction

The New World screwworm *Cochliomyia hominivorax* (Coquerel) is an obligate parasite of warm blooded animals including humans, and causes primary myiasis in pre-existing wounds. This larval habitat is obligatory and in the field, larvae can only develop on living animals (Spradbery 1994). The larvae from a single oviposition can kill smaller animals and

M.J.B. Vreysen, A.S. Robinson and J. Hendrichs (eds.), Area-Wide Control of Insect Pests, 393–403.

multiple infections can kill mature cattle (Krafsur et al. 1987), e.g. 1.3 million cattle died in 1934 in the south-eastern USA as a result of screwworm infestation (Dove 1937). The fly has a very high reproductive rate and females can oviposit up to 400-450 eggs at 3-4 days intervals on the dry edge of wounds or body orifices. The eggs hatch after 12-20 hours, the larvae migrate immediately to the wound and start feeding superficially on the wound fluids. The second and third instar larvae burrow deeply into the host tissue for feeding. Mature larvae leave the animal and pupate in the soil and the entire life cycle can be a short as 21 days under optimal temperature conditions (Spradbery 1994).

The New World screwworm has been eliminated from the southern USA, Mexico, Central America and Panama, using an area-wide integrated pest management (AW-IPM) approach that included the release of sterile insects. In the Darien gap of Panama, a buffer zone of 30 000 square kilometres was created through the weekly release of 40-50 million sterile males to protect the screwworm-free countries from reinvasion from South America. The annual direct benefits of this campaign to the livestock industry were estimated at USD 896 million, USD 328 million and USD 87.8 million for the USA, Mexico and Central America, respectively (Wyss 2000).

As well as in South America, New World screwworm continues to be a significant animal and human health problem in Cuba, Hispaniola (Haiti and Dominican Republic), Jamaica and Trinidad-Tobago. Since 1996, efforts have been undertaken to eradicate the pest from Jamaica, but the programme was beset by various difficulties and little progress was made until 2005 (Vreysen et al., this volume). In view of their geographical location and increased global trade, these countries continue to pose a significant threat to the screwworm-free countries in the region.

Cuba is the largest screwworm-infested territory in the Caribbean and from 1995 to 2003, 88 985 New World screwworm cases were reported in cattle, swine, sheep, goats, horses and humans. Ninety two percent of all myiasis cases were due to New World screwworm. The Government of Cuba signed an agreement with the Food and Agriculture Organization of the United Nations (FAO) to develop a national eradication programme which would be initiated with a pilot trial on the Isla de la Juventud followed by an island-wide effort (Vargas-Terán et al. 2005). The estimated cost to eradicate the New World screwworm from Cuba was USD 62.5 million over a period of four years.

In 2000, a suppression trial was initiated on the Isla de la Juventud with the objective of assessing the effects of systematic insecticidal wound treatments and adult fly trapping on native New World screwworm. Economic losses on this small island were estimated at USD 4.3 per animal per year, or close to USD 400 000 for the entire island (FAO 1998). The Instituto de Medicina Veterinaria implemented the programme and the International Atomic Energy Agency (IAEA) provided technical assistance through a Technical Cooperation project. The data from this two-year suppression trial are presented in this paper.

2. Materials and Methods

2.1. Study Area

The Isla de la Juventud, called Isla de Pinos until 1978, is the largest and most western island in the Archipiélago de los Canarreos. It has a surface area of 2419 square kilometres, a maximum elevation of 303 metres and is separated from Cuba by the 100 kilometres-wide Batabanó's gulf (Gort et al. 1994). The northern part of the island contains mainly pine groves and savannah areas whereas the most prominent feature in the south is the Ciénaga de Lanier marshland, a protected area that contains a high number of endemic plant species, and constitutes an important nesting site for various chelonian, amphibian, crustacean and fish species.

According to a livestock census in 2001, there were 86 124 domestic livestock of which

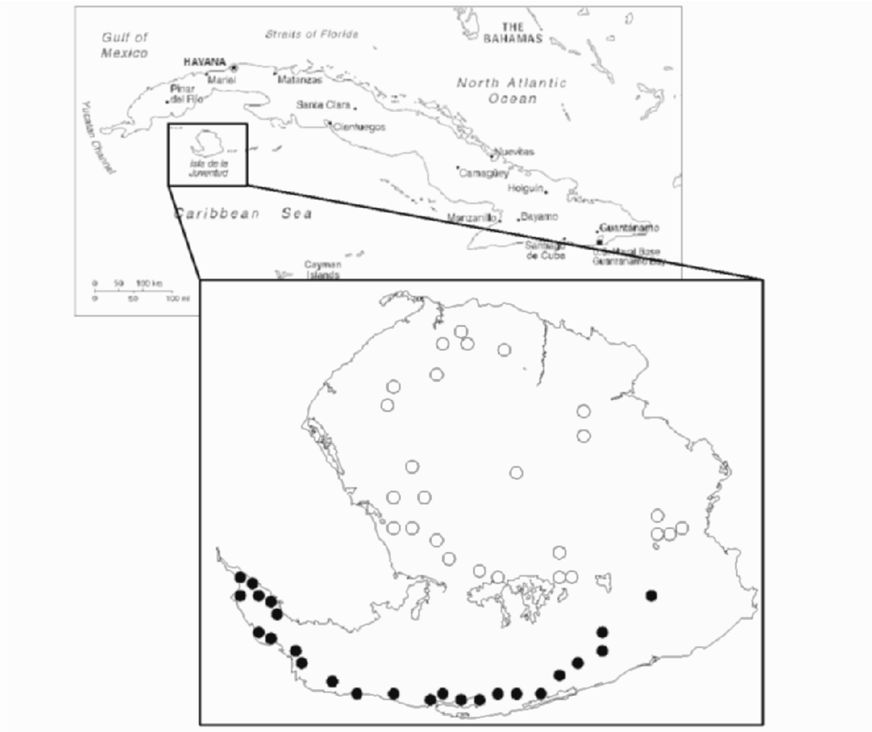

Figure 1. *Map of Cuba and the Isla de la Juventud, indicating the trap locations in the north (open points) and in the south (solid points) (Map of Cuba reproduced with permission from www.worldatlas.com).*

the majority were cattle (34 770), followed by pigs (21 161), sheep and goats (9883), and horses (1364). Wildlife such as deer (2500) and jutia conga *Capromys pilorides* (Say) are likewise abundant whereas wild pigs, monkeys and feral domestic animals are common in the protected areas (Rivero 1999).

Taking into consideration the distribution and abundance of livestock, the existing network of roads, accessibility, and topographical features, the entire island was divided into four operational blocks, each subdivided into ten zones. Four laboratories were established on the island to ensure correct and timely identification of the collected samples.

2.2. Logistics

There were 50 veterinarians and 103 technicians on the island and 21 of these staff were engaged full-time in the pilot project. The protected areas in the south were managed by the National Company for the Protection of Flora and Fauna and its personnel collaborated with the project and reported any myiasis case immediately.

2.3. Implementation of the Trial

The efficient collaboration of all stakeholders, including the livestock farmers and animal and pet owners ensured the smooth implementation of the pilot trial. Project personnel distributed more than 15 000 sampling kits to the livestock owners and to personnel of the collaborating organizations. Each kit contained forceps for the removal of larvae from the wounds, plastic vials with alcohol to pre-

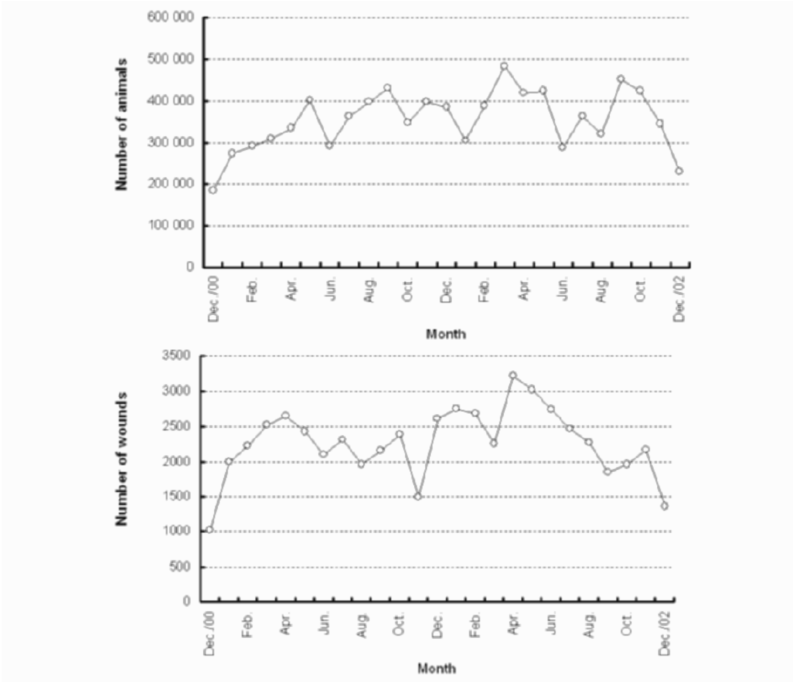

Figure 2. *(upper) The monthly number of animals inspected for wounds and New World screw-worm infestations on the Isla de la Juventud (December 2000-December 2002), and (lower), the monthly number of wounds treated with insecticides.*

serve the larvae, a sachet of insecticide powder (coumaphos), an instruction leaflet and a data sheet. All samples were sent to one of the four laboratories for species identification and the results compiled in a database Epi Info 6 (CDC 2005).

Daily visits were made to sites which were known to have high infestation levels and all animals in each site were inspected, larvae removed from wounds and all wounds (infested and non-infested) treated with insecticides. The correct treatment of a wound will kill for seven to ten days any ovipositing female. Most of the inspection sites were located in the northern half of the island.

Adult sampling was done with triangular vertical sticky traps (dimensions 30 centimetres x 30 centimetres x 42.5 centimetres) (Welch 1994, Welch and Garcia 1997) baited with the chemical attractant swormlure-4 (Mackley and Brown 1984). Each week, 25 to 125 traps were deployed in easily accessible areas (i.e. mainly along existing roads) in the northern half of the island and between 25 to 175 traps in the southern half. The traps were checked at least every two days, depending on the location. The traps were used to monitor the adult population and acted as an additional suppression tool.

2.4. Data Analysis

The percentage infestation was defined as the number of animals infested expressed as a proportion of the total animals inspected. Data on monthly percentage infestations were analysed per quarter, and data on weekly fly catches of the northern and southern part of the island were analysed per month. To normalize the data, monthly percentage infesta-

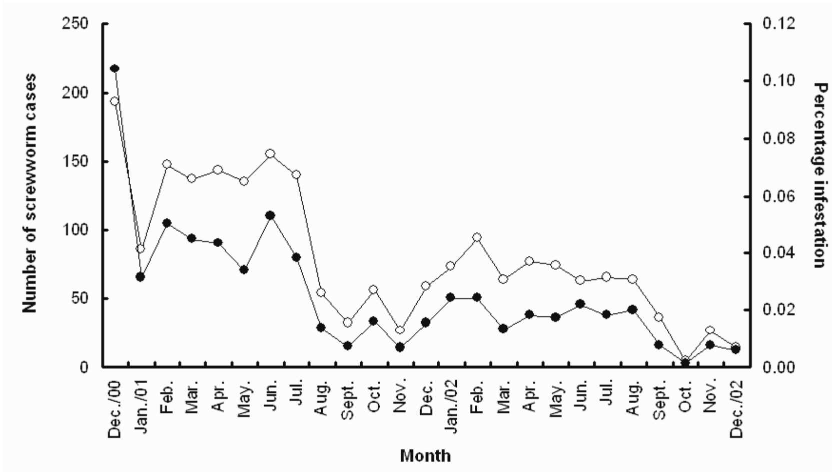

Figure 3. *The monthly number of screwworm cases (open points) and the percentage infestation (solid points) on the Isla de la Juventud from December 2000 to December 2002.*

tion data were arcsine transformed and weekly fly catch data log (n + 0.01) transformed. All data were analysed by single factor ANOVA and Tukey's HSD test was used to separate the means at $P < 0.05$. Comparison of pairs of data sets of number of animals inspected and wounds treated were analysed by a paired *t*-test.

3. Results

3.1. Myiasis and Percentage Infestation

Over a period of 25 months (December 2000 to December 2002), a total of 8 841 432 animals were inspected, on average 338 921 and 369 622 per month in 2001 and 2002, respectively (t = 0.35, d.f. = 11, P = 2.57) (Fig. 2, upper). During the same period, a total of 56 525 wounds were treated with insecticides, which represents an average of 2261 wounds treated per month (Fig. 2, lower). The number of wounds treated in the first year did not change significantly from that in the second year (n = 2141 for 2001 and n = 2390 for 2002) (t = 0.53, d.f. = 11, P = 2.20). Larvae were most frequently found in the navel area (24.8%), in wounds caused by barbed wire (23.8%), from bites (16.5%), in the vulva area post-parturition (11.0%), by ear tags (8.7%) and branding (6.8%) and others (less than 2%). Cattle were mostly affected (59.8%) followed by pigs (31.1%), whereas birds, lambs, dogs, goats and horses were much less infested.

From December 2000 to December 2002, a total of 2022 New World screwworm myiasis cases were found (i.e. an average of 80.8 ± 49.8 cases per month). Most of the cases (99%) were found in the northern half of the island, where livestock was abundant. The percentage infestation was 0.104% in the first month, December 2000 (Fig. 3). The ANOVA analysis showed significant temporal differences in the average quarterly percentage infestation (F = 6.48, d.f. = 17, $P < 0.001$), with significantly less animals infested in quarters 3 and 4 of 2001 and quarters 3 and 4 of 2002 ($P < 0.05$, Tukey HSD) as compared with the first quarter (data for December 2000 were included in the first quarter 2001 for the analysis) of the project. The percentage infestation was not significantly different in the first and second quarters of 2002 than in the first quarter. This increase in screwworm myiasis cases was likewise reflected in the adult trap data. The average percentage infestation in the last quarter of 2002 was 0.005%, which

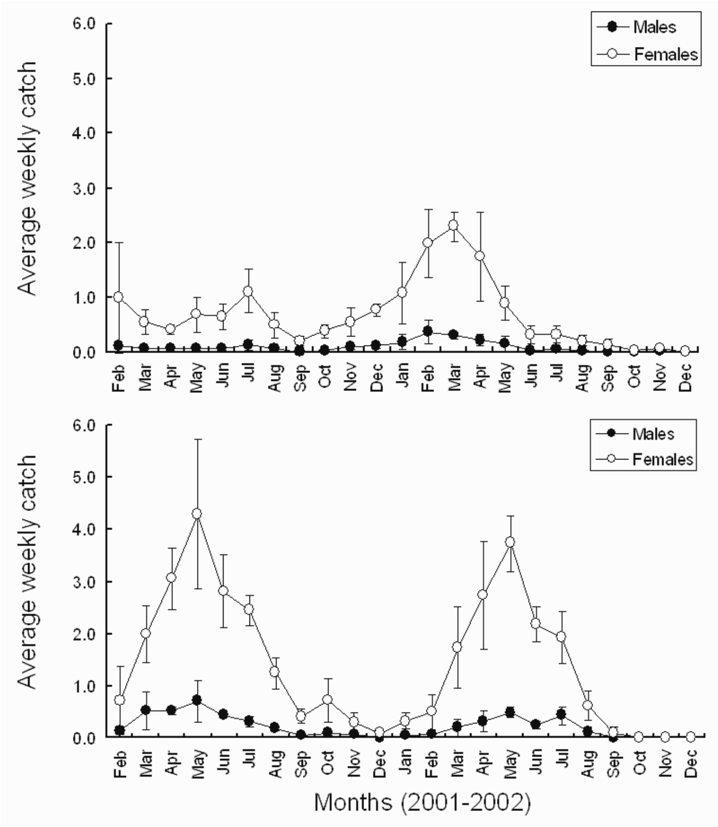

Figure 4. *The average weekly catch (male and female flies/trap/week) of New World screwworm in the northern (upper graph) and southern (lower graph) half of the Isla de la Juventud from February 2001 to December 2002.*

represents a 92% reduction as compared with the first quarter of 2001.

3.2. Sampling Adult New World Screwworm Cochliomyia hominivorax *Flies*

During the pilot trial, a total of 7143 and 11 241 adult New World screwworm flies were trapped in the northern and southern parts of the island, respectively. In 2001, average weekly male and female catches were significantly higher in the south than in the north, i.e. 0.28 males/trap/week (south) versus 0.07 males/trap/week (north) (F = 9.93, d.f. = 92, $P < 0.01$), and 1.7 females/trap/week (south) versus 0.57 females/trap/week (north) (F = 12.18, d.f. = 92, $P < 0.001$). In 2002, however, average weekly male and female catches were similar in the north and south, i.e. 0.18 males/trap/week (south) versus 0.12 males/trap/week (north) (F = 0.0002, d.f. = 90, $P > 0.05$), and 1.31 females/trap/week (south) versus 0.85 females/trap/week (north) (F = 0.11, d.f. = 90, $P > 0.05$) (Fig. 4). In both parts of the island, the sticky traps caught significantly more females than males, i.e. 88.1% and 87.1%, respectively (χ^2, $P < 0.001$).

The temporal fluctuations in the average weekly catches of male and female flies were considerable, especially in the south. Weekly catches in the northern part of the island were not significantly correlated with those of the south (for females: r = 0.24, d.f. = 21, $P > 0.05$ and for males: r = 0.04, d.f. = 21, $P > 0.05$) and therefore the data were analysed and presented separately (Fig. 4).

The average weekly female catch varied significantly with time, both in the south (F = 37.92, d.f. = 22, $P < 0.001$) and the north (F = 15.79, d.f. = 22, $P < 0.001$). In the south, the highest female catches were in April-June 2001 (range 2.80-4.29 females/trap/week) and 2002 (range 2.17-3.73 females/trap/week). In the north, the highest average female catches were in May-July 2001 (range 0.68-1.11 females/trap/week) and February-April 2002 (range 1.74-2.29 females/trap/week). The vertical sticky traps caught the least females in September 2001 and October-December 2002 in the north, and in December 2001 and October-December 2002 in the south (Fig.4).

The temporal fluctuations in the average weekly trap catch of the males were less than in the females but the ANOVA showed significant temporal changes, both in the south (F = 17.47, d.f. = 22, $P < 0.001$) and the north (F = 8.28, d.f. = 22, $P < 0.001$).

The weekly catch of males was highly significantly correlated with those of females, both in the north (r = 0.89, d.f. = 18, $P < 0.001$) and in the south (r = 0.93, d.f. = 18, $P < 0.001$), indicating a similar trap response.

4. Discussion

The SIT was an essential part of the AW-IPM programme that eradicated the New World screwworm from the USA, Mexico and Central America (Wyss 2000). This programme emphasized IPM, which is a sustainable approach to managing pests by the integration of biological, cultural, physical and chemical tools in a way that minimizes economic, health, and environmental risks (National IPM Network 2001), and AW, which is the application of control tactics against an entire pest population within a delimited geographical area, with a minimum size large enough or protected by a buffer zone so that natural dispersal of the population occurs only within this area (Klassen 2005).

Even in the early days of the screwworm programme in the USA, it became rapidly clear that:

> *...an effective surveillance programme carried out well in advance of the release of sterile flies, was a vital part of a successful eradication programme (Meyer 1994).*

This need prompted the development of an effective adult screwworm suppression tool that could reduce populations to levels where sterile males could effectively compete with the native male flies. The final result was the screwworm adult suppression system (SWASS), which contained a powerful attractant (swormlure) (Mackley and Brown 1984), a food-bait as a short range attractant, and an insecticide to kill the adult flies feeding on the mixture (Snow et al. 1982). In dry areas of the southern USA and northern Mexico, the SWASS pellets were dispersed by aircraft for four to ten weeks at a rate of 0.18 kg/km^2 (Snow et al. 1982). This short period was sufficient to reduce screwworm populations by up to 90% (Coppedge et al. 1978). As the eradication programme progressed towards the more humid, tropical areas of southern Mexico and Central America, the swormlure lost much of its attractiveness and the SWASS became less effective (Spradbery 1994). Together with the high cost (Snow et al. 1982) and concerns about environmental pollution (Spradbery 1994), SWASS was finally abandoned and intensive treatment of animal wounds with insecticides that killed ovipositing females became the prime suppression tactic.

This two-year pilot trial, demonstrated that a systematic, properly executed animal inspection programme, (on average more than 330 000 animals were inspected each month for a total livestock population of 86 000 animals), where every wound detected was consistently treated with insecticides, could significantly reduce screwworm infestations in livestock. The 92% reduction of the average monthly percentage infestation from the first to the last quarter is testimony to the efficacy of the approach. However, it should be noted that the hurricanes that passed over the island could have contributed to some reduction of the population.

Many screwworm eradication programmes have in the past relied on "the number of screwworm cases" to monitor programme progress. Vreysen (2005) and Vreysen et al. (this volume) have cautioned this approach especially in those programmes where farmers were requested to inspect their animals and report cases to the programme (passive sampling). The fluctuations in reported cases were likely more related to farmer collaboration and reporting efficiency than actual variations in the pest population density. Only when the same number of animals are inspected in each time unit, does the number of screwworm cases measure progress. The data presented in this paper corroborate the above observations, as exemplified by the following case in point: from February to May 2001, the number of screwworm cases declined from 147 to 135 cases, which is a reduction of only 8%, whereas the percentage infestation was reduced from 0.05 to 0.034%, i.e. a reduction of 32%. This again demonstrates the importance of presenting and analysing screwworm case data as a proportion of inspected animals to allow accurate data interpretation.

Progress was also monitored through the trapping of adult flies. However, the effect of the suppression programme was less clear from the fly trapping data than from the percentage myiasis infestation (monthly total fly catches were nevertheless, significantly correlated with the monthly percentage infestation ($r = 0.55$ d.f. $= 21$, $P < 0.05$)). This was most likely related to the spatial characteristics of the suppression programme, i.e. most of the livestock were present in the north, where most of the cases (99%) were also found. Livestock were largely absent in the south with the only animals present being wildlife and small pets belonging to fishermen and the staff of the national park. Consequently, the fly population in the south was little affected by the insecticidal wound treatment programme, and this is illustrated in the seasonal, natural dynamics of the screwworm population (Fig. 4).

In the north, adult screwworm catches remained fairly low in 2001 as a result of the insecticidal wound treatment, with average weekly catches not exceeding 1.11 females/trap/week and 0.12 males/trap/week. In November 2001, a category four hurricane (Michelle) passed over the island which destroyed much of the vegetation in the south and left large areas flooded for several weeks. This created unfavourable conditions for the screwworm population and most likely stimulated fly migration to the north, which was much less affected by the hurricane. This might explain the increase in average weekly fly catches in the north between December 2001 and March 2002, whereas in the south, the fly population only recovered from the impact of the hurricane as of March 2002. On 19 and 30 September 2002, two hurricanes (category one and two) passed over the island, affecting the north and south equally. Average weekly fly catches remained extremely low in the following months as did the number of screwworm cases.

The traps were not deployed along a regular grid, and hence the trapping data might have been biased. Nevertheless, the data collected were an important indicator of programme progress and provided valuable complementary information on screwworm population dynamics (Vreysen 2005). The spatial complexities of the often highly aggregated screwworm populations could be more efficiently analysed both in space and time using geo-referenced data collection (using Global Position System (GPS)) and geographic information systems (GIS)-based analyses (Cox and Vreysen 2005, Cox, this volume).

On average, 75 and 84 sticky traps were deployed every week in the southern and northern parts of the island, respectively. These sticky traps caught more than 16 000 females during the trial. Although no data were available on absolute wild fly densities, this high number of trapped females seems to indicate that these traps (Welch and Garcia 1997) show potential as an additional suppression tactic for New World screwworm. The traps are cheap, easy to handle and deploy and the odour bait (swormlure-4), while not very effective for sampling gravid females (Guillot et al. 1977a,b) is a good attractant for young females (Coppedge et al. 1977). The vertical sticky trap (baited with swormlure-4) is a new design, and field tests in Costa Rica indicated its superior performance for catching male and female flies (871 flies trapped) as compared with the standard wind-oriented-trap (Broce et al. 1977) (11 flies trapped) (Welch 1994). Sterile screwworm flies released around the mass-rearing facility in Tuxtla Guttièrez, Mexico (as part of biosecurity measures) were sampled up to five kilometres from the rearing facility with the wind-oriented-trap but up to 30 kilometres with the vertical sticky trap (R. Garcia, unpublished). Although the deployment of many traps over large surface areas is labour intensive and logistically demanding, it will probably be cost-effective in those countries with low labour costs. Each young wild female fly that is trapped will be equal to three to five wounds not becoming infested, preventing the potential development of 800 to 1200 larvae.

5. Conclusions

In most operational screwworm programmes, suppression using insecticidal wound treatment was usually initiated simultaneously with the release of sterile insects, masking the relative contribution of each control tactic to the progress of the campaign. The data from this pilot trial have shown that a properly implemented insecticidal wound treatment programme can reduce New World screwworm myiasis considerably. Due to the lack of livestock there was no suppression of the screwworm population in the south, which in view of the high mobility of the fly and the small size of the island must have created the possibility of flies migrating to the north. Suppression would have been improved had the control tactics been applied on the entire screwworm population, following an AW-IPM approach.

The pilot trial was carried out in preparation of the release of sterile insects on the island. The data from the suppression phase of the project, which was planned to last only six months but was implemented for two years, indicate that the release of sterile insects would have been the next logical step in order to achieve eradication. Due to a variety of reasons, some political, the programme never received the necessary follow-up and the release of sterile insects was never implemented. This is very unfortunate as the pilot suppression programme succeeded in creating optimal conditions for the sterile males to compete effectively with the native males. Initiating systematic wound treatment possibly combined with a dense trapping network before initiating the release of sterile males, would make the SIT component of screwworm AW-IPM programmes more cost-effective, especially in countries with low labour costs.

6. References

Broce, A. B., J. L. Goodenough, and J. R. Coppedge. 1977. A wind oriented trap for screwworm flies. Journal of Economic Entomology 70: 413-416.

(CDC) Centers for Disease Control and Prevention. 2005. http://www.cdc.gov/EPIINFO/Epi6/ei6.htm

Coppedge, J. R., E. Ahhrens, J. L. Goodenough, F. S. Guillot, and J. W. Snow. 1977. Field comparisons of liver and new chemical mixture as attractants for the screwworm fly. Environmental Entomology 6: 66-68.

Coppedge, J. R., J. L. Goodenough, A. B. Broce, F. H. Tannahill, J. W. Snow, M. M. Crystal, and H. D. Petersen. 1978. Evaluation of the screwworm adult suppression system (SWASS) on the Island of Curaçao. Journal of Economic Entomology 71: 579-584.

Cox, J. St. H., and M. J. B. Vreysen. 2005. Use of geographic information systems and spatial analysis in area-wide integrated pest management programmes that integrate the sterile insect technique, pp. 453-477. *In* Dyck, V. A., J. Hendrichs, and A. S. Robinson (eds.), Sterile insect technique. Principles and practice in area-wide integrated pest management. Springer, Dordrecht, The Netherlands.

Dove, W. E. 1937. Myiasis of man. Journal of Economic Entomology 30: 29-39.

(FAO) Food and Agriculture Organization of the United Nations. 1998. Pérdidas económicas del gusano barrenador del ganado en Cuba y análisis del beneficio-costo del programa de erradicación. La Habana, Cuba.

Gort, A. S., T. Escobar, J. Izquierdo, M. Correoso, and N. Singh. 1994. Isla de la Juventud, su naturaleza. Instituto Cubano del libro, Ciudad de La Habana, Cuba.

Guillot, F. S., J. R. Coppedge, J. L. Goodenough, T. S. Adams, and E. Ahrens. 1977a. Behaviour and reproductive status of native female screwworm attracted to a host. Annals of the Entomological Society of America 70: 588-590.

Guillot, F. S., J. R. Coppedge, J. L. Goodenough, E. Ahrens, and T. S. Adams. 1977b. Reproductive status of female screwworms captured from hosts or in traps. The Southwestern Entomologist 2: 49-52.

Klassen, W. 2005. Area-wide integrated pest management and the sterile insect technique, pp. 39-68. *In* Dyck, V. A., J. Hendrichs, and A. S. Robinson (eds.), Sterile insect technique. Principles and practice in area-wide integrated pest management. Springer, Dordrecht, The Netherlands.

Krafsur, E. S., J. Whitten, and J. Novy. 1987. Screwworm eradication in North and Central America. Parasitology Today 3: 131-137.

Mackley, J. W., and H. E. Brown. 1984. Swormlure-4: a new formulation of the swormlure-2 mixture as an attractant for adult screwworms, *Cochliomyia hominivorax*. Journal of Economic Entomology 77: 1264-1268.

Meyer, N. L. 1994. History of the Mexico-United States screwworm eradication program. Vantage Press, New York, USA.

National IPM Network. 2001. http://www.ag.ndsu.nodak.edu/aginfo/ndipm/ipmdefinition.htm

Rivero, G. M. 1999. Conozca Cuba. Flora y Fauna. Instituto Cubano del libro, Ciudad de La Habana, Cuba.

Snow, J. W., J. R. Coppedge, A. B. Broce, J. L. Goodenough, and H. E. Brown. 1982. Swormlure: development and use in detection and suppression systems of adult screwworm (Diptera: Calliphoridae). Bulletin of the Entomological Society of America 28: 277-284.

Spradbery, J. P. 1994. Screw-worm fly: a tale of two species. Agricultural Zoology Reviews 6: 1-61.

Vargas-Terán, M., H. C. Hofmann, and N. E. Tweddle. 2005. Impact of screwworm eradication programmes using the sterile insect technique, pp. 629-650. *In* Dyck, V. A., J. Hendrichs, and A. S. Robinson (eds.), Sterile insect technique. Principles and practice in area-wide integrated pest management. Springer, Dordrecht, The Netherlands.

Vreysen, M. J. B. 2005. Monitoring sterile and wild insects in area-wide integrated pest management programmes, pp. 325-361. *In* Dyck, V. A., J. Hendrichs, and A. S. Robinson (eds.), Sterile insect technique. Principles and practice in area-wide integrated pest management. Springer, Dordrecht, The Netherlands.

Welch, J. B. 1994. Developing new trapping techniques for New World screwworm (NWS) in Central America. Report on Project SCN/INT/001(MUL), Cooperative Agreement No. 58-6240-3-F089. USDA-ARS, San Jose, Costa Rica.

Welch, J. B., and R. R. Garcia. 1997. Field comparisons of three swormlure-4 baited traps for primary screwworm (Diptera: Calliphoridae). SADA-ARS.

Wyss, J. H. 2000. Screw-worm eradication in the Americas – overview, pp. 79-86. *In* Tan, K. H. (ed.), Proceedings: Area-Wide Control of Fruit Flies and Other Insect Pests. International Conference on Area-Wide Control of Insect Pests, and the 5th International Symposium on Fruit Flies of Economic Importance, 28 May-5 June 1998, Penang, Malaysia. Penerbit Universiti Sains Malaysia, Pulau Pinang, Malaysia.