2016

Investigation into Introduction of New World Screwworm into Florida Keys

USDA

Table of Contents

Background

On September 30, 2016, entomologists at the United States Department of Agriculture, Animal and Plant Health Inspection Service, Veterinary Services (USDA-APHIS-VS) National Veterinary Services Laboratories (NVSL) in Ames, Iowa, confirmed a diagnosis of screwworm myiasis in a Key deer (*Odocoileus virginianus clavium*) from Big Pine Key, Florida and identified New World Screwworm (*Cochliomyia hominivorax; NWS*) as the causative agent. An investigation was initiated by USDA-APHIS-VS to determine the origin of the screwworm infestation and try to understand pathways through which introduction may have occurred. On November 1, 2016, three epidemiologists from the Center for Epidemiology and Animal Health (CEAH) arrived in Florida to join the incident management team in assisting the Florida Department of Agriculture and Consumer Services (FDACS) in the investigation and response. The investigation focused on descriptive epidemiology of the initial outbreak in deer and pets, retrospective case finding, and interviews with individuals whose work occurs in relation to known pathways for screwworm introduction.

Objective: To improve our understanding of the time course of screwworm introduction into the Florida Keys, to identify retrospective cases that may have not been recognized previously, and to examine risk pathways for screwworm fly introduction and possible changes in risk.

Descriptive epidemiology of the outbreak

Key deer

The first known observation of an infested Key deer occurred on July 5, 2016, on Big Pine Key. The deer was examined by a wildlife biologist from the National Key Deer Refuge, and the presence of maggots in a leg wound was noted. Since Key deer are an endangered subspecies, all mortality events are recorded and geo-located by the staff of the National Key Deer Refuge.

Beginning in August, the refuge staff noticed an unusual increase in buck mortalities that were not road-related. By September, the mortality rate reached levels that were approximately twice as high as normal (Figure 2). That month, refuge personnel visited with a local veterinarian regarding the cases and learned that the veterinarian had previously seen a few cases of fly strike, or myiasis, in pets. The refuge staff decided to submit maggot samples for identification. New World screwworm was confirmed by entomologists at the NVSL on September 30th, 2016.

The estimated numbers of infested deer by week are shown in Figure 1, Panel A. The locations of the first cases of Key deer mortalities from screwworm myiasis for the month of July are shown with red dots in Figure 1, Panel B. The carcasses of these deer were transported to a site in the northern part of Big Pine Key to be returned to the landscape, consistent with the refuge's normal procedures for deer mortalities. The location of the disposal site is shown as a black star in Figure 1, Panel B. The first cases were reported from Big Pine Key in July, with cases reported from No Name key in August. By October, NWS infestation among Key deer was reported on several Keys. Following the official diagnosis of screwworm myiasis, infested carcasses were no longer returned to the landscape and alternative disposal methods were used.

In 2016, deer mortalities ranged from 7 to 30 deaths per month through the end of September (Figure 2). Overall, a gradual increase in monthly deer mortalities was seen throughout the year, with a small spike in mortalities in May, and the majority of those mortalities were attributed to road kills.

Because all of these deer were inspected and recorded as explained mortalities, it is unlikely that screwworm larvae were present and not noted. A large increase in mortality numbers began in September and peaked in October. October had the highest mortalities of Key deer by any cause (98 total deaths) recorded in any month over the past 10 years (Figure 2). A comparison of monthly mortality data from 2016 and median monthly mortality data from 2010-2015 suggests that the early months of 2016 experienced normal Key deer mortality prior to the outbreak (Figure 2). In addition, interviews with wildlife biologists at the refuge suggested that the fawn crop in the spring of 2016 was excellent. If screwworm had been present in large numbers during the fawning season, the biologists felt they would have seen myiasis cases associated with the naval area of newborns. No cases of myiasis in newborn Key deer fawns were observed in 2016.

A. Number of Key deer mortalities associated with NWS by week

B. Locations of deer mortalities associated with NWS by month

C. Locations of suspect animals by month

Figure 1. The number of deer infested by week (Panel A) in the Lower Florida Keys, and the spatial distribution of infested deer (Panel B) and pets (Panel C) by month in 2016. The red dots are infested deer, the brown dots are infested dogs, pink dots are infested pigs, and the gray dots are infested cats.

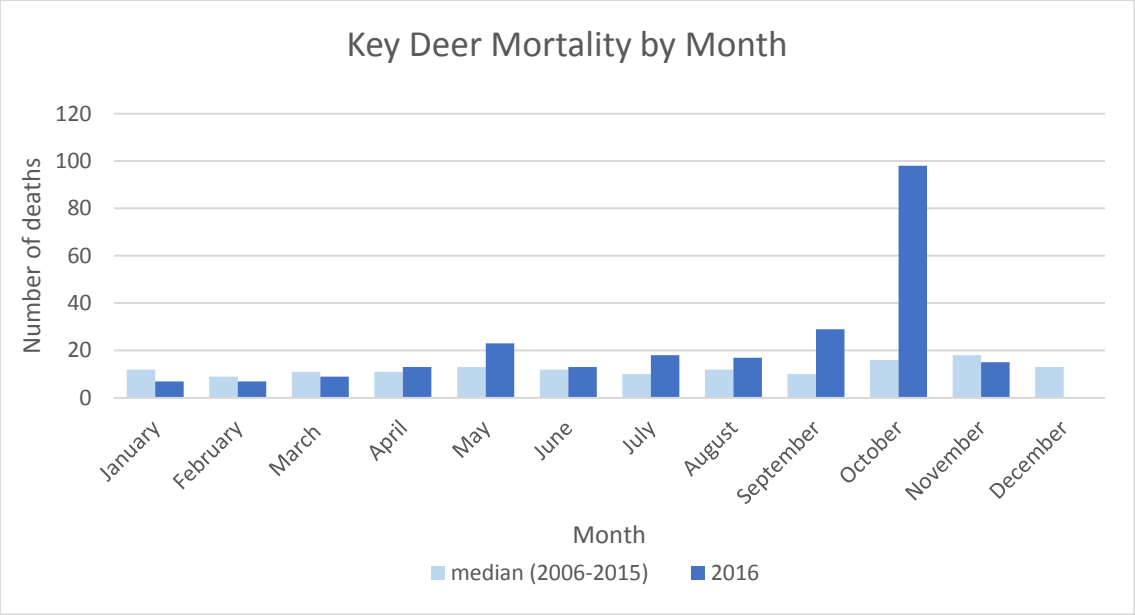

Figure 2: Key deer mortality by month, 2006-2015; median number of deaths by month versus 2016deaths by month.

Companion animals

Several cases consistent with screwworm infestation were identified by local veterinarians prior to this investigation. The spatial progression of these cases is shown in Figure 1, Panel C. However, additional cases might not have been recognized by the local veterinary community. In order to identify these possible, additional historic cases, a questionnaire was developed and administered to veterinarians and animal facilities throughout the Keys.

Retrospective case finding

The questionnaire for veterinarians and animal facilities inquired about any unusual cases of maggot infestation that might have been seen during 2016. For any mentioned suspect cases, the owners of the animals were further contacted in order to obtain additional history, demographic, and clinical details. Throughout the Florida Keys, 22 animal facilities were visited. This survey included 22 facilities: 17 (77%) veterinary clinics, 4 (18%) pet animal shelters, and 1 (5%) petting zoo. The veterinary clinics see a reported median of 60 (range: 5 to 300) animals per week routinely. All of the pet animal shelters and the petting zoo completed the questionnaire, while 15/17 (88%) of veterinary clinics completed the questionnaire. The two veterinary clinics not completing the questionnaire were both mobile veterinary services, and both had disconnected or non-working phone numbers.

A majority of the respondents to the veterinary clinic questionnaire, 17/20 (85%), reported that they had not seen any cases of myiasis or maggot-infested wounds, while 3/20 (15%) reported they had seen one or more cases of myiasis or maggot-infested wounds throughout 2016. None of the animal shelters or animal control facilities reported seeing any myiasis cases over the course of 2016. All of the animal shelters have relationships with local veterinary practitioners, and any animal arriving at a shelter needing clinical care would have been taken to a local veterinarian. A local organization that works with the feral cat population also did not report seeing any cases of myiasis or open wounds with maggots in

2016. Further, they also have a relationship with a local veterinarian, and any animal requiring veterinary care would have been referred to the local veterinarian.

Three (15%) of the veterinary clinics completing the questionnaire reported that they had seen at least one case of myiasis in 2016. The nine cases reported from the veterinary clinics included seven dogs, one cat, and one pig (Table 1). One of the clinics reporting cases had seen only one case in a canine, one clinic reported seeing three canines, and another clinic reported seeing three canines, one porcine, and one feline. The reported myiasis cases occurred between July 22, 2016, and November 5, 2016. All of the reported myiasis cases occurred after July 5, 2016, which is when the first suspected case in a Florida Key deer was seen.

Table 1: Species, date examined by the veterinarian, and route of case identification for suspect and confirmed cases in companion animals. Three animals (3/9, 33%) were identified by the questionnaire and not routine reporting.

SPECIES	DATE EXAMINED	ROUTE OF CASE IDENTIFICATION
DOG	7/22/16	Vet report
DOG	7/25/16	Questionnaire
PIG	7/30/16	Vet report
DOG	8/6/16	Questionnaire
DOG	8/26/16	Vet report
DOG	8/28/16	Questionnaire
DOG	9/15/16	Vet report
CAT	10/17/16	Vet report
DOG	11/5/16	Vet report

The animal owners of the nine cases reported from veterinary clinics were contacted for follow up by Veterinary Medical Officers with the USDA-APHIS-VS to obtain additional information. Three attempts were made to contact the owners, after which time, if there was no response they were classified as a non-responder. Non-responders accounted for 4/9 (44%) of owners, while owner surveys were completed for 5/9 (56%) of reported cases.

The completed owner surveys included four canines and one feline. Among the five respondents, 3 (60%) were confirmed NWS positive, 1 (20%) was presumptive positive, and 1 (20%) was a case of reported maggot infestation with an unknown type larvae. The animals were seen by a veterinarian during the period July 22 through November 5, 2016, and all of the animals had recovered from their infestations at the time of interview. None of the five reported using any fly control, heartworm prevention, or flea and tick prevention prior to the diagnosis, and only one out of the five had been dewormed in 2016. When asked to rank the level of fly problems at the time of illness on a scale of 1 -5 with 5 being the worst, 4/5 (80%) respondents reported a level 1, while only one respondent reported a level 3. In estimating the percentage of time the pet spent outdoors, one respondent reported 1-25%, one respondent reported 26-50%, one respondent reported 76-99%, and two respondents reported the pet spent 100% of its time outdoors. Most of the respondents (4/5, 80%) reported that they live near water. None of the animals had traveled outside the Florida Keys in 2016, and none had contact with any animals known to have traveled outside the Florida Keys.

Investigation into known pathways for introduction of New World screwworm

There are several known pathways for introduction of NWS, most of which rely on larvae being carried into the United States on a human or an animal. Humans may have entered the United States unknowingly infested with NWS larvae, or they may have unknowingly brought in animals infested with NWS larvae. These movements could have occurred either legally or illegally. To investigate these pathways, the appropriate agencies were visited to discuss both human and animal international movements directly into the Florida Keys.

Other potential pathways such as the movement of flies or larvae on products, such as hides or skins, or within conveyances, such as boats, were not explored as part of this investigation. Natural dispersal, including long-distance flights across open water, has occurred in the past and was responsible

for the rapid annual colonization of United States by the fly from over-wintering areas in southern Texas and Mexico prior to eradication (Spradley, 1994). The flight range of individual adult screwworm flies is between 3 to 300 km depending on environmental conditions and host density, though it is typically 10 to 20 km in warm humid environments (OIE, 2013). Wind and other climatic conditions, habitat factors, and the availability of resources, such as food and hosts, all influence fly dispersal, making clear associations between fly incursions and weather-related events difficult (Mayer and Atzeni, 1993). This route has not yet been explored as part of this investigation due to the uncertainty around introduction times or locations.

Undocumented human and animal movements

The local Customs and Border Protection (CBP) office in Marathon was visited, but unfortunately, specific data regarding the numbers and locations of illegal boat landings, and possible interdictions that included an animal, were not readily available. Whenever there is an interdiction involving an animal, CBP reports the animal to the Centers for Disease Control and Prevention (CDC) quarantine station in Miami, which then collects owner and location information and contacts the local animal control agency, which then picks up the animal. The animal is taken to a local shelter, and if necessary, to a local veterinarian. The animal remains in quarantine at the shelter or veterinary clinic until it can be returned to its owner or adopted out. Of the animal shelters interviewed, only one reported receiving any animals (2-3 animals to date) in 2016 from CBP interdictions, and none of these animals had wounds requiring veterinary care. Although the Coast Guard's website on migrant interdictions appears to be unavailable, several independent local news sources have cited a dramatic increase in boat landings and interdictions during the summer of 2016. During the week of July 19th, for example, the Miami Herald reported 107 Cuban immigrants arrived in the Florida Keys in the span of a single week (Herrera, 2016). They estimated that successful boat migrations were 106% greater than the same time last year. The number of Cuban migrants in particular has surged since late 2014, when the U.S. announced that it was reestablishing ties

with Cuba. The Pew Research Center found that 46,635 Cubans have entered the U.S. via ports of entry in the first 10 months of 2016, already exceeding the total number of migrants from 2015 and almost double the number of migrants from 2014 (Krogstad, 2016). While Cubans account for the majority of interdictions, migrants from Haiti and the Dominican Republic are the second largest group (United States Coast Guard, 2016). All three of these countries are known to be infested with screwworms, and the undocumented movement of people and pets from these countries continues to pose a risk to the U.S for introduction of NWS.

Legal human and animal movements

The legal entry of people and pets through airports and water ports represents another potential pathway of introduction of NWS. The CBP agricultural specialist at the Key West Airport was contacted in order to better understand the volume and management of animals coming through Key West Airport. The only international flights received at Key West Airport are private flights. Between January and July of 2016, three dogs were cleared for entry to the US from international flights. Two of the dogs came from Nassau, Bahamas, and one dog came from Grand Cayman Islands. These countries do not currently report the presence of NWS, and all three dogs were examined and reported to be in good physical condition at the time of entry. The Marathon municipal airport also receives only private aircraft; however, the reporting and inspection of animals there is variable. Following the detection of screwworms on the Florida Keys, a new procedure was developed, which requested that the NWS Incident Command Post (ICP) be notified when an animal is received at the Marathon municipal airport from an international flight. Historic information on incoming pets during the first six months of 2016 was not available. The inspection and reporting of animals arriving on international private watercraft also appears to be variable, and records of pets entering on private watercraft were not available.

In order to assess the possibility of human introduction, representatives from the Monroe County Public Health Department were contacted. They reported no human cases of NWS in 2016 or cases of wounds with severe myiasis that could be consistent with NWS.

Since persons may or may not seek medical attention for themselves or their pets, a public outreach survey was launched to allow the public to report any unusual myiasis cases in people or pets that could have been screwworms during 2016. The survey link was distributed throughout the Florida Keys on flyers and via websites. The survey is currently active, and people can continue to submit reports. Discussions with field staff involved in the outbreak response identified one local person who felt that s/he may have seen a screwworm-infested deer as early as March; however, no additional information was available. To date, five responses have been received for the public survey. All five involved reports of deer with clinical signs consistent with NWS (open wounds in live animals, presence of maggots, strange behavior including stumbling, head shaking, and depression). The earliest report references an animal seen in late June or early July on Big Pine Key. Other reported sightings of possibly infested deer occurred on July 15th, August 8th, sometime in August, and September 29th.

Discussion

Before the 2016 Florida Keys outbreak, NWS infestations capable of sustained reproduction had been eradicated from the United States, though periodic incursions have occurred. The first known Florida Key deer likely to be infested with NWS larvae was observed on July 5, 2016. The first presumptive positive canine infestation was believed to have occurred on July 22, 2016. There were no reported cases in companion animals that raised suspicion of NWS from veterinary clinics in the Florida Keys prior to July 22, 2016. CBP did not report any interdictions among aircraft or watercraft with suspected diseased animals, and the local public health department of Monroe County did not report any human cases of NWS infestation among humans.

Given the high infestation rate among Key deer, and the lack of reported infested companion animals observed prior to the first Key deer infestation, NWS infestation among companion animals was probably a spillover event from infested Key deer. In addition, none of the owners of companion animals identified as infested reported travel of a pet outside of the Florida Keys during 2016, making the case for the spillover from deer more likely. The descriptive epidemiology of the outbreak in deer would suggest that only very low levels of infestation could have been present on Big Pine Key prior to July, and additional information on the 2016 fawn crop and overall deer population has been requested.

The population doubling time for the screwworm fly can range from 54 to 139 days in density-independent growth conditions, such as those likely to prevail during outbreaks in initially screwworm-free territory. Under ideal conditions, it is plausible that screwworm outbreak populations could double in 1-2 months. However, the time needed can vary based a wide variety of factors, such as temperature,

sunlight, moisture, etc. The typical life cycle of New World screwworm is shown in Figure 3 (Fernandez and White, 2010).

An adult female fly lays eggs in an open wound on a host. After 8-12 hours, larvae emerge, enter the wound, and begin to feed. After 5-7 days, the mature larvae exit the wound and burrow into surrounding soil, where they pupate for 7-60 days, depending on temperature and environmental conditions. After pupating, adult flies emerge, feed, and rest for approximately 3-5 days, at which point they are ready to mate and seek out a host for egg laying. In tropical conditions (84° F) the entire cycle may be as short as 18 days (Schlater and Mertins, 2008).

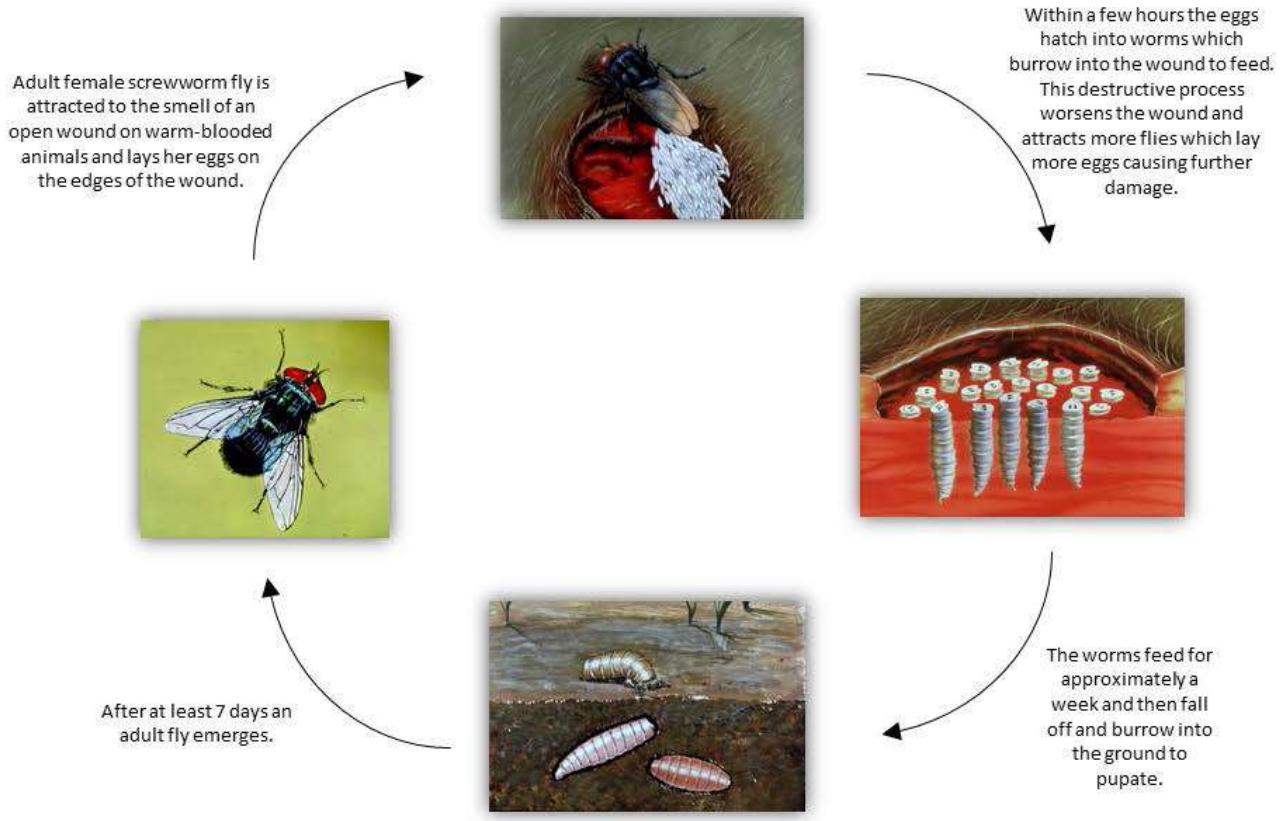

Figure 3. Life cycle of New World Screwworm from Fernandez and White, 2010.[1]

[1] Photo source: USDA APHIS. STOP Screwworms: Selections from the Screwworm Eradication Collection, Special Collections, National Agricultural Library.http://specialcollections.nal.usda.gov/screwworm/index.

Given the difficulty of detecting sparse outbreak populations and the presence of undetectable phases in the life cycle of the fly, introduced screwworm populations could easily double several times before discovery (Matlock and Skoda, 2009). Observations in the field of the stages of larvae found in the wounds of deer in early October were consistent with NWS being present on Big Pine Key since June; however NWS could have been present on other Keys at low levels for several months before then.

There were limited data available regarding animals arriving into the Keys legally from international destinations; however, the available information suggests that this is an infrequently identified occurrence and remains a low likelihood of disease introduction. The large increase in movements of undocumented people from screwworm-infested countries during mid-2016 remains a concern. The genotyping of the fly could provide additional insight into the most likely source and route of introduction, and the information described in this report should be re-evaluated as more information becomes available from that analysis.

The pathway of introduction for this occurrence of NWS has not been identified, though several plausible pathways exist and could not be ruled out. The information gathered suggests that NWS was not present prior to 2016 and was most likely introduced into the Keys in the spring of 2016, where and when the presence of a very suitable host (Key deer) allowed the fly to become established.

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Authors: Amy Delgado, Morgan Hennessey, David Hsi

For more information about this report, please contact:

Amy Delgado

Director, Monitoring and Modeling Unit

Center for Epidemiology and Animal Health

2150 Centre Ave, Building B

Fort Collins, CO 80526

Phone (970) 494-7302