DISEASE RESPONSE STRATEGY
NEW WORLD SCREWWORM MYIASIS

FAD PReP
Foreign Animal Disease Preparedness & Response Plan

United States Department of Agriculture

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The Foreign Animal Disease Preparedness and Response Plan (FAD PReP)—*Disease Response Strategy: New World Screwworm Myiasis (2018)* provides strategic guidance for responding to an animal health emergency caused by New World screwworm (NWS) in the United States.

This *Disease Response Strategy: NWS Myiasis* was last updated in **January 2018**. Please send questions or comments to:

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INTRODUCTION

New World screwworms (NWS), *Cochliomyia hominivorax*, are fly larvae that infest living tissue of warm-blooded animals, causing a condition known as myiasis. Female NWS flies lay their eggs at the edges of wounds or on mucous membranes. The eggs hatch into larvae, which burrow into the tissue and continue to feed and grow. Infestations of NWS can be fatal if untreated. NWS is currently known to exist in parts of every country in South America except Chile, and in five countries in the Caribbean, but is not resident in the United States.

Other USDA APHIS Veterinary Services (VS) documents provide further detail on incident coordination and response to foreign animal diseases (FADs) and foreign pests, such as NWS. The *APHIS Foreign Animal Disease Framework: Roles and Coordination* (FAD PReP Manual 1–0) provides an introduction to APHIS FAD preparedness and response, an overview of the roles and responsibilities of different government agencies involved in an FAD response effort, as well as information on funding, incident management, and communication strategy. Additionally, an overview of FAD response strategies is available in the *APHIS Foreign Animal Disease Framework: Response Strategies* (FAD PReP Manual 2-0). These documents along with Disease Response Plans, National Animal Health Emergency Management System Guidelines, and other strategic documents are available publicly at http://www.aphis.usda.gov/fadprep.

NATURE OF THE DISEASE

NWS myiasis occurs when female flies are attracted to warm-blooded animals and lay eggs at the edges of wounds or on mucous membranes like nostrils, ears, eye orbits, mouth, or genitalia. Within 10 to 12 hours, larvae (commonly known as maggots) emerge from the eggs and immediately begin to feed. As they feed on host fluids and underlying tissues, the damage caused by their hook-like mouthparts enlarges and deepens the wound. The odor, serum, and blood emitted by the infested wound can attract other female flies that also lay their eggs; the result is additional myiasis and increasing damage. Severe infestations can lead to host death.

Hosts

All living warm-blooded animals, including birds, can be infested by NWS, but it occurs most often in mammals (including humans). Unlike many other species of

blow flies, female NWS flies will lay eggs only on living animals because NWS larvae do not feed on dead tissue or carrion.

Life Cycle

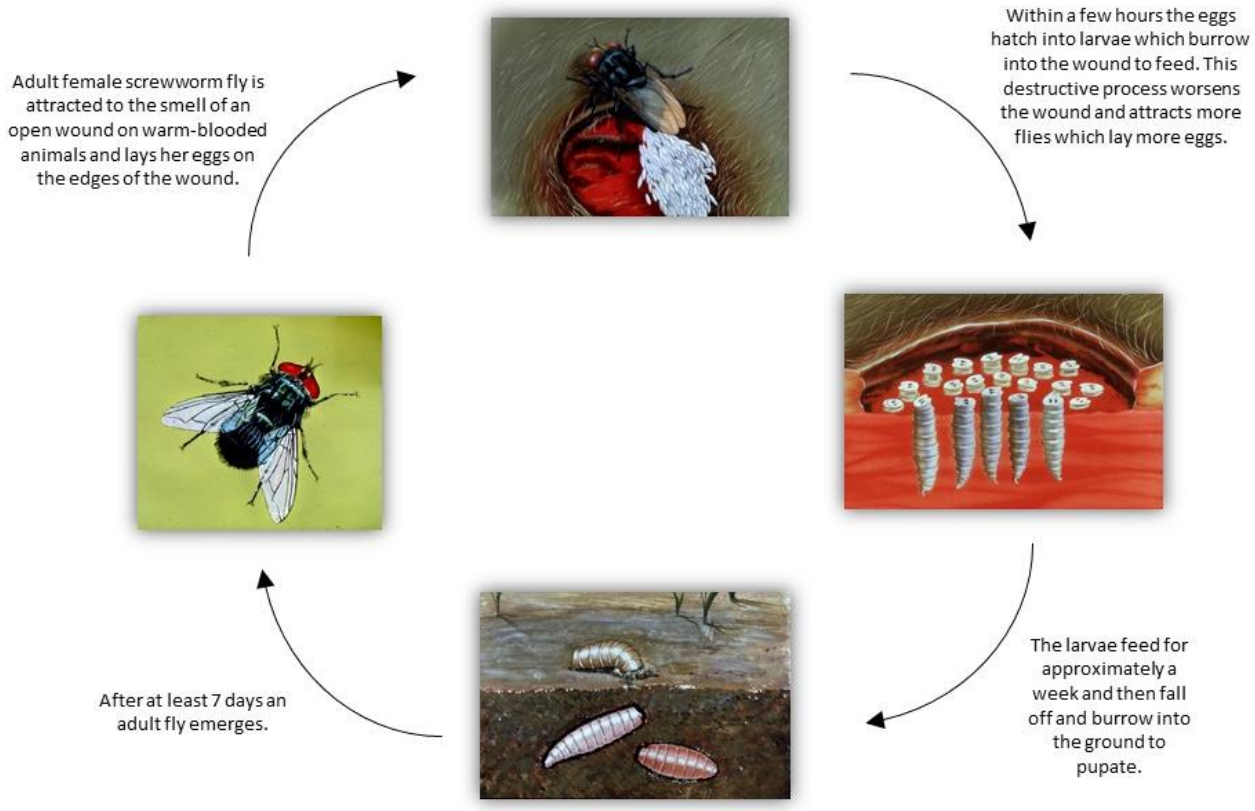
The duration of the NWS life cycle varies depending on the local climate. In cool climates, a complete life cycle may take 2 to 3 months, whereas in temperate climates (average temperature is 22° C/72° F), the NWS life cycle lasts approximately 24 days. In tropical conditions (29° C/84° F), the entire cycle may be as short as 18 days.

A female NWS fly mates with a male only once in her lifetime. Three to four days after mating she lays her eggs at the edge of an open wound or on mucous membranes of a living host. Every 3 or 4 days throughout her fertile lifespan, the female fly lays an egg mass of 100 to 350 eggs. The eggs hatch within 10 to 12 hours, and the larvae burrow into the wound and begin to feed. The larvae go through three stages of development, called instars, which involve two molts. The first molt (into the 2nd instar) occurs after about 24 hours, and the second molt (into the 3rd instar) occurs after an additional day.

Five to seven days after hatching, the mature larvae exit the wound and burrow a few centimeters into the ground where they pupate. If the larvae are unable to penetrate the soil or other substrate, they can move to a shaded area to pupate. Pupal development is temperature dependent. It can be as short as 7 days in warmer temperatures (28° C/82° F) or as long as 60 days in cooler temperatures (10–15° C/50–59° F), but pupae are killed if the soil is consistently below 8° C/46° F.

After emerging as adults, male flies live approximately 14 to 21 days and feed on flower nectar, while female flies live an average of 10 days (maximum 30 days) and feed on both flower nectar and on animal wounds as they deposit eggs. Males are ready to mate about 1 day after emergence, but females usually take 3 days to reach sexual maturity and become receptive to mating. Figure 1 provides an overview of the screwworm life cycle.

Figure 1. Life Cycle of New World Screwworm[1,2]



Morbidity and Mortality

Morbidity is variable for NWS myiasis; in areas with high NWS populations, the percentage of newborn animals with infested navel wounds can reach 100 percent. If left untreated, animals can die of trauma, toxicity, and/or secondary bacterial infections within 1 to 2 weeks. When NWS was still resident in South Texas in the 1950s, white-tailed deer fawns experienced mortality rates of 20 to 80 percent.

Clinical Signs and Differential Diagnosis

NWS myiasis is often associated with pre-existing wounds, though infestation can also occur on mucous membranes, such as nostrils, eye orbits, ears, mouth, and genitalia. Characteristics of infested wounds include drainage, suppuration (discharge of pus), discharge of blood and serum, enlargement, and distinctive

[1] Text adapted from: Fernández, P.J., & White, W.R. (2010). *Atlas of Transboundary Animal Diseases*. Paris: World Organization for Animal Health. 218–219.

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

odor. Upon closer examination of the wounds, egg masses arranged in 'shingle-like' patterns/layers at the edges of the wound might be visible.

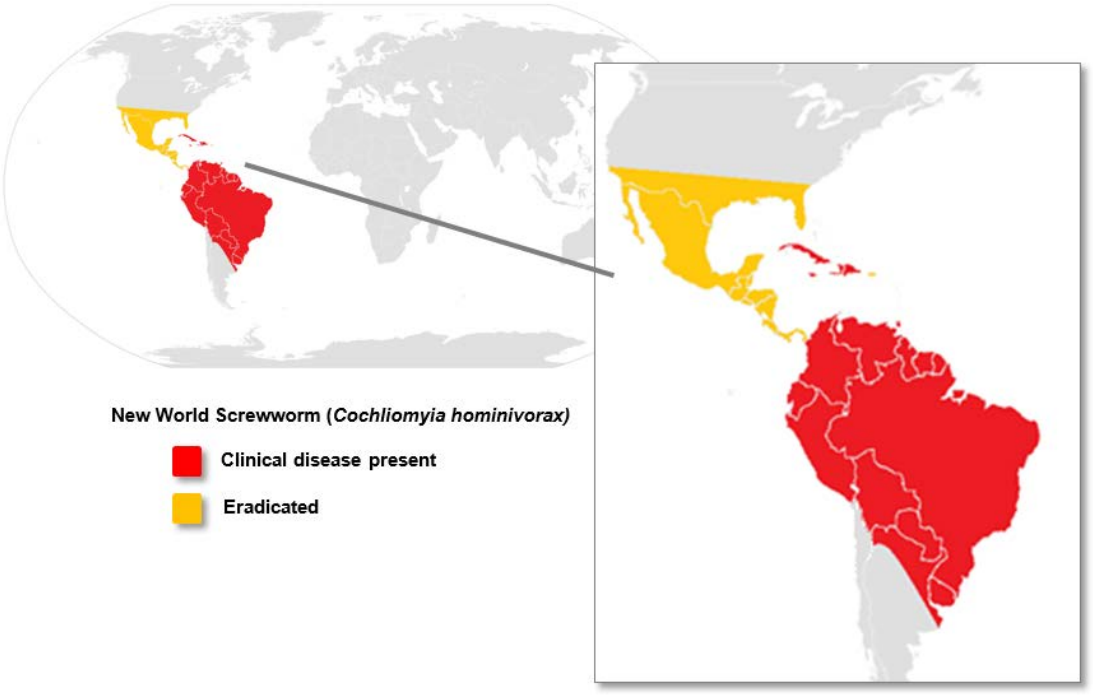
NWS larvae are visible by the third day; they can be 2.0 millimeters to 1.5 centimeters (0.08–0.60 of an inch) in length and are positioned with their posterior ends at the surface of the wound. In cases where the wound is deep, pocket-like and with a small opening, minor movement within the wound may be the only indicator of infestation. Secondary bacterial infections are also likely to occur, enlarging the wound area to 3 centimeters (1.2 inch) or more in width and up to 20 centimeters (7.9 inch) in depth. Co-infestation with maggot species that feed on dead tissue may also occur. Samples should be submitted to the National Veterinary Services Laboratories (NVSL) for expert identification (see Laboratory Diagnosis).

Animals with NWS infestations often display discomfort, lethargy, depression, and may separate themselves from the herd. Anorexia and decreased milk yield may also be observed.

Occurrence

As illustrated in Figure 2, NWS is found in tropical or semitropical regions of the Western Hemisphere, usually below 2,100 meters (7,000 feet) of elevation. From 2010 to 2016, the World Organization for Animal Health (OIE) received reports of NWS in either wild or domestic animals from Argentina, Aruba (immediately eradicated in 2011), Bolivia, Brazil, Colombia, Cuba, Dominican Republic, Guyana, Haiti, Jamaica, Panama (confined to zone near Colombian border), Paraguay, Peru, Suriname, Trinidad and Tobago, United States (eradicated in 2017), Uruguay, and Venezuela. NWS eradication programs have been successful in Curaçao, Puerto Rico, the U.S. and British Virgin Islands, United States, Mexico, and Central America. Imported cases of animal or human NWS myiasis are reported periodically in the United States, Mexico, and other countries where NWS has been eradicated.

Figure 2. Distribution of New World Screwworm



Environmental and Chemical Responses

NWS flies are able to travel long distances to find a suitable host. Although they generally remain within a 3-kilometer (1.9-mile) range when there is a high host density and suitable environment, flies are known to move 10 to 20 kilometers (6.2 to 12.4 miles) in warm, humid settings. Long distance movement of NWS is generally a result of the movement of an infested animal.

Although they prefer hot, humid environments, NWS are able to survive in a range of temperatures and climates. Table 1 provides information on the NWS response to certain environmental or chemical factors.

Table 1. Response of New World Screwworm to Physical and Chemical Factors[3]

Factor	Response
Soil Temperature	Pupae are killed in soil temperatures consistently below 8° C (46° F) or by freezing.
Chemicals	NWS is susceptible to insecticidal organophosphate, carbamate, and pyrethroid compounds.
Ecology	Flies prefer hot, humid environments, with air temperatures of 25 to 30° C (77 to 86° F) and relative humidity of 30 to 70 percent, but they can survive in suitable humid microclimates (e.g., irrigated areas) in otherwise dry conditions. In addition, availability of hosts with suitable wounds is fundamental for persistence of populations.

Prevention

In areas where NWS is found, measures should be implemented to prevent wounds and avoid myiasis. For example, eliminate wounding procedures (e.g., castration), handle livestock with care, and inspect pens for sharp objects. Please see the Prevention of Wounds and NWS Myiasis section for more information.

Treatment

Organophosphate, carbamate, and pyrethroid compounds are effective against larvae and adult flies. Animals suspected of NWS infestation should have their wounds treated at 2- to 3-day intervals and remain in quarantine until the wounds are healed to ensure mature larvae are killed before leaving the wound and dropping on the ground to pupate. For more information, see the Treatment of Wounds and Myiasis section.

Laboratory Diagnosis

NWS myiasis is on the U.S. National List of Reportable Animal Diseases-National Animal Health Reporting System Reportable Disease List.[4] Accredited veterinarians must collect, submit, and report suspect NWS myiasis. Diagnostic testing for NWS will be performed by the NVSL in Ames, Iowa. Although other agencies and entities may make a tentative identification, NVSL will assign the definitive parasite identification. Identification is by microscopic examination of the larvae (or possibly other life stages) and based on morphological characteristics. To obtain specimens for identification, gently remove larvae from several sites within the open wound using forceps. Because secondary myiasis

[3] World Organization for Animal Health (OIE). (2013). Screwworm (Old World and New World). *Technical Disease Card.* www.oie.int.

[4] The list can be located here for further reference: https://www.aphis.usda.gov/aphis/ourfocus/animalhealth/monitoring-and-surveillance/sa_disease_reporting/ct_disease_list.

may be present and is most often found near the surface of the wound, it is especially important to collect specimens from the deepest part of the wound. If possible, collect larvae of different sizes for submission.

Preserve the specimens in alcohol (ethyl or isopropyl).[5] The concentration should be 70 percent by volume, if the specimens are identified using stereo microscopy. If for scientific study, or the possible use of molecular identification techniques, then 95 percent ethyl alcohol (ethanol) is the preferred medium for preservation. Specimens should be submitted to the NVSL with a Parasite Submission Form (VS Form 5-38) available on the APHIS website, located here: http://www.aphis.usda.gov/library/forms/pdf/VS_Form5_38.pdf.

For detailed information concerning the handling and shipping of diagnostic specimens, as well as overall guidance on FAD investigations, please see *APHIS VS Guidance Document 12001* and the *FAD Investigation Manual* (FAD PReP Manual 4-0), available at http://www.aphis.usda.gov/fadprep.

NWS Myiasis Response: Control and Eradication

The APHIS goals of an FAD response are to (1) detect, control, and contain the disease in animals as quickly as possible; (2) eradicate the disease using strategies that seek to protect public health and the environment, and stabilize animal agriculture, the food supply, and the economy; and (3) provide science- and risk-based approaches and systems to facilitate continuity of business for non-infested animals.

Achieving these three goals will allow individual livestock facilities, States, Tribes, regions, and industries to resume normal production as rapidly as possible. The objective is to allow the United States to regain NWS-free status without the response effort causing more disruption and damage than the outbreak itself.

Strategy for Responding to NWS Myiasis in the United States

Two basic epidemiological principles form the foundation of a response to control and eradicate an infestation of NWS in the United States.

1. *Prevent contact between NWS flies and non-infested animals.* This is accomplished through
    a. prevention, detection, and treatment of wounds in non-infested animals; and

[5] NVSL-Ames. (2017). Diagnostic Testing. http://www.aphis.usda.gov/animal_health/lab_info_services/downloads/AmesDiagnosticTestingCatalog.pdf.

b. quarantine of infested livestock, movement controls, and inspections of livestock in regulatory control areas.

2. *Stop the production cycle of NWS flies.* This can be accomplished through
   a. detection and appropriate treatment of infested animals; and
   b. use of the sterile insect technique (SIT) (see later section).

Case Definitions

The following case definitions are APHIS VS Center for Epidemiology and Animal Health (CEAH) definitions for NWS myiasis (draft November 2017).

Suspect case: An animal or person with clinical signs consistent with blow fly or screwworm myiasis.

Presumptive positive imported case: A suspect case that has travel history outside the United States to any screwworm-infested country within the previous 10 days.

Presumptive positive autochthonous case: A suspect case that has no travel history outside the United States within the previous 10 days, **and** was

- located near a previous confirmed positive, **or**
- identified as screwworm by a lab other than NVSL, **or**
- identified as screwworm by a collector with screwworm experience.

Confirmed positive imported case: NVSL confirms presence of screwworm from a presumptive positive imported case by visual identification of the egg mass, larvae (first, second, or third instars), or adult fly.

Confirmed positive autochthonous case: NVSL confirms presence of screwworm from a presumptive positive autochthonous case by visual identification of the egg mass, larvae (first, second, or third instars), or the adult fly.

REPORTING

NWS myiasis is a United States FAD and an OIE-notifiable disease. Suspect cases must be reported to a State Animal Health Official or APHIS VS Assistant District Director who will decide if the report warrants further investigation by a Foreign Animal Disease Diagnostician to assess the possibility of a NWS detection or infestation. For more information on FAD investigation procedures, please refer to *APHIS VS Guidance Document 12001*, and to the *FAD Investigation Manual* (FAD PReP Manual 4-0), available at http://www.aphis.usda.gov/fadprep.

Critical Activities

Epidemiology Investigation and Tracing

For any detection of NWS myiasis in the United States, a thorough epidemiological investigation is required to determine if the infestation was acquired domestically or in a foreign location. If it is concluded that the myiasis was not acquired in the United States, the investigation must determine if a domestic population of NWS may be in the process of developing due to the myiasis introduced from a foreign source. If a domestic population of NWS is known to be present or suspected to be developing, epidemiological investigation and movement tracing are critical in controlling and eradicating that population.

Epidemiological investigation and tracing are typically the responsibility of multiple staff components within the Incident Command System (ICS), including the Disease Surveillance Branch (Operations Section), Epidemiologists (Planning Section), and the National Situation Unit (Planning Section).

Tracing

Trace Back: Identifying the origin and movements over the last 10 days for all animals and people detected with myiasis, in order to determine the original source of the myiasis, or potential locations of additional infestation.

Trace Forward: The tracing of all animals and people that have left an infested location in the last 10 days and could have possibly transmitted infestation to a new location. The premises that received the animals should be investigated and kept under surveillance.

Information Management

Information management and reporting during a NWS outbreak ensures that responders, stakeholders, and decision-makers have access to accurate and timely critical emergency response information. Ideally, local, State, Tribal, and Federal information management systems are compatible for information and data sharing. The Emergency Management Response System 2.0 (EMRS2) is the official USDA APHIS system of record during a NWS outbreak. EMRS2 contains data on infested animals, fly releases, fly trapping, movements and traces, any zones established, and other information.

In a NWS outbreak, the response goal is to have EMRS2 information downloads or data entry processes performed at 12-hour or shorter intervals. Data should be entered as quickly as possible in both an accurate and consistent manner across widespread field operations. Field personnel should be provided with access to mobile technology devices necessary for collecting, monitoring, and sharing information. Information within EMRS2 will provide the data necessary for daily,

weekly, and ad-hoc situation reports. It is imperative that outbreak information management, data quality, and data integrity are a priority. Additional resources on information management systems and tools can be found in *Information Management and Reporting* (FAD PReP Manual 3-0).

COMMUNICATION

APHIS Legislative and Public Affairs (LPA) will serve as the primary Federal government liaison with the news media in the event of a NWS outbreak. Under the ICS, a Joint Information Center (JIC) is established. During a NWS outbreak, APHIS LPA and the USDA Office of Communications operate from the JIC. Effective communication should be carried out and maintained by

- establishing a network of stakeholders and systems for communication prior to an incident or outbreak;
- briefing the media, public, industry, Congress, trading partners, and others on the NWS outbreak status and the actions being taken to control and eradicate the infestation;
- coordinating with Federal, State, and local agencies (especially those responsible for public health or wildlife); Tribal entities; producer groups; and the Land-Grant University-based Cooperative Extension System to ensure consistent messaging regarding animal health, public health, and food safety; and
- assuring consumers that USDA is working on animal health issues, in an informed and timely manner, along with the Federal Department of Health and Human Services, which is working on human health issues.

In addition, all communications should highlight the importance of sound preventive measures and steps that producers and owners can take to protect against NWS infestation in their own animals.

PUBLIC EDUCATION

Educating the public, particularly animal owners and hunters, to recognize and report possible cases of myiasis will be critical. A large publicity campaign may be warranted to broadly disseminate information and seek public cooperation during a NWS response. Due to the wide host range for NWS, awareness campaigns should partner with public health and wildlife agencies.

Providing timely information to local livestock owners and producers, veterinarians, physicians, hunters, pet owners, and the general community can help generate reports of possible cases of NWS myiasis. Education on wound prevention and treatment can help limit the number of cases that occur. Cooperative Extension System agents have contact with animal owners and can serve a valuable role in an educational campaign. Although educational material may need to be tailored to the location and population affected by an outbreak, a basic example of information for the public is available at

https://www.aphis.usda.gov/publications/animal_health/bro-new-world-screwworm.pdf. Additional APHIS FAD PReP resources for the public include NWS Ready Reference Guides (1) Maps and Timelines, (2) Historical Economic Impact, and (3) Sterile Insect Response. Also available is the NWS Story Map, which includes interactive maps on the 2016–2017 Florida NWS Response. Links to these materials are available in the References and Resources section.

QUARANTINE AND MOVEMENT CONTROL

Quarantine refers to imposing restrictions on entering or leaving a premises, area, or region where disease exists or is suspected. Quarantine stops the movement of infested animals.

Movement control refers to activities regulating the movement of animals within an area subject to certain criteria. Movement control is accomplished through a permit system that allows entities to make necessary movements without creating an unacceptable risk of spreading the infestation.

Quarantines and movement controls are effective measures to prevent the spread of infestation. While controlling the spread of female NWS flies is nearly impossible, dispersal has been observed to be largely due to movement of animals with myiasis and not the result of flies seeking out new hosts.[6] These animal movements can result in long-distance spread and establishment of infestations in entirely new geographic areas. Therefore, quarantines and movement controls will be a primary strategy of NWS response efforts.

USDA may impose a Federal area quarantine and restrict interstate commerce from the infested States, asking the States (or adjoining countries) to provide resources to maintain and enforce the quarantine. State quarantines may be placed on individual infested animals or premises with infested animals. Of most importance is the control of livestock movement within and out of an infested area, using a system that requires inspection for wounds and myiasis. This may include permit requests for permitted movement.[7] For example, ICS personnel could issue a permit for movement out of a quarantine area after an inspection for wounds and myiasis, followed by treatment of the animal with an approved insecticide. Other approaches may also be reasonable, based on the epidemiological characteristics of the incident.

All decisions in regard to quarantine and movement control will be based on science-based assessments of the current extent of NWS infestation, risk of

[6] Animal Health Australia. (2007). *Disease Strategy: Screw-Worm Fly* (Version 3.0). Australian Veterinary Emergency Plan, Edition 3, Primary Industries Ministerial Council, Canberra, ACT.

[7] For more information on permitting, please see the document *Permitted Movement* (FAD PReP Manual 6-0).

spread, and the interaction of other factors, such as seasonal climate and weather conditions.

Individual animal or premises quarantines can be lifted and movement can resume once all wounds of infested animals have been treated, other animals within the group or premises have been treated prophylactically, and re-inspection shows that no viable NWS remain.

Control Area (or Other Zone) Designations

Appropriate Control Area (or other zone) designations may be required for implementation of quarantine and movement control measures. The Incident Commander will work with the Disease Surveillance Branch (Operations Section) and Situation Unit (Planning Section) to establish a Control Area or other zones, once it is determined that a domestic population of NWS is present or suspected to be developing. Once the Control Area is established, quarantine and movement controls, including a permit system (as appropriate), may be implemented.

NWS Eradication Using the Sterile Insect Technique (SIT)

SIT employs exposure of lab/factory-reared 5- to 6-day-old NWS pupae to gamma radiation to create sterile NWS files. Field release of these mass-produced sterile flies results in sterile males overwhelmingly mating with wild female flies that then lay unfertilized eggs. Because female NWS flies normally mate only once, the wild population of NWS is progressively reduced and, ultimately, eradicated.

USDA scientists performed a successful SIT field experiment in 1951 on Sanibel Island, Florida, but its proximity to infested mainland Florida didn't allow for long-term eradication. In 1954, on the Caribbean island of Curaçao (Netherlands Antilles), SIT was used effectively to eradicate NWS in approximately 6 months. The next set of SIT applications in the United States started in 1957 in Florida. After the success of this campaign, SIT was used to eradicate NWS successively from the United States, Mexico, and Central America.

Before the most recent autochthonous cases of NWS myiasis were detected in Florida in 2016, there had been at least 27 post-eradication findings of NWS

larvae in animals or people in the United States.[8,9,10,11] These cases were typically linked to recent travel or residence of the host in a NWS-endemic country. In two separate incidents in 1987, both involving dogs with NWS myiasis detected after return from foreign travel, it was determined that use of the SIT was warranted. Sterile flies were released for 6 weeks around locations in Florida, Louisiana, and New Mexico, and no additional local NWS larvae were ever found.

USE OF THE STERILE INSECT TECHNIQUE

Use of the SIT should be considered if it is determined that a population of NWS is present, or may be in the process of developing, within the United States. This determination is made based on multiple factors, or combinations of factors, relative to the index case of myiasis detected in an animal or human host. These factors include: stage of larval development, the affected host's history of international travel, time elapsed since United States entry, locations visited since returning, treatment provided, and environmental and seasonal considerations.

More specifically, there are two situations in which SIT should be considered:

1. finding NWS larvae in an animal or person that did not travel outside of the United States in the previous 10 days;
2. finding NWS larvae in an animal or person that did travel outside of the United States in the previous 10 days, with evidence that larvae may have left the host in the United States (e.g., myiasis detected 5 or more days after United States arrival, or collection of NWS pupae) and could complete pupation (e.g., access to soil, favorable local temperatures, suitable seasonal climate).

In the second situation, intensive surveillance for NWS myiasis or flies may initially be a reasonable alternative to using the SIT. If surveillance finds evidence that confirms a population of NWS is present in the United States, SIT would then be called for to pursue eradication.

[8] Alexander, J.L. (2006). Zoonosis Update: Screwworms. *Journal of the American Veterinary Medical Association*, 228(3), 357-367.

[9] Spickler, A.R., & Roth, J.A. (Eds.). 2006. Screwworm-New World (*Cochliomyia hominivorax)* in the United States, 2000. In *Emerging and Exotic Diseases of Animals* (3rd ed.: 105-107). Ames, IA: Institute for International Cooperation in Animal Biologics, Iowa State University College of Veterinary Medicine.

[10] USDA APHIS. (2008). 2007 United States Animal Health Report. *Agriculture Information Bulletin No. 803*. http://www.aphis.usda.gov/animal_health/animal_health_report/downloads/AHR_08/ahr2007.pdf.

[11] Corn, J.L. (Ed.). (2011). *Proceedings - 114th Annual Meeting of the United States Animal Health Association*. Saint Joseph, MO. http://www.usaha.org/upload/Proceedings/USAHAProceedings-2010-114th.pdf.

It is important to note that the SIT would be just one of several control strategies employed in the event of an infestation; movement controls, tracing, surveillance, and treatment and prevention would be components of any NWS myiasis response.

Production of Irradiated Pupae

If it is determined that use of the SIT is warranted to control and eradicate an outbreak of NWS myiasis in the United States, APHIS VS will request that APHIS International Services (IS) oversee the production and shipment of irradiated (sterile) NWS pupae from the production facility in Pacora, Panama.[12]

The NWS production facility in Panama is designed and constructed for a barrier-maintenance production capacity of 40 million pupae per week (year round) and a maximal production capacity of 100 million pupae per week for suppression of any outbreaks. The plant normally produces about 20 million pupae per week—the number needed to maintain the NWS barrier zone in eastern Panama—and can ramp up production to 80 million pupae per week for 20 weeks or longer, if required. Based on those parameters, production can initially be increased to provide approximately 40 million sterile NWS pupae per week for shipment to the United States while still continuing at least a minimal level of barrier activities. That would be enough pupae to release sterile flies at the optimal rate (i.e., 875 flies per square kilometer/2,266 flies per square mile per week) for the eradication of a NWS infestation covering 38,850 square kilometers/15,000 square miles. By comparison, the original eradication of NWS from the entire State of Florida in the late 1950s was accomplished with a maximal production of 50 million sterile pupae per week.

The first air shipment of 4 to 6 million pupae could arrive in the United States as soon as 3 days after a request, assuming that preparations for receiving pupae and releasing flies at the infested location would be completed that soon. This quantity of pupae would produce enough flies to cover an infestation area of at least 3,885 square kilometers/1,500 square miles for one week. Shipments of that size or greater could be made on a daily basis, although the ideal operational tempo in the United States would more likely be to receive shipments twice per week. Within 2 weeks of the initial request, shipments could total 40 million pupae per week. If required, production could eventually be increased to 80 million pupae per week to eradicate an outbreak, while still producing 20 million pupae per week for the Panama barrier zone.

An import permit from APHIS VS National Import Export Services is required for shipments of pupae from Panama. The permit can be obtained in about an hour, once an address and specific person are identified to receive the incoming shipment. A permit is valid for multiple shipments and for a period of one year.

[12] Budgeting of response costs will need to include reimbursement to the Panama facility for pupae production at current market prices.

Timing of Sterile Fly Release

In a worst case scenario, the initial detection of NWS myiasis would not occur until 3 weeks or more after the initial introduction of NWS larvae into a United States location favorable for pupation and ongoing maintenance of the NWS life cycle. In this scenario, a viable population of NWS flies would already exist in the United States at the time of myiasis detection in an animal or person. Releases of sterile NWS flies would be required for at least 9 to 12 weeks in order to control and eventually eradicate that population. The sterile fly releases would need to begin as soon as possible. During the 2016–2017 NWS outbreak in Florida, samples were not sent to the NVSL for identification until 84 days (4 life cycles) after presumptive positive identification by local veterinarians.

Perhaps more likely is a scenario in which the initial introduction of myiasis is detected in an animal or person that recently entered the United States from a NWS-infested country, and it is determined that some of the larvae may have already exited the wound and begun to pupate. In such a scenario, even under ideal climatic conditions, it would be at least 10 days after the host entered the United States before the first female NWS flies could be mature and ready to mate. If release of sterile male NWS flies began by that time, establishment of a population of NWS flies probably could be prevented.

Release Logistics

Pupae would be shipped by express air delivery in large polystyrene foam coolers or insulated chests, each holding about 44 liters of pupae, enough to produce approximately 333,000 flies. Additionally, coolers could be shipped with 24 to 33 liters of pupae each and packed with ice-packs for additional cooling if necessary. Due to variability over time, pupal size will be continually monitored to better estimate the quantity of sterile pupae that are shipped.

The simplest and most rapidly implemented dispersal of sterile NWS flies will be through ground release. Ground release containers were used in Chiapas, Mexico, in outbreaks in 2001 and 2003, to augment aerial dispersal of sterile flies in specific key areas. Ground release containers were the sole means of dispersing sterile flies to eradicate outbreaks in Aruba in 2004 and 2011, and in Florida during the 2016–2017 outbreak.

The pupae will need to be transported from the arrival airport to a handling site near the release area. This site can be as basic as an air-conditioned room or an open air space shaded by a roof. At this point, the pupae must be transferred from the shipping coolers into their intended ground release containers. These containers may be cardboard or plastic boxes, or even larger structures, depending on the needs of the particular situation. Release containers (Figure 3) can be placed in the field as early as the day following arrival from Panama, or the

emergence of the flies can be delayed for a few days by chilling the pupae to 50° F (10 ° C) in a refrigerated room, a walk-in cooler, or a refrigerated tractor-trailer.

Figure 3. Release Container Used in the Florida Keys, 2016–2017

Photo: USDA APHIS Veterinary Services

Sterile NWS flies should generally be released throughout an area within 10 kilometers (6.2 miles) of each location where a case of myiasis has been detected. Similarly, in cases where an infested animal or person traveled to multiple locations during the period of larval maturation, release of flies may be warranted within 10 kilometers of each location where pupation could have occurred. Alternatively, in such exposed areas where myiasis has not been detected but fly development is considered possible, intensive surveillance may be applied initially, and sterile fly release may begin only if NWS myiasis is subsequently detected or wild NWS flies are trapped in the area.

Dispersal of flies by air, from specially equipped fixed-wing aircraft, should be considered if factors, such as the large size of an infested area or limited accessibility to large portions of an infested area, make ground release impractical or ineffective. APHIS personnel, working with various plant and animal pest control or eradication programs, including the NWS program in Panama, have experience in contracting for air services.[13]

[13] Dynamic Aviation is a provider of air services for SIT programs (http://www.dynamicaviation.com/index.php/flight-solutions-and-services/sterile-insect-technique/).

Throughout the dispersal area, the weekly release rate of sterile NWS flies should be 875 per square kilometer, or 2,266 per square statute mile, or 3,000 per square nautical mile. Twice-weekly release (half the weekly target total in each release) was proven effective in the NWS eradication program in Mexico and Central America. That program employed fixed-wing aircraft to release flies at a regular rate (e.g., 6,000 flies per linear nautical mile) along flight lanes drawn in a grid manner over the targeted infestation area. The distance between flight lanes in the dispersal grid was usually 4 nautical miles, with subsequent flights splitting the lane width every 3 to 4 days.[14]

With ground release of flies, the pattern used in air release could be duplicated or some other pattern that achieves a uniform dispersal over a 7-day period could be employed. Depending on their size, release containers may be filled with from 1,000 to 240,000 pupae each; this will produce a minimal release of 850 to 204,000 sterile flies per container placement. A practical and versatile release container might contain 2,000 pupae to produce at least 1,700 sterile flies for release. Such a container would provide coverage for an area of about 4 square kilometers, or about 1.5 square statute miles, for half a week (i.e., each square kilometer needs 875 flies per week, each square statue mile needs 2,266 flies per week); the proper placement of 100 of these containers, twice a week, would release approximately enough flies to cover one complete 400 square kilometer infestation area.

Another advantage of ground release is that it may be possible to more closely target habitats that are favorable for wild NWS flies rather than simply using a uniform dispersal pattern. Analysis of satellite imagery of the intended release area can potentially locate favorable habitat in which to concentrate ground releases. If favorable habitat areas are accessible for the placement of fly containers, more than 875 flies per square kilometer would be effectively released each week, and fewer flies would be released in areas with less favorable habitats. Experts from APHIS IS, APHIS VS CEAH, and the Agricultural Research Service of USDA should be consulted for such analysis.

[14] Smith, S.C. (2009). A Guide for the Eradication of Screwworms. Comision Mexico - Americana para la Eradicacion del Gusano Barrenador. http://www.flsart.org/screwworm/Screwworm%20Eradication%20Guide%20Print%20Version.pdf

Weekly Release Rate Summary

- Per square kilometer: 875 sterile NWS flies
- Per square statute mile: 2,266 sterile NWS files
- Per square nautical mile: 3,000 sterile NWS flies

Example

For an *infestation area* of 400 square kilometers, the following would result in a sufficient release of sterile NWS flies:

- 100 containers
- Placed twice per week
- 2,000 pupae per container (with an emergence rate of 85 percent or more, this results in at least 1,700 sterile flies)

The area of release may be enlarged or reduced based on local conditions, including distributions of livestock, wildlife, and human populations. To facilitate the logistics of release, particularly by air, it may be useful to square the 10 kilometer radius around an infested location into a 20 kilometers by 20 kilometers (12.4 miles by 12.4 miles) square area, comprising a total of 400 square kilometers (approximately 154 square miles) and centered on the location of myiasis detection or possible pupation.

Release of sterile flies should continue for at least three life cycles, or about 9 weeks in warm conditions, past the last detection of NWS myiasis within any given circle of 10 kilometer radius. Continuing release for four life cycles (about 3 months) would provide even more certainty of eradication. Factors such as local weather, seasonal climate, and ecological conditions should be considered in determining when to stop releasing sterile flies.

SURVEILLANCE

The purpose of surveillance for NWS is to define the extent of any current infestation, detect new infestations, and establish NWS-free areas. Surveillance activities can aid in establishing priorities for control and mitigation strategies and in evaluating the efficacy of response efforts. Surveillance is also critical to maintaining continuity of business and providing evidence for proving freedom from NWS myiasis following an outbreak.

Visual inspection of animals will be a primary surveillance tool. Animals on premises in the Control Area and in a surrounding Surveillance Zone should be monitored every 5 to 7 days for wounds and evidence of NWS myiasis. Animals must also be visually inspected for wounds and myiasis prior to any permitted movement within, and potentially out of, the Control Area. All maggot specimens detected must be submitted to the NVSL for definitive identification.

Trapping can be used to document the absence of fertile NWS flies (through their absence in traps) in the Surveillance Zone surrounding a Control Area and to help prove freedom from NWS after sterile fly release is discontinued. Trapping can

also be used for quality control within the Control Area to evaluate the release and dispersal of sterile NWS flies. Taking into account typical flight distance and weather patterns, traps may be set up at varying distances from points of known infestation. Methods available for trapping NWS flies include luring flies to decomposing liver (ca. 0.5 kilogram/site/1 hour) and collecting them with nets, or wind-oriented traps with chemical attractants or baits. Swormlure-4, a blend of chemicals that releases a strong odor, has been used as an attractant for trapping with wind-oriented traps, such as the Vertical Sticky Trap.

Once flies are attracted, different trapping mechanisms may capture them, including sticky boards and enclosures with insecticide strips. Trapping and surveillance activities should be conducted in favorable NWS habitats, such as the edges of wooded areas, and in such a manner that the trapping/surveillance site is located up-wind, so the odor of the attractant carries into the favorable habitat.

For more information, please see the document *Fly Surveillance & Site Selection Methods* (http://www.aphis.usda.gov/fadprep, navigate to the NWS page). More detailed guidance on designing an outbreak-specific surveillance plan and conducting surveillance activities in the field will be available to Disease Surveillance Branch and other Incident Command personnel during an incident.

Educating local livestock owners and producers, veterinarians, physicians, hunters, pet owners, and the general community will facilitate passive surveillance for NWS myiasis. Agents of the Cooperative Extension System can serve a key role in disseminating information on surveillance and assisting in sample collection.

Due to the wide host range for NWS, awareness campaigns should also partner with public health and wildlife agencies. Although the confirmation of NWS must be made by the NVSL, possible cases of myiasis in people should be reported through public health agencies; partnering with State wildlife agencies will facilitate surveillance for NWS myiasis in wildlife species.

TREATMENT OF WOUNDS AND MYIASIS

All wounds detected in animals within a Control Area should be treated prophylactically with insecticide, every 2 to 3 days until healed, to prevent female NWS flies from laying eggs and to kill any eggs or larvae already present. All detected myiases must be treated. The protocol for treatment is as follows:

1. Clean the wound and the surrounding tissue with warm water and a mild antiseptic.
2. If myiasis is found, physically remove as many larvae as possible. Retain 10 or more larvae for identification (see Laboratory Diagnosis section).
3. Apply an effective topical treatment (i.e., insecticide) to kill any remaining larvae.
4. Treat animal with longer-lasting systemic insecticide for prophylaxis.

Table 2 provides current Environmental Protection Agency (EPA)-registered products with known efficacy against NWS. All products are registered only for labeled use. Please check the EPA website (https://www.epa.gov/pesticides) to determine if products are still registered for use.

*Table 2. EPA Registered Products Against New World Screwworm**

Product	EPA Registration Number	Manufacturer Name and Contact	Active Ingredient
0.5% Permethrin Aerosol Spray	71-1	L. Perrigo Company	Permethrin
Champion Insecticide Spray	498-188	Chase Products Company	Permethrin
Claire Bed Bug, Lice and Dust Mite Spray	706-110	Claire Manufacturing Company	Permethrin
Black Jack Multipurpose 0.5% Insecticide	8848-73	Safeguard Chemical Corp.	Permethrin
CT Residual Spray	47000-100	Chem-Tech LTD	Permethrin
Permethrin Insecticide Spray (Cantron IV)	11556-171	Bayer Healthcare LLC	Permethrin
Permanone Multi-Use Insecticide Spray	73049-301	Valent Biosciences Corp.	Permethrin
Co-Ral Coumaphos Flowable Insecticide	11556-98	Bayer Healthcare LLC	Coumaphos
Co-Ral Fly and Tick Spray	11556-115	Bayer Healthcare LLC	Coumaphos

*No recommendation implied.

PREVENTION OF WOUNDS AND NWS MYIASIS

Within the Control Area, measures should be implemented to prevent animal wounds and avoid NWS myiasis. For example, to the extent possible, eliminate or delay performing wounding procedures such as dehorning, branding, shearing, ear notching, tail docking, and castration. Additionally, livestock should be handled with care, and pens should be inspected for sharp objects. Measures should be taken to protect livestock from other wound-causing parasites, such as ticks. Untreated umbilical cords of newborn animals and foot lesions are commonly infested sites. Immediately treat all wounds with approved insecticides; it may also be prudent to follow up with precautionary spraying of animals with insecticide before transport.

WILDLIFE MANAGEMENT

It should be assumed that some wildlife within an infested area will be subject to NWS myiasis. It is therefore important to minimize the potential dispersal of wildlife located within a NWS-infested area. One measure that should be considered is a temporary prohibition on hunting in the Control Area. APHIS VS

will collaborate closely with Federal, State, and local wildlife health officials to ensure that the most appropriate decisions are made in managing wildlife.

EUTHANASIA

During NWS surveillance and control, individual animals may require euthanasia for welfare reasons.

DISPOSAL

Disposal frequently is not a great concern, as depopulation activities will typically be minimal. If small numbers of dead animals must be disposed of, responders must ensure that no viable NWS larvae are on or in the carcass, especially if burial is used. Incineration is a preferred disposal method for NWS-infested carcasses. Because NWS feed only on living flesh, the focus of pre-disposal examinations should be on very recently deceased animals. For further information on disposal, see the *National Animal Health Emergency Management System (NAHEMS) Guidelines*: *Disposal* available at http://www.aphis.usda.gov/fadprep.

CLEANING AND DISINFECTION

Because NWS larvae are obligate parasites, requiring living flesh to remain viable, it is extremely unlikely that larvae would be transported on animal products or byproducts. However, there is a small risk that carcasses of very recently deceased animals might still be infested, and they should therefore be thoroughly checked before leaving the Control Area. Be aware that larvae typically and rapidly vacate a wound and pupate when the host animal dies.

NWS larvae normally pupate in 2 to 3 centimeters (about 1 inch) of soil, but pupation can occur anywhere there is a slight buildup of organic material, such as in feces. Maggots can also pupate in other protected sites, like cracks and crevices, or below bedding materials. Therefore, areas where infested or susceptible animals have been held, including vehicles, must be immediately and thoroughly cleaned and treated with insecticide as part of an effective control effort. Furthermore, animal material that may contain viable pupae, such as manure, should be disposed of in a manner that will conclusively kill that stage; incineration is preferred. To avoid these situations, inspections and cleanings of transport vehicles should be conducted in areas with concrete or otherwise hard and sealed floors. Trucks, trailers, or other conveyances used to transport infested animals should also be treated with insecticide before further use.

HEALTH AND SAFETY AND PERSONAL PROTECTIVE EQUIPMENT

Protecting the health and safety of personnel assigned to emergency response activities is everyone’s responsibility. During an outbreak response, responders

may be exposed to a number of different hazards. Taking precautions to prevent adverse human health events related to emergency response efforts is important.

NWS larvae can infest humans, so responders should take precautions when potentially exposed to NWS flies. If responders have open wounds, those injuries should be thoroughly cleansed and covered. For most responders, the appropriate level of personal protective equipment (PPE) during screwworm response efforts will be Level D. Level D is the lowest level of protection, and requires only a basic work uniform to protect the body against contamination and no respiratory protection. Disposable gloves, and possibly cut-resistant gloves (if warranted by specific activities), are needed for hand protection. Although this is the suggested minimal level of PPE for screwworm, the final decision is always based on an assessment of the specific circumstances and activities in the field. Some response activities may require the use of protection higher than Level D.

For further information on health, safety, and PPE, see the *NAHEMS Guidelines: Health and Safety and Personal Protective Equipment* available at http://www.aphis.usda.gov/fadprep.

Appraisal and Compensation

The response to a NWS infestation should not require significant, if any, destruction of animals or other assets. However, USDA is authorized by the Animal Health Protection Act (7 U.S.C. 8301 et seq.) to pay claims to owners for any assets taken or destroyed in the course of a response effort. Title 9 of the Code of Federal Regulations, Part 53, outlines the expenses that the Department may pay for purchasing, destroying, and disposing of animals and materials in these situations. Fair market value appraisals will be made for animals and materials destroyed to prevent the spread of NWS. Please refer to the APHIS Livestock Appraisal, Indemnity, and Compensation website for further information.

Criteria for Proof of Freedom from NWS Infestation

The OIE does not provide specific criteria for proof of freedom from NWS myiasis. A declaration of NWS freedom after an infestation in the United States would be based on surveillance for NWS that includes trapping of flies and visual inspection of animals for myiasis. Depending on specific weather and seasonal conditions in the area(s) of infestation, surveillance should be carried out for 3 months past the last NWS detection, generally 3–4 life cycles (~24 days/life cycle) during an outbreak. Historically, when eradicating NWS from a previously endemic area, USDA APHIS declares an area to be "Technically Free" of NWS after 6 months without a detection and "Officially Free" after 12 months without a detection.

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ABBREVIATIONS

APHIS	Animal and Plant Health Inspection Service
CEAH	Center for Epidemiology and Animal Health
EMRS2	Emergency Management Response System 2.0
EPA	Environmental Protection Agency
FAD	foreign animal disease
FAD PReP	Foreign Animal Disease Preparedness and Response Plan
ICS	Incident Command System
IS	International Services
JIC	Joint Information Center
LPA	Legislative and Public Affairs
NAHEMS	National Animal Health Emergency Management System
NVSL	National Veterinary Services Laboratories
NWS	New World screwworm
OIE	World Organization for Animal Health
PPE	personal protective equipment
SIT	sterile insect technique
U.S.C.	Code of Laws of the United States of America
USDA	United States Department of Agriculture
VS	Veterinary Services