The Connecticut Agricultural Experiment Station

The Connecticut Agricultural Experiment Station
Putting Science to Work for Society since 1875

At a Glance

JASON C. WHITE, Ph.D., *Director*
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***Established* – 1875**
***Statutory authority* – CGS 22-79 – 22-118**
***Central office* – 123 Huntington Street, New Haven, CT 06511**
***Number of employees* – 103**
***Recurring operating expenses*:**

General Fund –	**$ 7,968,733**
Federal Funds –	**$ 3,720,675**
Other/Pass Thru –	**$ 2,476,544**
Total –	**$14,165,952**

***Organizational structure* – Administration, Analytical Chemistry, Entomology, Environmental Science and Forestry, Plant Pathology and Ecology, Valley Laboratory (Windsor, CT), Griswold Research Center (Griswold, CT).**

Mission

The mission of The Connecticut Agricultural Experiment Station is to develop, advance, and disseminate scientific knowledge, improve agricultural productivity and environmental quality, protect plants, and enhance human health and well-being through research for the benefit of Connecticut residents and the nation. Seeking solutions across a variety of disciplines for the benefit of urban, suburban, and rural communities, Station scientists remain committed to "Putting Science to Work for Society, Protecting Agriculture, Public Health and the Environment," a motto as relevant today as it was at our founding in 1875.

Statutory Responsibility

Statutory responsibilities for The Connecticut Agricultural Experiment Station (CAES) focus on insects, ticks, plants and related diseases, and the development of methods to reduce pesticide use (i.e., integrated pest management). Within available resources, field and laboratory studies are conducted, as determined by the agency's Board of Control, state residents (e.g., growers), or as requested by the General Assembly, pursuant to Connecticut General Statute (CGS Section 22-81). Scientists and technicians analyze food and other items at the request of any state agency; test hemp for THC content at the request of the Department of Agriculture; test adult use Cannabis products for THC and contaminants at the request of the Department of Consumer

Proteciton; test ticks for *Borrelia burgdorferi*, *Babesia microti*, and *Anaplasma phagocytophilum*, the infectious agents that cause Lyme disease, Babesiosis and Anaplasmosis, respectively, upon request of a citizen, state or municipal health officer or for scientific research purposes; test mosquitoes for public health threat from encephalitis viruses (CGS Sec 22-81a); oversee official control, suppression or extermination of insects or diseases, which are or threaten to become serious pests of plants; conduct research on integrated pest management (CGS Section 22-84a); inspect for diseases of honey bees, *Apis mellifera*, and register beekeepers (CGS Sections 22-89, 22-90); and survey towns for spongy moth (formerly known as gypsy moth), *Lymantria dispar*; Asian longhorned beetle, *Anoplophora glabripennis*; emerald ash borer, *Agrilus planipennis*; and other insect pests of economic or public health importance. In many instances, there are interactions with scientists or other officials in federal agencies. The Director oversees all matters pertaining to serious pests of plants and has regulatory authority (CGS Sections 22-84); responsibilities include the inspection and certification of nurseries, the registration of dealers of nursery stock, and enforcement of federal and state quarantines or regulations. Findings are reported to the public and scientific community by correspondence, lectures, media interviews, the agency's website, or published works. Emphasis is placed on submitting scientific manuscripts to peer-reviewed journals.

Station staff members provide prompt answers to routine and difficult but important agricultural, food safety, forestry, environmental, consumer protection, or public health questions by performing analyses; providing services to state residents; assisting small and large businesses, municipalities, state agencies and the scientific community; and by giving oral and written reports of research findings. Transferring new scientific information to the public and businesses is a high priority. The agency website (https://portal.ct.gov/caes) continues to be an efficient means of communicating research findings and reducing operating costs. Social media is also being used to reach out to our constituents via Facebook www.facebook.com/CT.CAES, Twitter www.twitter.com/CT_CAES, YouTube www.youtube.com/user/CTAGEXPSTATION, Instagram www.instagram.com/ct.caes, and Pinterest www.pinterest.com/caes123. The CAES also maintains a Wikipedia page http://en.wikipedia.org/wiki/Connectcut_Agricultural_Experiment_Station. Staff members gave 488 talks and interviews to civic groups and the media. Our annual open house event (the 112th) was held at our Lockwood Farm facility during the summer; more than 911 state residents had an opportunity to interact with scientists, hear presentations on scientific progress, view experimental plots and barn exhibits, hear from CT Department of Energy and Environmental Protection Commissioner Ms. Katie Dykes, and to make comments on research and outreach programs.

Public Service

Public service remains a high priority. This includes public education to reduce pesticide use and promote non-chemical management of nuisance arthropods, protection of public health, conservation of natural habitats and species, protection of agriculture, and protection of urban structures and buildings. The public offices directly serve private citizens, pest management professionals, the real estate industry, nurseries, land care businesses, arborists, health departments, other medical professionals, charities, manufacturing, the hospitality industry, schools, colleges, and universities, housing authorities, museums, municipalities, libraries, law enforcement, native American tribes, state government, the media and scientific communities within particular areas of expertise. More than 48,000 jobs in agriculture, wood-products industry, and other business sectors are supported by the services provided by CAES staff members. People

bring or mail samples or call with questions to the New Haven and Windsor facilities. Extensive contacts with state residents are particularly important for the early detection of emerging insect or plant disease problems. Global marketing of plants and plant products increases the chances for the introduction of invasive pests, such as the spotted lanternfly, *Lycorma delicatula*; Asian longhorned beetle, emerald ash borer, southern pine beetle, *Dendroctonus frontalis*; box tree moth, *Cydalima perspectalis*; beech leaf disease, *Litylenchus crenatae mccannii*; and boxwood blight, *Calonectria pseudonaviculata*. The emerald ash borer was first detected on July 16, 2012, and has subsequently spread throughout Connecticut. State regulations control the movement of wood and other regulated articles into Connecticut. Expanding its range, the southern pine beetle was detected in Connecticut on March 17, 2015, and attacks "hard" pines such as red pine (*Pinus resinosa*), Scotch pine (*Pinus sylvestris*), Austrian pine (*Pinus nigra*), and our native pitch pine (*Pinus rigida*). Box tree moth, a federally regulated pest, was intercepted in a consignment of boxwood shipped to a Connecticut garden center. Only one larva was found, but inspection efforts are ongoing.

More than 40,000 state residents received direct or remote assistance from staff members at the CAES during the past year. Station scientists also visit farms when difficult or unique problems arise and provide information to growers and the media when asked. In addition, scientists served on advisory boards and provided information to more than 150 stakeholder organizations. Employees of other state agencies, such as the Departments of Agriculture, Consumer Protection, Public Health, and Energy and Environmental Protection also requested help from Station staff members when they sent specific samples for chemical, biological, or microscopic analysis. All of these activities helped identify emerging problems, facilitated prompt and accurate responses to state residents' inquiries, and ensured safe foods and other products. CAES chemists, along with the Departments of Agriculture and Consumer Protection, have established a regulatory testing program for hemp and hemp-related products, as well as for adult use Cannabis products. Receiving comments from citizens on evaluation or survey forms at public workshops, open house events, and other agency functions helps administrators gauge the effectiveness of research programs and services and provides opportunities to realign program goals. In addition, there is an annual assessment of whether objectives listed in the agency's 5-year strategic plan are being achieved. The strategic plan and accomplishment reports are required by the USDA for funding support. Both documents are reviewed annually by federal officials.

Scientific research at the CAES involves identifying a problem, investigating existing published knowledge, and designing experiments which will provide new information to help solve the problem. This enhances Connecticut's economy and/or improves the well-being of state residents. For example, new testing procedures are developed as needed to improve analyses, particularly when samples require more sensitive and specific methods or if a novel contaminant emerges, such as PFAS (per- and polyfluoroalkyl substances, which are persistent contaminants comprised of synthetic organofluorine chemical compounds). In many instances, scientific results have national impacts.

Specific examples include the following:

Food Safety: Connecticut General Statute [Sec. 22-81(c)] directs the CAES to conduct analyses as requested by other state agencies. In addition, CAES chemists work closely with the US Food and Drug Administration (FDA) in the Food Emergency Response Network (FERN). CAES is now in its 17th year of funding ($5.1 million through 2025 under this program), with the current funding cycle concluding in 2025. Separately, CAES has completed an FDA grant that enabled

the Department of Analytical Chemistry to expand ISO 17025 Accreditation as described in the Food Safety Modernization Act (FSMA). The accredited program involves a surveillance of fresh and manufactured human foods for aflatoxins and pesticides, the later also in plant materials; results are published in Bulletins that are freely available to the public. Separately and in conjunction with the Connecticut Department of Agriculture, CAES has successfully brought animal feed chemical analysis under accreditation as described in FSMA. This project, which is measuring mycotoxin contamination in feeds, was brought under accreditation in February 2018 and has been expanded to include label guarantee analysis (fat and crude protein). These accredited programs were audited in March 2023 by the Association for Laboratory Accreditation (A2LA) and accredited was extended to 2025. These three FDA grants were recently combined in 2020 into a single cooperative agreement program, the Laboratory Flexible Funding Model (LFFM), to which the CAES applied and was awarded on September 1, 2020. Under this model, CAES analyzed 380 samples of human food for pesticide residues, heavy metals and mycotoxins, including the dried fruit, produce, apple juice, applesauce, almond beverages/milk/flour, maple syrup and baby food during the 2022-2023 fiscal year. Also, 155 animal feed samples were analyzed for mycotoxins, heavy metals, macro minerals and proximate (protein, fat, and fiber) during the period.

CAES staff is continuing work with the FDA to develop the use of liquid chromatography with high resolution mass spectrometry for the detection of natural compounds, including melatonin in supplements and vitamin B1 in animal feed. CAES chemists are also actively using this new platform in many of our state programs, including the analysis of foods and environmental samples for emerging contaminants such as PFAS. Three CAES staff members participated in the CT Interagency PFAS Task Force. The human food program (formerly Manufactured Food Regulatory Program Standards or MFRPS), which CAES conducts with the Connecticut Department of Consumer Protection and the FDA, serves as the sole chemical surveillance and monitoring effort in the state, assuring that the food supply within Connecticut is free from adulteration and contamination. During the period between July 2022 and June 2023, CAES chemists analyzed 105 food samples for pesticides, 101 samples for arsenic, and 28 consumer complaint samples for contamination with foreign material product adulteration or tampering, and off taste/smell, among other contaminants of interest. An important highlight of this work recently was the revelation of the presence of the insecticide carbofuran in imported fresh asparagus produce. Carbofuran is banned for use in the United States. This work resulted in the foreign processor of the produce being added to the "red list" attachment of FDA's Import Alert 99-05, *Detention Without Physical Examination Of Raw Agricultural Products for Pesticides*. This is a significant accomplishment requiring sample analytical packages from CAES to be reviewed by multiple regulators within the FDA. Similarly, the Animal Food program (formerly AFRPS or Animal Feed Regulatory Program Standard), conducted with the Connecticut Department of Agriculture and the FDA, serves as the sole chemical surveillance and monitoring effort in the state for pet and livestock feed. A breakdown of the numbers showed that during July 2022 and June 2023, CAES scientists analyzed 30 animal feed samples for mycotoxins, 55 samples for macro minerals, contaminants, moisture and proximate.

Pesticides, PCBs, and Fertilizers for CT DEEP and CT DoAg: Additionally, CAES staff analyze pesticides, herbicides and PCBs for the Connecticut Department of Energy and Environmental Protection (DEEP). During the period under review, 21 pesticide and herbicide,

and 58 PCB samples were analyzed. Similarly, analysis of fertilizers is conducted for the Connecticut Department of Agriculture to confirm label claims for nutrients, including nitrogen, phosphorus and potassium. During fiscal year 2022-2023, 41 fertilizer samples were analyzed.

Hemp Testing and Adult Use Cannabis Programs: The 2018 Farm Bill allowed for hemp to be grown as a crop, but prior to harvest, the crop must be tested for THC content. In conjunction with the Department of Agriculture, CAES developed a program for THC testing of both grower and inspector collected regulated samples in 2019. This program continues to support farmers in the state who are growing this crop. To this end, a total of 149 pre-harvest samples were submitted to this program during July 1, 2022, to June 30, 2023, with the CAES providing a 48-hour turnaround on analytical results so that the crop could be harvested in a timely fashion. In addition, basic research was incorporated into the program during the year to assess various varieties of hemp for compliance with THC levels throughout the growing season and the maximum potential yield of CBD. Separately, since the legalization of adult use marijuana in July 2021, there has been a need to develop a program for the analysis of marijuana products for their cannabinoid contents, as per label claims. The Station has been tasked by the Department of Consumer Protection, Drug Control Division to develop this program, which will involve testing marijuana products for THC, pesticides, mycotoxins, terpenoids, and heavy metals. During fiscal year 2022-2023, 50 samples of marijuana containing products were analyzed for THC and reported back to Drug Control.

Mosquito-Borne Disease Surveillance: Mosquito surveillance for eastern equine encephalitis (EEE) and West Nile virus (WNV) is integral to the public health response to these mosquito-transmitted diseases in Connecticut and provides an effective early warning system for citizens of the State (CGS Section 22-81a). CAES scientists and technicians monitor mosquito and encephalitis virus activity at 108 trapping sites from June through October. A total of 216,500 mosquitoes were trapped, represented by 15,279 pooled samples tested for arboviruses. West Nile virus was isolated from 185 pools, obtained from 7 species: *Culex pipiens* = 156, *Cx. restuans* = 15, *Cx. salinarius* = 2, *Ae. vexans* = 1, *Oc. japonicus* = 7, *Coquillettidia perturbans* = 1, and *Uranotaenia sapphirina* = 3; WNV isolates were obtained from 50 trapping sites in 43 towns located among all eight counties. The first WNV positive mosquitoes were collected on July 13 and the last on September 13. The majority of WNV virus activity was detected in densely populated urban and suburban regions in Fairfield, Hartford, and New Haven counties. Six human cases of WNV-associated illness were reported (4 neuroinvasive, 2 fever), with no fatalities reported. The dates of onset of symptoms ranged from August 20 to October 14. Patients ranged from 35 to 77 years of age. All human cases were locally acquired, with no out-of-state travel reported. There were no isolates of eastern equine encephalitis (EEE) made from mosquito pools and no EEE infections reported in humans or equines. Other mosquito-borne viruses isolated included: Jamestown Canyon virus = 9 isolates from 6 species (June 13-August 11), and Flanders virus = 13 isolates from 2 species (June 30-September 8). CAES continues to closely monitor the expansion in Connecticut of two exotic mosquito species from Asia, *Aedes albopictus* (Asian tiger mosquito) and *Aedes japonicus*, which are aggressive human biters and have been implicated in the transmission of several human pathogens, including dengue, chikungunya, EEE, and WNV.

Invasive Aquatic Plants: CGS Section 22-81(c) directs the CAES to perform experiments on plants. Invasive aquatic plants have been introduced to Connecticut from other parts of the world. With no natural enemies, they spread rapidly, threaten the ecological and recreational value of

Connecticut's lakes, ponds, and rivers, and have public health implications. In 2022, the Connecticut Legislature formed the Office of Aquatic Invasive Species (OAIS) at CAES. This office formalized Connecticut's commitment to protecting its waterbodies from the degradation caused by aquatic invasives. The office is an extension of the CAES Invasive Aquatic Plant Program (IAPP). Since 2004 the IAPP has completed 406 aquatic vegetation surveys of 258 lakes, ponds, and rivers. Nearly 60% contain invasive plants. Many waterbodies have been resurveyed multiple times to determine how they have changed over time.

In fiscal year 2022-2023, OAIS surveyed 17 lakes and ponds. Lake Candlewood, Connecticut's largest lake, was studied for the 14th consecutive year to determine the effects of winter drawdowns and introduced grass carp, *Ctenopharyngodon idella*, on the plant community. Surpassing over 500 acres, invasive Eurasian watermilfoil, *Myriophyllum spicatum*, posed a great concern. Prior to 2022, the acreage of Eurasian watermilfoil was directly correlated with the depth and longevity of the winter drawdown. In 2022, Eurasian watermilfoil and most other plants were gone. This was likely because the grass carp had grown to sufficient size and herbivory outpaced plant growth. Complete vegetation removal from lakes can adversely affect the entire aquatic ecosystem, particularly the fishery. OAIS is collaborating with CT DEEP to begin removing grass carp and documenting the extent of plant regrowth.

Government and local officials request CAES assistance in finding methods to protect their lakes, ponds, and rivers. We have over 20 years of research with strategic applications of herbicides to control variable watermilfoil, *Myriophyllum heterophyllum*, in Bashan Lake and have restored the lake to pre-infestation conditions. A new invasive plant called fanwort, *Cabomba caroliniana*, has now appeared in the lake and control research is underway. Hydrilla, *Hydrilla verticillate*, is a very troublesome invasive aquatic plant in many southern states. Following reports of the plant occurring in the Connecticut River, a task force of over 30 regional experts led by CAES performed surveillance from central Vermont to southern Connecticut. Nearly 1000 acres of hydrilla occurred from Agawam, MA to the Long Island Sound. The hydrilla found in the river is more robust than seen elsewhere in Connecticut. CAES, in collaboration with the University of Wisconsin-Whitewater, performed genetic tests on the Connecticut River hydrilla and found it to be a unique strain. This could mean the plant has an enhanced ability to spread, harm aquatic ecosystems, and resist current control practices. Movement of this strain to lakes and ponds is of the utmost concern. In 2023, OAIS confirmed the CT River hydrilla had moved into East Twin Lake in Salisbury, CT.

OAIS is now working formally with the United States Army Corp of Engineers to develop hydrilla management strategies including dye tests to track water movement, phenology research to quantify the plants growth characteristics, and herbicide trials to find products that are both effective and least toxic to nontarget organisms. OAIS has extensive public outreach via workshops, speaking engagements, and a comprehensive website available at https://portal.ct.gov/caes-iapp. Results are also published in scientific journals, technical reports, and CAES bulletins.

Spongy Moth (Formerly Gypsy Moth), Emerald Ash Borer, and Spotted Lanternfly: In March 2022, the Entomological Society of America changed the name of *Lymantria dispar dispar* from gypsy moth to spongy moth. In December 2021 through March 2022, a spongy moth egg mass survey was conducted on a 7-mile grid (102 sites) throughout Connecticut. Egg mass counts were high only in Litchfield County, which indicated the potential for an outbreak there in summer of 2022. Subsequently, without spring rains for the spongy moth fungus *Entomophage maimaiga* to inoculate and harm the caterpillars, approximately 46,072 acres were extensively defoliated in

the spring and early summer of 2022. Monitoring for the emerald ash borer (EAB) through *Cerceris* wasp colonies continued in 2020 and 2021 with EAB now present throughout the state. Biocontrol releases for EAB, which began in 2013 and have continued through 2021, have been successful with all three species of released parasitoids recovered within one year after release at each site. Work is ongoing to assess the impact of biocontrol on regeneration of ash in Connecticut. The first established population of the spotted lanternfly (SLF) was detected in Greenwich, CT in September 2020 and subsequently found in most of Fairfield County, New Haven County, and areas of Litchfield, Hartford, and New London counties. SLF has been intercepted many times in a wide array of agricultural and commercial products. The SLF is an exotic, invasive sap-feeding planthopper that has the potential to severely impact Connecticut's farm crops, particularly apples, grapes, and hops, as well as several tree species. The Director of The CAES established a statewide SLF quarantine in January 2022.

Honeybee Health, Wild Bee Status, and Pollination: Beekeeping in Connecticut remains strong, with 800 new beekeepers getting trained at Connecticut's various beekeeping clubs and organizations. Current registration data shows approximately 9000 colonies and 891 beekeepers registered with the Office of the State Entomologist. The most prominent cause of colony death reported by beekeepers over the winter 2022-23 was "varroa" (Varroa destructor, and its associated viruses). Although the total number of honeybee colonies in the country has remained relatively stable over the last 20 years (~2.6 million colonies according to the USDA NASS Honey Reports), loss rates remain high, indicating that beekeepers are under substantial pressure to recover from losses by creating new colonies every year. In Connecticut, overall loss rates were slightly better than last year at 54% lose. The State Bee Inspector continues to issue free Varroa mite test kits and other mite management tools to Connecticut beekeepers. Beekeepers are also given instruction on the use of these of these tools during inspections.

The Wild Bee Monitoring Program has assessed that there are 383 species of bees documented for Connecticut. Four species are currently listed as species of conservation concern in Connecticut: *Bombus affinis*, listed as a species of Special Concern in Connecticut and federally listed as an Endangered Species; *Bombus ashtoni*, listed as a species of Special Concern in CT; *Bombus terricola,* listed as Threatened in CT, and *Epeoloides pilosula,* listed as Endangered in CT. Subnational ranks were given to 124 bee species by CAES in cooperation with CT-DEEP and NatureServe. Of the 124 bee species assessed, 21 were designated S1 (critically imperiled), four were designated S1/S2, seven were designated S2 (imperiled), seven were designated SX (extirpated from Connecticut), and 37 species were designated SH (known from historical records but still hope for recovery). *Bombus terricola* (S1/S2) is still persisting in Litchfield County, with the addition of one new town occurrence in the town of Litchfield. A collaboration was formed the University of Rhode Island and CAES to evaluate the outcome of NRCS funded pollinator plantings in Rhode Island and Connecticut. CAES staff is still monitoring ecological development at a habitat enhancement project in Robbins Swamp Wildlife Management Area in Falls Village, Canaan. Spatial and movement ecology of pollinating insects is being explored to provide recommendations to create functionally connected habitat patches.

Active Tick Surveillance: Human cases of Lyme disease are prevalent, other tick-borne diseases are increasing, and new tick species are becoming more common. An active tick surveillance program was initiated in Connecticut in 2019 and continued in 2022-2023 funded in part by a grant from the Centers for Disease Control and Prevention (CDC) through the Epidemiology and

Laboratory Capacity (ELC) program at the Connecticut Department of Public Health. Ticks were collected at 40 paired publicly accessible active tick surveillance sampling locations throughout Connecticut's eight counties, and screened for five human pathogens. The sample counts presented here reflect total specimens collected during 2022. Testing of 462 female and 234 nymphal *I. scapularis* ticks collected found adult blacklegged ticks were infected with *B. burgdorferi* (54%), *B. microti* (18%), *A. phagocytophilum* (15%), *B. miyamotoi* (2%), and Powassan virus (0.5%). For nymphal blacklegged ticks, the results statewide were *B. burgdorferi* (30%), *B. microti* (12%), *A. phagocytophilum* (3%), *B. miyamotoi* (1%), and Powassan virus (0.0%). Lone star ticks are increasingly being recovered in areas of the state such as where they have not been collected before, particularly in the four southern counties.

Passive Tick Surveillance and Testing Program: Ticks and tick-borne diseases continue to pose a major health concern for Connecticut residents. In recent years, populations of native ticks have progressively increased, and established populations of invasive tick species have been discovered in the state. As a result, an increasing number of communities are at risk of exposure to ticks and tick-borne pathogens. Increases in population densities, geographic range expansion, and the ensuing potential of greater interactions with humans and wildlife highlight the importance of ticks as a public health threat. It was estimated that 90% of the U.S. human vector-borne disease cases in 2017 were those transmitted by ticks. Based on recent estimates, 476,000 people have been treated for Lyme disease annually from 2010 to 2018. With a total of 14,571 Lyme disease cases from 2010 to 2019, Connecticut is among the 14 states from which 95% of all Lyme disease cases are reported and had the 9th highest incidence rate (disease cases per 100,000 population) in 2019. Similarly, the incidence of other tick-borne diseases, including anaplasmosis and babesiosis, has also been on the rise in Connecticut. In response to the growing challenges of ticks and tick-borne diseases, the CAES has established tick and tick-borne pathogen surveillance programs. These programs provide information on the abundance, distribution, and infection of tick vectors to assess the risk of human infection and track the range expansion of exotic and invasive tick species and their associated pathogens in the state. The passive tick and tick-borne pathogen surveillance program was established in 1990 following the first discovery of Lyme disease in Connecticut and several years of research on this disease at the CAES. Within the framework of the passive surveillance program, the CAES Tick Testing Laboratory (TTL) was initially mandated to screen the blacklegged tick for evidence of infection with *Borrelia burgdorferi*, the causative agent of Lyme disease. However, in 2015, the program was expanded to include testing for *Anaplasma phagocytophilum* and *Babesia microti*, the two important tick-borne pathogens responsible for human granulocytic anaplasmosis and babesiosis, respectively. The CAES-TTL receives nearly 3,000 tick submissions each year from residents, health departments, and physician's offices; however, this number has increased to 6,000 in recent years.

The blacklegged/deer tick, *Ixodes scapularis*, is currently responsible for transmitting seven pathogens to humans, of which the three most common are *B. burgdorferi*, *B. microti*, and *A. phagocytophilum*, causing Lyme disease, babesiosis, and anaplasmosis, respectively. In 2022, the CAES-TTL received a total of 3,895 ticks submitted by residents, health departments, and physicians' offices for identification and testing. Of these, 3,048 (78.3%) were identified as *Ixodes scapularis* (blacklegged or deer tick), 584 (15.0%) as *Dermacentor variabilis* (American dog tick), 247 (6.3%) as *Amblyomma americanum* (lone star tick), and 16 (0.4%) as other tick species. Of 2,950 adult female and nymphal blacklegged ticks screened for evidence of infection with three most prevalent tick-borne pathogens, 917 (31.1%) tested positive for *B. burgdorferi*, 157 (5.3%)

for *A. phagocytophilum*, and 215 (7.3%) for *B. microti*. A total of 267 ticks were co-infected with two or more pathogens. Co-infection with more than one pathogen in ticks could lead to concurrent human infection with *B. burgdorferi* and *B. microti* or *A. phagocytophilum*, which may complicate diagnosis, lead to insufficient treatment, and increase the severity of disease.

In addition, within the framework of a passive tick surveillance program, the CAES-TTL continues to monitor the range expansion of native ticks and incursion of invasive ticks in Connecticut. On August 26, 2021, we discovered an established population of the Asian longhorned tick (*Haemaphysalis longicornis*) in New Haven County in addition to reported populations of this tick in Fairfield County in September 2020. In August 2020, we reported an established population of the Gulf Coast tick (*Amblyomma maculatum*) in Fairfield County for the first time in Connecticut and the Northeast. We also discovered establishment of the lone star tick in New Haven County in 2020 in addition to reported establishment of this tick in Fairfield county in 2019.

Grapevine Research: CAES plant pathologists continued a USDA-funded project, in collaboration with Christy Haynes from the University of Minnesota and Tania Guardado from Xotramorphic LLC, to develop nanoparticles as potential carriers of RNA molecules to control plant virus infections. Plant viruses cause an estimated $30 billion in crop loss every year worldwide. Since no viricide is available for direct control of these pathogens, there is an increasing demand for innovative and sustainable ways of managing virus epidemics in agricultural systems. Scientists at CAES have identified specific ribonucleic acid (RNA) molecules that induce RNA interference (RNAi), an evolved plant defense mechanism that we are seeking to activate or enhance, in plants and this can prime plants to successfully resist viral diseases. The scientists are now working on the last step of this multidisciplinary project, which aims to develop a delivery system for these RNA molecules to protect crops against these devastating pathogens.

Forest Health Surveys: New disease surveys have been initiated by CAES scientists to monitor the health of our forests. An invasive disease of American beech called Beech Leaf Disease (BLD), first discovered in Ohio in 2012, can kill established beech trees in as few as three years. Caused by the foliar nematode, *Litylenchus crenatae mccannii*, BLD was first identified in Connecticut by CAES scientists in a Fairfield County state park in 2019. By 2021, CAES surveys, supplemented by reports from the public (stakeholders, foresters, arborists), confirmed that BLD was established in all 8 CT counties. BLD reached unexpected and unprecedented levels of severity in the spring of 2022, repeated in 2023, when buds, harboring high numbers of overwintering nematodes, flushed few if any leaves. The CAES forest pathologist, a member of a multistate BLD Working Group that serves as a forum for collaboration in BLD monitoring and research, has developed a highly sensitive molecular diagnostic system for early detection of the nematode, and has developed a DNA fingerprinting system for the nematode, based on 17 microsatellite loci, that is being used to study numerous aspects of the epidemiology of the disease and the life cycle of the nematode. Awarded a 3-year, $450,000 grant from the International Programs Division of the US Forest Service, the forest pathologist will be co-leading trips to Japan in 2024 and 2025 to search for the origin of the BLD nematode, and to study a similar disease affecting, but not killing, the native Japanese beech. In addition, CAES scientists continue to monitor for the expected appearance of oak wilt, a devastating vascular wilt disease caused by the ascomycete fungus *Bretziella fagacearum*. Symptoms of the disease can be easily confused with other biotic and

abiotic factors that also result in crown dieback, and therefore, proper and complete diagnosis of oak wilt must be completed in the laboratory, using both traditional culturing methods as well as molecular techniques involving DNA extraction and PCR. This devastating disease typically kills oaks within a single season, and spreads rapidly via root grafts as well as vectoring by native sap beetles.

Chemical Ecology of Crop Pests: We aim to understand how pests, such as spotted wing Drosophila (SWD) and spotted lanternfly (SLF) interact with crops. At the core of this research endeavors lie a set of focused objectives: 1) Exploring Ecologically Relevant Chemical Cues: We strive to unravel chemical signals used by insects for vital functions such as sexual communication, host location, and their ability to evade natural enemies and harmful microbes. 2) Investigating Neurons and Receptors: We study the sensory neurons and receptors responsible for detecting these chemical cues toe understand how insects perceive and respond to their chemical environment. 3) Analyzing Behavioral Outputs: We investigate the behavioral outputs elicited by these cues, studying how they influence mating patterns, host selection, and defense mechanisms in insects. This knowledge forms the foundation for the development of targeted strategies to disrupt or manipulate insect behavior for pest control and integrated pest management (IPM), ultimately benefiting Connecticut's agricultural industry and food production systems.

Improvements/Achievements 2022-2023

Patents, Trademarks, and Licensing:

Statutory authority (CGS 22-82a) permits the CAES to seek patents, trademarks, and licensing agreements. License agreements have been established for a new cultivar of strawberry and four disease-resistant tobacco cultivars. Portions of the royalties are being used for operating costs and reinvesting into the crop research programs.

Online Registration:

The Experiment Station is utilizing the state’s e-licensing software program for the online registration of nursery growers, nursery dealers and beekeepers. The program also allows inspectors to enter and store regulatory inspection data in the online program. The statutorily required registration and inspection process is much more efficient for both the agency and registrant and provides the agency and state with significant cost savings.

Energy Conservation:

Efforts continue to reduce energy and other operating costs to become more efficient in performing research and delivering services to our residents. The agency has actively participated in the Governor’s Lead by Example Energy Efficiency Program over the years. The agency has converted all interior and exterior lighting to LED technology, changed over from heating oil to natural gas to heat our buildings and is in the process of replacing old drafty windows with energy efficient windows to lower heating and other operating costs. Our renovated Jenkins-Waggoner Laboratory building, which opened in January 2015, received a federal LEAD gold energy efficiency certification. Plans to renovate failing infrastructure and facilities at our Valley

Laboratory, as well as outdated CAES greenhouses, with state-of-the-art technology have been initiated.

CAES Projects:

CAES scientists were awarded a competitive $5 million, 5-year grant from the Centers for Disease Control and Prevention to investigate the impacts of the treatment of wild deer and mice on tick and pathogen presence on the heels of the successful experimental systemic treatment of deer in Norwalk for adult and nymphal lone star ticks, *Amblyomma americanum*, and in Bridgeport for adult blacklegged ticks, *Ixodes scapularis*, as well as mice in Guilford to manage juvenile blacklegged ticks. If enough animals are treated, this strategy has the potential to significantly reduce public health risk and reduce the number of cases of tick-borne disease at a town-wide level. In this first year of the study, scientists are establishing baseline tick, mouse, and pathogen presence data at 250 cooperating private, residential property owners in the Towns of Woodbridge and Bethany, CT. Thus far, over 2,000 nymphal blacklegged ticks have been sampled and shipped to CDC for pathogen testing. The mouse trapping effort is just now commencing. Treatments of mice and deer will occur in the 2024, 2025, and 2026 field seasons.

Two USDA-NIFA grants were continued by a CAES plant pathologist collaborating with CAES analytical chemists to investigate the role of nanoscale nutrients for plant health. Single applications of nanoscale sulfur (S) applied to tomato roots and foliage suppressed Fusarium wilt disease, increased yield, and had direct stimulatory effects of plant defense mechanisms. Since the popular heirloom cultivars of tomato are highly susceptible to the wilt disease, nanoscale S could offer a safe inexpensive strategy for tomato management. In addition, nanoparticles of phosphorus (P) that were embedded in bio-degradable capsules can allow P to slowly release around plant roots. The reduction in leachable P that would enter ground water and cause algal blooms has far reaching benefits in reducing costs to growers and damage to environmentally sensitive ecosystems.

A CAES forest pathologist has developed a highly sensitive molecular diagnostic system for early detection of the nematode, *L. crenatae mccannii,* that causes the Beech Leaf Disease currently threatening Connecticut's forests. Additionally, a DNA fingerprinting system based on 19 microsatellite loci has been developed for use in investigating the epidemiology of the disease. The Plant Disease Information Office responded to 159 inquiries about BLD from professionals, foresters, and homeowners. CAES scientists have formed a multistate partnership with several states to monitor the development and spread of BLD.

Plant pathologists continued to monitor and research boxwood blight, a disease caused by the fungus *Calonectria pseudonaviculata*. New to North America, the disease was first detected on boxwoods in nurseries in Connecticut in 2011 and on pachysandra in landscapes in 2012. This disease has continued to spread throughout North America. Boxwood blight was confirmed on 47 of 248 samples that were submitted to the Plant Disease Information Office. Best management practices (BMPs) in the mitigation of boxwood blight have been prepared and basic information on the fungus (including an identification guide with pictures of infected plants) are posted on the CAES website (https://portal.ct.gov/CAES/PDIO/Boxwood-Blight/Boxwood-Blight). Recent research at CAES has demonstrated effective control in landscapes and nurseries with chemical and cultural tactics and improved understanding of disease epidemiology to better model risk. Scientists are working with plant breeders to select boxwood plants resistant to the disease.

A plant pathologist at the Valley Laboratory is working on development of the Boxwood Blight Resistance Evaluation Program, which is supported by the USDA and Connecticut

Department of Agriculture. The breeding of disease-tolerant boxwood cultivars is important for reducing the incidence of boxwood blight in Connecticut while providing landscapers with cultivars that have desired traits. In order to better assess boxwood tolerance to blight among cultivars, he has collaborated with researchers across the United States to create a standard protocol for boxwood evaluations that can be conducted across institutions. This includes rating cultivars against previously tested plants to assign a scaling of 1 (most susceptible) to 5 (least susceptible). The evaluation program began in 2018 and has grown in subsequent years to include hundreds of selections from multiple breeding programs being assayed at the Valley Laboratory and at other institutions in the United States. These ratings are being used by plant breeders to assess tolerance and by nurseries to convey susceptibilities to consumers. He and his collaborators observed a very good range of responses in percent leaf infection, leaf and stem lesions per plant and percent defoliation. The very susceptible varieties such as *B. suffruticosa* were severely diseased and eventually killed. There is significant potential for the development and release of blight resistant boxwood cultivars in the future.

A CAES scientist received a USDA-NRCS subaward from the University of Rhode Island, $247,589, to monitor wild native bees in Farm Bill conservation plantings in Connecticut and Rhode Island to evaluate the efficacy of existing Farm Bill practices and to suggest practices to improve the program. Wild native bees provide an estimated $3 billion annually in pollination services in the U. S. However, native bees have declined in recent decades with habitat loss and land use intensification. The Farm Bill has invested in a range of incentive-based conservation programs on agricultural land to mitigate recent bee declines while providing multiple other benefits for agriculture and surrounding environments. However, documentation that these programs have achieved their desired outcome of increasing wild native bees in the landscape is lacking. To address this, the scientist will document changes in wild bee species richness and abundance over time, evaluate the relationship between plant diversity and bee species richness, and provide information for developing seed mixes specific to Connecticut and Rhode Island.

A CAES research team has recently established a new research focus to determine the effects of microbial predators called protists on plant growth and health. Protists influence the plant microbiome and microbial ecology They have amassed the nation's largest collection of plant-associated protists, and determined which types thrive on leaves and roots. In FY2023, they initiated a new $819,000 USDA project to identify how the plant beneficial function of bacteria in the rhizosphere is affected by protists. In the early stages of the project, the team has identified dozens of candidate rhizosphere bacteria whose survival might be enhanced by protists. By understanding how these bacteria are protected or stimulated by predators, this project can pave the way for using soil predators as a sustainable strategy toward enhancing crop growth and resilience.

CAES plant pathologists continued a USDA-funded project to understand the role of the flower microbiome in pollinator interactions, fruit development, and host resistance to the apple pathogen *Erwinia amylovora*. Recently, the scientists discovered that some flower colonizing yeast-like fungi, such as *Aureobasidium pullulans*, can induce host immunity in apple flowers. Through biochemical and molecular investigation approaches, scientists found that levels of the plant defense signal, salicylic acid, rise in flowers treated with the fungi, which resulted in excellent disease control efficacy against fire blight. Using cultural dependent and cultural independent methods, the composition, diversity, dynamics of these flower-colonizing yeasts on flowers have been determined. Scientists also found that such yeasts not only induce plant immune response in apples, but also in *Arabidopsis*, a model plant that has been used for understanding

plant-microbe interactions. A new screening method using a GUS reporter in *Arabidopsis* has been developed and now has been used to identify more yeasts that induce plant immunity. This line of research was recently selected for funding by USDA with $997,480 to further identify yeasts that induce plant immune response and to characterize its mechanism. Meanwhile, scientists are exploring the most effective, fruit safe control protocols for organic apple growers in eastern U.S. by using the existing yeast-based biocontrol products. Outreach activities include promoting and educating about the organic disease management practices to organic growers and conventional growers who want to transit into organic apple production.

Plant pathologists have made significant inroads into demonstrating a role for nanoparticles of copper and silicon in suppression of plant diseases of asparagus, eggplants, pumpkins, soybeans, strawberries, watermelon, and many ornamental plants. This novel strategy utilizes host nutrition of young plants to enhance late season disease suppression. CAES has hosted scientists and students from several domestic and international universities to conduct novel and innovative studies to understand how minimal amounts of nanoscale products can suppress disease, and enhance drought and salinity tolerance in plants, thereby increasing yields at significantly reduced economic and environmental cost.

CAES scientists are increasing our knowledge and understanding of the appropriate selection, location, and maintenance of trees in urban and suburban spaces to increase utility reliability, public safety, public health, environmental benefits, and reduce costs and risks for municipalities. Roadside trees and branches that fall during severe weather often cause extended power outages and extensive road blockages. CAES foresters are collaborating with utilities, environmental groups, landowners, and other state agencies to develop practical, cost-effective protocols to proactively foster healthy, storm-resistant roadside forests by integrating silvicultural and arboricultural practices. Ten demonstration areas including over 4,300 trees have been established throughout Connecticut. Lessons learned on tree selection and coordination from implementation at nine areas are being incorporated into treatments scheduled at the remaining sites. In addition, as part of a new program CAES scientists are testing the usability of ecophysiological and molecular markers for tree stress detection. This information will be used to develop diagnostic and management strategies to identify weakened trees, to reduce tree stress and to support tree health in urban environments. Advances in Christmas tree integrated pest management and transplant fertilization techniques now allow trees to be harvested one full year earlier, reducing inputs and increasing profits by about 10 percent.

Scientists in the Department of Environmental Science and Forestry have made progress in several areas. Staff scientists are conducting experiments to investigate the mechanisms driving formation and disruption of associations between mineral and organic constituents in the soil. These associations are critical for soil carbon sequestration and overall soil quality and health. Using a combination of stable isotopes and synchrotron radiation spectroscopy, staff scientists have shown that plant roots promote new associations and increase carbon content in the vicinity of roots, while the removal of roots can rapidly reverse this process. These findings highlight the importance for maintaining living roots in the soil to promote soil health and increase carbon stocks. In the Environmental Chemistry program, scientists continued field trials using hemp for phytoremediation of PFAS in collaboration with the Mi'kmaq Nation (Aroostook County, Maine) and other community members, and tested several different varieties of hemp. Variety ChinMa far outperformed the other options. New collaborations were established with the Liang lab at SUNY Albany and the Jaffe lab at Princeton University to investigate degradation of PFAS in plants used for phytoremediation. Additionally, a new method was published for detecting PFAS in dried and

whole blood samples. Work has continued detecting new and emerging contaminants in wastewater and related matrices. A sampling campaign was completed where paired wastewater samples were collected during wet and dry weather to examine the effects of stormwater on contaminants in effluent from the East Shore Water Pollution Abatement Facility in New Haven.

Scientists in the Department of Environmental Science and Forestry are monitoring urban tree health for targeted management in a changing climate. Urban trees provide a critical role in improving the habitability of towns and cities in Connecticut where 86% of the population lives in urban areas. Results from a CAES urban tree survey in New Haven in 2020 indicate that urban maple mortality in New Haven has increased from 2010, but the causal factors are unclear. CAES scientists are currently quantifying the impact of neighborhood temperature, drought, soil compaction, and soil properties on urban maple health. The results from this project can be used to target tree care on sites with high tree stress, and to predict which trees are at higher risk of mortality. During the field work, the involved CAES scientists have discussed the importance of urban tree health with more than 50 members of the public. Also, Connecticut forests are changing in response to multiple interacting stressors, including invasive species and the overabundance of white-tailed deer. Forest ecologists at CAES are studying how these changes will affect the future composition of Connecticut's forests by monitoring patterns in tree regeneration in response to changing forest disturbance regimes. For instance, dieback and mortality of ash trees from Emerald Ash borer can facilitate the establishment and spread of understory invasive plants, which thrive on nutrient-rich sites where ash trees are typically found. Scientists at CAES are studying whether invasive plant removal treatments can increase the growth and diversity of regenerating trees while also enhancing forest carbon sequestration. Advances are being made in urban agriculture as well, where vegetable yields from small container plantings as well as cut-and-come-again harvesting of greens are being quantified and investigated.

In a study by the Department of Entomology, funded by the Centers for Disease Control and Prevention, CAES scientists evaluated the efficacy of two novel chemical lures to improve collection of mosquitoes that are poorly captured by standard trapping methods. The new trap lures enhanced collection of *Aedes triseriatus* and *Aedes japonicus* mosquitoes, and testing of these collections indicated the entomological risk of La Crosse virus is much higher in Connecticut than previously thought. Historically, La Crosse virus is only rarely detected in this region, but there are suspicions that the main vector species (*Ae. triseriatus*) is systematically under-sampled by conventional trapping methods. In laboratory experiments, scientists from the Department of Entomology have discovered that when mosquitoes from diverse genera are provided a non-infectious bloodmeal after the initial infectious bloodmeal significantly increased transport of a virus (West Nile virus, La Crosse virus, or Mayaro virus) from the gut to the salivary glands, greatly increasing the insect's ability to transmit that virus to its host, and may help explain the explosive epidemic potential of viruses transmitted by mosquitoes. These data are predicated on the mosquitoes acquiring a full second blood meal; however, in nature mosquitoes often take partial blood meals. Further research has demonstrated even partial blood meals can facilitate this increased transport. Scientists in the department, using their recently developed axenic (bacterial-free) mosquito model, have demonstrated that not only the presence/ absence of bacteria can alter mosquito susceptibility to dengue and chikungunya virus, but that the composition of the microbiome can greatly impact susceptibility.

Scientists from the Entomology Department partnered with the CDC and Cornell University to address insecticide resistance in local *Culex pipiens* mosquitos, main vector of West Nile virus in the region. Insecticide resistance compromises the effectiveness of mosquito control

in the Northeast; CAES scientists are taking a comprehensive approach at the problem by characterizing resistance in local populations, determining their likelihood to develop (or loose) insecticide resistance, and dissecting the genetic components responsible for insecticide resistance. A scientist from the Entomology Department is tracking and studying the movement of invasive mosquitoes to naïve areas in collaboration with local, national, and international mosquito control districts and academic institutions. Mosquitos involved in the transmission of historically tropical diseases such dengue and Zika are shifting their distribution northward due to trade, human migration, and climate change. Using genetic markers and reference panels, scientists determined the source of recent introductions of the yellow fever mosquito in the USA. Likewise, local mosquitoes involved in the transmission of West Nile virus and Easter Equine Encephalitis are moving north as the environment becomes more permissive, CAES scientists are taking a proactive approach by investigating the movement patterns of these mosquito populations and their relationship to the environment.

Scientists at the Valley Laboratory have collaborated with arborists to identify chemical controls of the nematode pathogen causing beech leaf disease, a new disease first observed in the United States about 20 years ago and in Connecticut two years ago. They are conducting research to determine the best way and time to use these tactics to control the disease.

The CAES reaffirms its continuing policy of commitment to affirmative action and equal opportunity employment as immediate and necessary objectives and relies solely on merit and accomplishment in all aspects of the employment process and research programs. The Plant Health Fellows program is a federally funded summer internship program initiated by CAES scientists and professors at Southern Connecticut State University. The program has provided mentored research experiences and career development training to 49 students since 2017, roughly 60% of whom are first generation college students or underrepresented minorities, and the majority of whom are from Connecticut. Long-term tracking and evaluations indicate that the program has been very effective in preparing students for the agricultural workforce, with alumni going on to enter federal, industry, and academic agricultural and forestry positions. CAES and SCSU received $500,000 in additional USDA funding last year to extend the program through 2026, training over 40 additional students.

CAES scientists were part of an NSF grant that funded a Summer Undergraduate Research Experience program where undergraduates gained valuable experience working in CAES laboratories. The interns included 1 minority male and 1 minority female. The goals of mentoring programs are to promote interest in science and provide specialized training. Station scientists also participated remotely as judges in science fairs in New Haven and Hamden. Through these and other direct interactions, staff encouraged high school students to further their science education. CAES provided diversity training or training refreshers to 94 employees in FY2022, and is also participating in the University of Connecticut's Employee Assistance Program. The agency's goals in awarding contracts to small businesses and minority business enterprises were exceeded.

Scientists in the Department of Entomology have established a local collaboration with Yale University, State Schools, and Albertus Magnus College to train the next generation of vector-born disease experts by offering short and long-term internships and rotations within our laboratories.

A CAES Chemical Ecologist has been granted an award of $616,120 from the National Institutes of Health (NIH). The purpose of this grant is to fund an in-depth research project that aims to unravel the mechanisms by which the spotted wing Drosophila locates and targets crop fruits. The spotted wing Drosophila, an invasive fruit fly species, poses a significant threat to

agricultural crops, particularly fruits such as berries, cherries, and grapes. Unlike other fruit flies, this species possesses a unique ability to puncture unripe fruits, causing substantial damage and rendering them unsuitable for consumption or marketability. Understanding the mechanisms employed by this pest to locate and infest crop fruits is crucial for developing effective strategies to mitigate their impact on agricultural production.

Information Reported as Required by State Statute

Scientists and technicians performed chemical, seed, soil, fertilizer, pesticide, animal feed, mosquito, and tick tests; answered inquiries; conducted plant, nursery, and bee inspections; and surveyed for the spongy moth and other insect pests as listed below.

Service or Test Number	**2022-2023**
Inquiries answered (all departments)	22,181
Field visits and diagnostic tests	203
Nematode diagnostics	127
Soil Tests Completed	
New Haven	7,631
Windsor	4,831
Samples Tested	
Department of Agriculture	348
Department of Consumer Protection (DCP)	460
Department of Energy and Environmental Protection (DEEP)	83
CAES Departments	181
FDA, Municipal Health Departments, Cities/Towns, and Misc. Foundations	35
UConn Cooperative Extension	17
University research collaborations	2752
Seed samples tested (vegetable, lawn, field crop)	340
Consumer plant samples tested	1,547
Boxwood blight samples	248
Nursery and Seed Inspections	
Number of registered nurseries	190
Phytosanitary certificates issues	500
Nursery stock containers and bare root	46,697
Nursery inspections	142
Tobacco (bales, boxes, bundles, and cartons)	97,460
Permits to move homeowner plants out of state	8
Seed (cartons and bags)	366
Acres of nursery stock inspected	5,000
Spongy Moth Survey	
Forest acres surveyed for spongy moth by air	1.8 million
Bee Inspection	
Beekeepers registered	896
Beehives examined for mites and foulbrood	1,115

Tick Identification and Testing – Active Surveillance	
Ticks identified	3,206
Ticks tested for human pathogens	1,010
Ticks infected with *Borrelia burgdorferi* (Lyme disease)	378 (37.4%)
Ticks infected with *Babesia microti*	130 (12.9%)
Ticks infected with *Anaplasma phagocytophilum*	95 (9.4%)
Tick Identification and Testing – Passive Surveillance	
Ticks identified	3,895
Ticks tested for human pathogens	2,950
Ticks infected with *Borrelia burgdorferi* (Lyme disease)	917 (31.1%)
Ticks infected with *Babesia microti*	215 (7.3%)
Ticks infected with *Anaplasma phagocytophilum*	157 (5.3%)
Tick Identification and Testing – Other CDC-Funded Projects*	
Ticks identified	3,901
Mosquito Testing	
Mosquitoes trapped, identified, and tested for EEE, West Nile, and other encephalitis viruses	216,500
Number of trapping sites	108

***** = Scott Williams' research on CDC-funded projects sampled and identified 3,901 ticks in FY 2022-2023 that are in addition to the Active and Passive Tick programs.