SALT LAKE CITY MOSQUITO ABATEMENT DISTRICT

Executive Director's Report

August 2025

1. **Personnel:**

Personnel	
Staff	Seasonal
12	37

Type of Work	2025	3 - Year Average
Adulticiding	39.00	87.58
Wetlands / Rural	889.75	812.58
Fish Culture	265.25	162.92
Catch Basins / Gutters	710.50	615.33
Tree Holes	163.00	212.33
Prison	9.75	46.33
Service Request	19.00	26.58
Traps	278.75	450.92
Laboratory	772.50	1,075.83
Office / Administration	931.50	895.92
Equipment Maintenance	311.25	326.83
Facility Maintenance	468.00	256.50
Training	11.00	48.75
Education	300.75	162.58
Unmanned Aerial System	345.25	294.25
CSU Grant	867.50	146.25
Other Work - U of U Research	0.00	0.00
Other / Errands	194.25	332.33
Comp. Time Used	66.00	76.92
Vacation	71.00	72.50
Additional Hours	0.00	32.00
Holidays	0.00	0.00
Sick Leave	32.00	43.92
Total	**6,746.00**	**6,179.15**

2. Office/Lab/Shop Activities:

Ary Faraji, Executive Director

- Executive Director Faraji completed the 2025 Utah Pesticide Discharge Eliminations Systems permitting on 1 August 2025.
- The District hosted Andrew Rivera in the dormitories on 4-8 August 2025. Andrew was working in collaboration with our staff on insecticide resistance monitoring to Spinosad formulations in order to ensure continuing efficacy.
- The District hosted Heather Andreson from Utah Association of Specials Districts and friends on 4 August 2025.
- Aerial trials with Dibrom were conducted on 5 August 2025.
- Executive Director Faraji and staff met with Dr. Spiros Mourelatos from Ecodevelopment Greece regarding collaborative projects on 6 August 2025.
- The annual MosquitoThon between SLCMAD and MAD-Davis was held on 8 August 2025 at the District.
- The District hosted Joshua Jackson, MS student from Kansas State University, on 10-15 August 2025. Josh shadowed our control and surveillance teams to learn about vector surveillance and control techniques.
- Executive Director Faraji and CFO Fairbanks met with Curtis Tonks from the Utah Local Governments Trust on 12 August 2025.
- Aerial trials with Remoa Tris were conducted on 12 August 2025.
- Executive Director Faraji attended the bi-weekly meetings of the Rockies and High Plains Vector Borne Center of Excellence on 13 August 2025.
- Executive Director Faraji attended the monthly meetings of the Utah Mosquito Abatement Association on 13 August 2025.
- Executive Director Faraji conducted a bi-weekly meeting for the Medical, Urban, and Veterinary Entomology section of the Entomological Society of America on 19 August 2025.
- Executive Director Faraji attended the bi-weekly meetings of the Rockies and High Plains Vector Borne Center of Excellence on 27 August 2025.

Aleta Fairbanks, CFO

- 12 August 2025 – Michele and I met with Curtis Tonks and Ryan Hatch, with the Utah Local Governments Trust, to discuss the Trust Integrity Promise program.
- 22 August 2025 – Attended "Understanding Your Tier 1 Pension" Webinar with Robert Goodick.
- 22 August 2025 – Attended "Understanding Your Tier 2 Hybrid Pension" Webinar with Robert Goodick.

Greg White, Assistant Director

Weekly Construction Meetings plus other construction meetings
Mosquitothon planning, setup and running – 8/6 to 8/8
RaHP VEC biweekly calls – 8/13
Work on ULV spray tunnel with intern – multiple days a week through 8/15
Help collect Cx tarsalis for Neil Vickers lab – 8/8
Coordinate and visit with Norah Saarman and her students – 8/19, 8/27
Write report on Western IPM grant – 8/25

Arrange TissueLyser Demo with Qiagen – 8/13

Meet with Carroll-Loye Biological Research – 8/11
UMAA Mangers Meeting – 8/13

Chris Bibbs, Laboratory Director

Aug 1	Drafting dragonfly study methods, data analysis, results, and figures
Aug 4	Andrew Rivera visit and natular resistance testing; literature review, introduction, and discussion draft for dragonfly manuscript
Aug 5	Finishing methods and first draft of Exhale mycelium paper; methoprene study 6727 final report for CLS; RaHP VEC Aerial trial 7
Aug 6	Meeting w/ Spiros (Greece); meeting w/ Haley Johns (Valent) on ADrop; meeting w/ Dan Killingsworth (CLS)
Aug 7	Compiling methoprene data and final report data for CLS;
Aug 8	Colony starters for Andrew Rivera; MosquitoThon
Aug 11	Orientation for Josh Jackson (USDA, surveillance shadowing); call w/ Carroll-Lloye biological on yeast encapsulated larvicide testing; Intern evaluation for Liza (BYU); review for AJTMH
Aug 12	Surveillance training w/ Josh Jackson; RaHP VEC Aerial trial 8
Aug 13	WNv testing training w/ Josh Jackson; emergence container fabrication w/ Andrew;
Aug 14	SRI student scheduling for Fall 2025; treehole data review and manuscript editing w/ Amy; Fox News Ch13 interview
Aug 15	Khai exit presentation
Aug 18	CDPHE orientation for surveillance and facility tour; SRI schedule planning; Emily/Thad visit (Saarman lab)
Aug 19	Stats w/ Sage; meeting w/ Saarmon lab; training CDPHE visitors on surveillance processing and data management
Aug 20	WNV extraction training w/ CDPHE visitors; stats w/ Sage; revising Exhale manuscript and submitting to JME
Aug 21	Intern exit presentations (Sage, Avery, Rebecca); SRI stream leader meeting
Aug 22	Sydney Farris and Clara Morris (SRI) semester start; Circadian rhythm project orientation for new students; PLoS One manuscript review
Aug 26	Kaden Bergher (SRI) semester start
Aug 29	Barricor testing project orientation for Natalee and Kaden

Michele Rehbein, Education Specialist

- Dr. Rehbein sent out the SLCMAD August 2025 issue 5 newsletter on 1 August.
- Dr. Rehbein gave Heather Anderson and her five nieces a tour of the facility on 4 August.
- Dr. Rehbein submitted Year 1 and Year 2 reports for the Utah Pollinator Habitat Program on 5 August.
- Dr. Rehbein worked on writing a grant proposal for the National Endowment for the Humanities (NEH) Public Humanities Projects for a planning project (to be proposed for the SLCMAD museum).
- Dr. Rehbein and Evelyn Acosta went to King’s Peak Coffee Roasters to pick up burlap coffee bags for the pollinator garden walkway on 7 August.
- Dr. Rehbein helped prepare Evelyn Acosta and Julia Shroyer for the Partners in the Park event on 12 August.
- Dr. Rehbein coordinated Fox 13 News interview on 14 August.

- Dr. Rehbein sent out the SLCMAD August 2025 issue 6 newsletter on 15 August.
- Erin Cadwalader from EnSoc asked Dr. Rehbein on 15 August to be a PACT mentor again this year.
- Dr. Rehbein, Brad Sorensen, and Andrew Dewsnup visited the USCF to complete plumbing the fish tanks for the least chub program on 25 August.

- Dr. Rehbein attended an AMCA national campaign committee meeting on 7 August.
- Dr. Rehbein conducted exit interviews for Nadia Greding, Brooklyn Rodgers, Dylan Hinson, Ian White, and Eliott on 8 August.
- Dr. Rehbein participated in BugFest at the NHMU with Evelyn Acosta, Danny Glover, and Thomas Widmer on 9-10 August.
- Dr. Rehbein had a phone called with Yevgeny Pevzner from Kearns Junior High about setting up in-class visits and a field trip to SLCMAD for October on 11 August.
- Dr. Rehbein attended a meeting with Aleta Fairbanks and Curtis Tonks from ULGT on 12 August.
- Dr. Rehbein met with Rachel Lam, Wisam Khudhair, and Keetland at the Hartland Partnership Center on 14 August to discuss collaborating and having a consistent education program at their youth center from SLCMAD.
- Dr. Rehbein started discussions with Sharon Kerr from the Guadalupe Center on 21 August to conduct outreach/STEM education with students this fall.
- Dr. Rehbein, Thomas Widmer, and Avery Derr tabled at Healthy Start West Valley on 22 August.

Nate Byers, Molecular Biologist

Installed droplet counting software on scope
Concluded intern research and debriefed the participants
Maintained mosquito and virus surveillance despite losing most of the lab crew
Coordinated the final two 2025 RaHPVec Trials

Assisted Andrew Rivera, Nate and Clarke staff 8/4-8/8
Met with Dan Killingsworth 8/6
Met with Valent technical staff virtually about microscope 8/6
Met with Tuttnauer Autoclave reps, obtained quote 8/7
Assisted Jordan Mandli Metropolitan MCD with PCR by video call 8/11
Hosted Josh Jackson (USDA, Constaedt Lab) 8/11-8/15
Called Duncan Blake of DAI scientific about Consolidated autoclaves, obtained quote 8/12
Attended the Utah arbovirus call 8/14
Hosted Cassie and Dr. Chris Roundy of Colorado DPHE 8/18 – 8/22
Met with Dr. Norah Saarman (USU) and students to discuss ongoing collaborative projects 8/19

Brad Sorensen, Aerial Operations Supervisor

Worked on Phase 2
Progress is slow on Hangar due to manufacturing/procurement issues
Lab and Cage buildings progressing great
Site work is progressing
Worked on Aerial Operations Program Future Planning
Airbus build is progressing great

Most equipment and electronics are installed
Aircraft is progressing through paint portion of build
September paint will be finished and moved to shop for completion
Continued to help build fish tanks at prison with Andrew
Worked on Airport Tower Adulticide Coordination
UAS program treated an additional 1,133 Acres putting us on track to surpass last season's acreage

8/6 – Airbus wACS Connectivity Meeting
8/6 – OAC Meeting
8/11 – Airbus Tech Rep (Tom Brown) Visit and Tour of SLCMAD Facility
8/13 – Virtual Meeting on Hangar timeline issue with Owners rep and Architects
8/13 – OAC Meeting and Hangar discussion
8/20 – Meeting with Bryan Rasmussen from SLC Airport Tower
8/20 – OAC Meeting
8/25 – Worked on Prison Fish Tank Install with Andrew
8/25 – Meeting with Keith Cave of Airbus about Helicopter Delivery Questions
8/27 – OAC Meeting

Andrew Dewsnup, IT/GIS Specialist
Met with Ontario Refrigeration on Aug 5th.
Finished up the prison tanks on Aug 25th.

Jason Hardman, Rural Field Supervisor
Field work, tour with Chris and Cassie, and adulticiding

Quinten Salt, Urban Field Supervisor
Build new fish dip nets
Train skylar on new state and flat bottom boat
Begin barrier spraying areas for adult control
ULV spray Air National Guard Base
Show Josh Jackson from USDA the urban programs and also take him out on the boat

3. Field Data:

Control:

ACRES TREATED

	Adulticide		**Larvicide**		
	Ground	Aerial	Ground	Aerial	**Total**
August's Total	845.00	66,560.00	1,274.16	3,192.00	71,871.16
August's 3 Year Avg.	597.98	32,722.67	844.93	1,144.33	35,309.91

Service Requests:

MOSQUITO SERVICE OPPORTUNITIES RECEIVED BY MONTH

	March	April	May	June	July	Aug.	Sept.	Oct.	Total
2025	5	11	40	44	22	25			147
3-Year Avg.	4.00	11.33	26.33	40.00	34.00	19.33	9.67	20.33	164.99

Inspection and Surveillance:

Larval Collections		
Species	**July**	**5-Year Average**
Ae. campestris	0	0.0
Ae. dorsalis	78	58.6
Ae. fitchii	0	0.0
Ae. increpitus	0	0.4
Ae. nigromaculis	0	0.2
Ae. niphadopsis	0	0.0
Ae. sierrensis	0	0.0
Ae. melanimon	0	0.0
Ae. varipalpus	0	0.0
Ae. vexans	0	1.8
Cx. erythrothorax	15	4.0
Cx. pipiens	23	22.8
Cx. tarsalis	178	120.2
Cx. impatiens	0	0.0
Cs. incidens	4	9.4
Cs. inornata	28	9.4
An. freeborni	2	0.4
Total	**328**	**227.2**

4. Weather:

August's weather was warmer (by 0.3º) and wetter (by 0.18") than normal.

Temperature:

	Monthly Avg.	Normal	High	Low
July	82.9º	81.1º	100º	63 º
August	79.4º	79.1º	102º	57 º

https://www.weather.gov/wrh/Climate?wfo=slc

Precipitation:

	Total for Month	Normal	Most in 24 hours
July	0.18”	0.49”	0.16” on 4th
August	0.76”	0.58”	0.64” on 27th

https://www.weather.gov/wrh/Climate?wfo=slc

Great Salt Lake (elevation in feet above sea level):

	Jul 1	Aug 1	Sep 1
2024	4,194.5	4,193.6	4,192.9
2025	4,192.7	4,192.0	4,191.5

ANNOUNCEMENTS

For mosquito abatement districts: Reminder that it is a requirement for MADs that are *new* to testing to please send the first 3 positives of the season to UPHL for confirmatory testing. If MADs are *not new* to testing, it is recommended that they send their first 3 positive pools to UPHL for confirmatory testing, but this is *optional*. UPHL does not charge for the pools that they perform confirmatory tests on.

Method for reporting mosquito data: We are highly recommending MADs start or continue to use VectorSurv this year to record mosquito data. When setting up a new account in VectorSurv, please work with Kacy Nowak (knowak@utah.gov) to share access to your mosquito testing data so that she can pull data from there for weekly and annual reports. If you won't be able to use a VectorSurv account this season, please enter your mosquito pool testing data into this spreadsheet. Request access to your districts tab if you don't already have access by emailing Kacy. Please enter weekly data by end of day Friday.

Community outreach and educational materials: For local health departments and other partners interested in community outreach and education, here are a few links to resources:

- Get rid of mosquitoes at home English and Spanish
- Mosquito Bite Prevention Door Hanger English and Spanish
- Mosquito Bite Prevention for Travelers English and Spanish
- Mosquito Bite Prevention in the U.S. English and Spanish
- CDC Fight the Bite Campaign Website
- EPA Find the Repellent that is Right for You Website
- DHHS educational materials
- DHHS WNV fact sheet

Surveillance Update

WEST NILE VIRUS (WNV)

2024

National:
As of January 3, 2025, a total of 1,466 cases of West Nile virus disease in people have been reported to CDC [in the US] in 2024. Of these, 1,063 (72.5%) were classified as neuroinvasive disease (such as meningitis or encephalitis).
Source: https://www.cdc.gov/west-nile-virus/data-maps/current-year-data.html

Utah:
In 2024, 319 positive West Nile Virus (WNV) mosquito pools (3.1% positivity rate) have been reported across the state of Utah by Box Elder, Cache, Davis, Duchesne, Grand, Millard, Salt Lake, Tooele, Uintah, Utah, Washington, and Weber counties. The Utah Public Health Laboratory and mosquito abatement laboratories tested a total of 10,344 mosquito pools. 14 human cases have been confirmed to date in Bear River, Davis County, Utah County, and Weber-Morgan health jurisdictions with all 14 cases classified as neuro-invasive (100%). One human death was reported due to West Nile Virus. 16 horses tested positive in Box Elder (2), Millard (1), Tooele (2), Utah (6), and Weber (5).

2025

National 2025:
As of September 9, 2025, there have been 771 WNV cases reported (490 neuroinvasive cases) and 205 presumptive viremic blood donors. 38 deaths due to WNV have been reported.

Utah 2025:
As of September 6, 2025, 401 WNV mosquito pools have been reported from Box Elder (20), Cache (34), Davis (52), Duchesne (3), Juab (4), Moab (1), Salt Lake (185), Tooele (4), Uintah (13), Utah (84), and Weber (1) counties. 27 positive human WNV cases have been reported out of Bear River (8), Davis County (3), Salt Lake County (4), TriCounty (1), and Utah County (11) health jurisdictions. The first case was reported on 8/8/25 out of Salt Lake County HD. Additionally, 11 positive WNV horses have been reported from Cache (3), Davis (1), Utah (5), and Weber (2) counties, along with 2 horses pending location information. The first positive horse was reported out of Utah County on 8/6/2025.

Utah Surveillance Updates

Mosquito Abatement

Updates on current mosquito activity and planned control efforts

- Bluff – Malia Collins
  - No updates
- Box Elder – Tyson Packer
  - *Culex tarsalis* numbers are declining
  - *Aedes dorsalis* numbers have increased
  - *Anopheles freeborni* are low
- Davis – Elizabeth Hart
  - *Culex tarsalis* are starting to drop
  - *Culex pipiens* increasing
    - *Culex pipiens* are where the positives have been coming from
  - *Anopheles freeborni* are starting to drop
- Emery – Cory Worwood
  - No updates
- Magna – Ryan Lusty
  - *Culex tarsalis* is still pretty high
  - *Culex pipiens* have dropped
  - *Aedes dorsalis* are spiking with the rain
  - 4 more positive pools – 2 WNV and 2 SLE
- Moab – Ben Wanamaker
  - Mosquito numbers are low compared to historic numbers
  - First WNV positive pool of season – weak positive just on threshold
  - Another that tested positive by manufacturer threshold, but so low that considering it inconclusive (but treating as if it was positive)
  - Found one additional *Aedes aegypti*
  - *Anopheles* are pretty much nonexistent
- Salt Lake – Nate Byers, Greg White
  - *Culex pipiens* are declining, right on historical average
  - *Culex tarsalis* are high – plateaued in July and have stayed high
  - Lots of WNV positive pools – 129 total
    - 109 WNV
    - 20 SLE
    - Even mix of *Culex tarsalis* and *Culex pipiens*
  - No *Aedes aegypti*
  - *Anopheles* have been low all season
- South Salt Lake – Dan McBride
  - Pretty sharp decline in mosquito numbers

- More SLE and WNV positive
  - CDC confirmed SLE pools
- Have gotten up to 40-50% positivity in traps
- No *Anopheles* or *Aedes aegypti*

- Southwest – Sean Amodt
  - No WNV positive pools, but catching up on testing
  - *Culex tarsalis* numbers have been the highest they have been all year
  - Lots of *Aedes aegypti* service requests
  - *Anopheles* numbers have been normal
- Tooele – Scott Bradshaw
  - Sharp decline in *Culex tarsalis*
  - Floodwater mosquitos have increased
    - Both *Aedes dorsalis* and *Aedes vexans*
  - High number of *Culex pipiens*
  - No *Anopheles freeborni*
- Utah County – Jason Bird and Andrew Blackburn
  - Mosquito numbers are declining this past week
  - WNV percent positivity has stayed about the same (about 30%)
  - No *Aedes aegypti* or *Anopheles*
- Uintah – Danny Rasmussen and Trevor
  - *Culex tarsalis* numbers are low and continue to decrease
  - 1 WNV positive pool last week
  - No *Aedes aegypti*
  - Very few *Anopheles freeborni*
- Weber – Mike
  - Traps are at a record for the season
  - More WNV positive pools, total of 17 for the season

Lab partners

Presumptive viremic donor updates or other relevant lab activity

- Utah Public Health Laboratory (UPHL) – Kim Christensen
  - No updates

- ARUP – Katy Reeder
  - No updates

Local Health Departments – Human Surveillance

Human activity, education, prevention

- Bear River – Angie White
  - No updates
- Central – Louise Saw
  - Put out press release when WNV mosquito pool was detected
- Davis – Sarah Willardson
  - Nothing new this week
    - Still at 3 WNV cases
      - 2 neuroinvasive
      - 2 hospitalized
      - 2 deaths
  - Also put out a press release
- Salt Lake – Tasha Cope
  - 1 recent WNV case for a total of 4
    - Neuroinvasive
    - Pt is reportedly doing well now
- Tisheena
  - No updates
- TriCounty – Cyndie Mattinson
  - First WNV case of the year
    - Currently hospitalized
    - Neuroinvasive
    - Pending interview
- Weber-Morgan – Amy Carter
  - One suspect WNV case that is pending information
  - Have been doing social media and website messaging for WNV prevention
- Utah Navajo Health Systems – Shawn Begay
  - No updates

<u>Additional partner updates</u>

Utah Birth Defects, Emergency Preparedness, Mother to Baby, PIO, AUCH, etc

- Tracey Aviary- Julie DeCubellis
  - No updates
- PIO – Charla Haley and Brielle Meyers
  - Nothing planned to go out right now, but should do an end of season wrap-up press release
- Emergency Preparedness – Lanette Sorensen
  - Not on call

Discussion topics

- Find DHHS arboviral weekly reports at: https://epi.utah.gov/west-nile-virus-reports/

Next meeting on Thursday September 25, 2025 2:30pm-3:15pm

Journal of the American Mosquito Control Association, 41(3):143–150, 2025

DO IT YOURSELF: EVALUATING COMMERCIAL CO_2 REGULATORS FOR SURVEILLANCE NETWORKS USING PRESSURIZED CYLINDERS

JAROM BRANDOW,[1,2,4] KELSEY A. FAIRBANKS,[1,4] M. ANDREW DEWSNUP,[1] GREGORY S. WHITE,[1] NATHANIEL M. BYERS,[1] ARY FARAJI[1,2] AND CHRISTOPHER S. BIBBS[1,3]

ABSTRACT. Carbon dioxide (CO_2) is a universal attractant for monitoring blood-feeding insects, such as mosquitoes. Although dry ice has been the historical benchmark, compressed gas cylinders can be used in tandem with a gas regulator to control CO_2 flow rate more precisely. The literature is sparse on best practices regarding how to choose or test regulators. We evaluated four commercially available regulator types from beverage and welding suppliers and compared them to a previously tested regulator used at the Salt Lake City Mosquito Abatement District (SLCMAD). Using environmental chambers, we simulated both the temperature drop of spring/fall or summer nights down to 9°C, as well as daytime highs within the seasonal expectations of the central ranges of Utah, up to 42°C. Two regulators failed to maintain calibrations in these screenings. The remainder were vetted by acquiring duplicates and rerunning the simulations with inverted temperature exposures, starting low and heating up, instead of starting warm and cooling down in the first tests. The remaining regulators were tested in the field for validation. After 56 trap cycles with 15 duplicates of three regulator models, general failure rates in real applications all decreased below 5% of total uses. The preexisting regulator used by SLCMAD performed well in simulations, but had double the failure rate of the other screened models. We use this study to highlight the scarcity and importance of conducting evaluations on the existing protocols or equipment for public health vector control programs and provide recommendations for addressing operational usage.

KEY WORDS Attractant, equipment, flow rate, mosquito trap, vector control

INTRODUCTION

The empirical nature of public health vector control elevates the demand for surveillance networks across the globe (Petrić et al. 2014, Aryaprema et al. 2023). Mosquito-focused programs base their intervention decisions on the abundance, diversity, and dispersion characteristics of their geographically relevant species (Petrić et al. 2014, Drakou et al. 2020). These efforts must be monitored through surveillance efforts performed in the field, such as human landing rates, public service requests, manual collections of larvae, and, most rigorously, with mechanical traps for adult mosquitoes (Chen et al. 2011, Sriwichai et al. 2015, Aryaprema et al. 2023). Selectivity to hematophagous insects in trap networks has been subsequently established with gaseous CO_2 (Reeves 1953), improving both the magnitude (Newhouse et al. 1966) and diversity of collections for mosquitoes (Magnarelli 1975, Feldlaufer and Crans 1979), with exceptional specificity to those species with a high vectorial capacity (Reisen et al. 1983, 2000). Historically, CO_2 was added via containers of dry ice (Reeves 1953, Newhouse et al. 1966, Magnarelli 1975, Feldlaufer and Crans 1979, Reisen et al. 1983, 2000). This is effective, widely available in an industrialized country, and was considered cost-effective for upscaling.

The methods used across supporting studies have varied, with dry ice blocks manually and arbitrarily divided (Newhouse et al. 1966), and the pieces wrapped in varying materials such as newspaper (Reeves 1953), plastic (Magnarelli 1975), or foil (Feldlaufer and Crans 1979). Unfortunately, dry ice has many sublimation variables, such as surface area, air temperature, humidity, receptacle shape, and how vapors are expected to escape the receptacle (McPhatter and Gerry 2017, Hafner 2023. It is not a rare occurrence that an operator would find their dry ice completely spent in one night and, on another night, still have some fragments actively sublimating at the time of trap collection (Reeves 1953). As a result, efforts have been made to better regulate CO_2 flow for consistent operation (Reisen et al. 2000). Generally, gas cylinders can function as well or better for collecting mosquitoes via CO_2 baiting (Mboera and Takken 1997, Reisen et al. 2000). A significant aspect of this is the ability to control and modulate CO_2 emission to suit needs, even increasing the CO_2 flow rates well above typical rates for a block of dry ice (Reisen et al. 2000). Gas cylinders also can be stored much easier than dry ice, allowing less frequent deliveries of CO_2 in cylinders versus dry ice and trap preparation can be performed days before deployment.

Gas cylinders require many additional components over dry ice, with a trap set-up requiring the secure mounting of a gas cylinder, appropriate flow controls with choke components, a pressure regulator, and lines extending from and directing the flow of CO_2 (Bibbs et al. 2024). At the scale they are used, the pressure regulators are a significant bottle-neck for the accessibility of gas cylinders for CO_2 because of their cost and maintenance. When maintaining a surveillance network of dozens of traps, set and collected at least weekly, operators

[1] Salt Lake City Mosquito Abatement District, 2215 North 2200 West, Salt Lake City, UT 84116.

[2] Rockies and High Plains Vector-Borne Diseases Center (RaHP VEC), Colorado State University, CVID 146, Fort Collins, CO 80523.

[3] To whom correspondence should be addressed.

[4] Contributed equally as lead investigators.

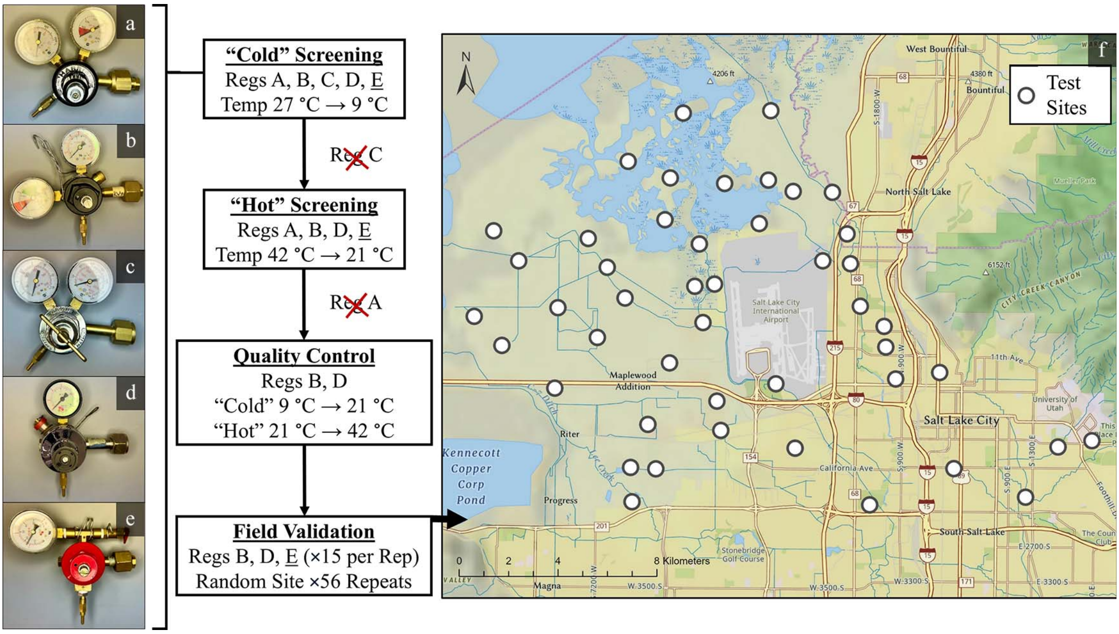

Fig. 1. Single-stage regulators were acquired from beverage and welding supply manufacturers (a-d) and compared to the preexisting, mass-used regulators (e) within the Salt Lake City Mosquito Abatement District for use with pressurized gas cylinders dispensing CO_2. Tolerance tests were conducted using environmental chambers to screen for cold temperature failures, followed by rejection of models that failed. Remaining models were screened again with hot temperature tests, followed by a second round of rejections for failed models. Remaining models were used in quality control tests with duplicates of regulators maintaining calibrations in prior stress tests. Final candidate regulators were deployed alongside the preexisting standard (Regulator E) in sets of 15 for a span of 52 trap nights across the SLCMAD surveillance network (f).

may struggle with systemic failures in their equipment (Ritchie et al. 2008, Chen et al. 2011, Crepeau et al. 2013,). In the case of compressed gas cylinders, the regulators need to be detached and re-attached every time CO_2 is refilled. In addition, calibrations for flow rate are managed with a diaphragm that can be tightened or loosened to change the CO_2 output. This complexity creates points of potential failure because of wear and general stress from environmental conditions including expansion and contraction of the materials during temperature fluctuations. When failure occurs, flow can be blocked or have excessive expulsion of CO_2, which reduces the run time. More importantly, unknown regulator failures could contribute to inaccurate treatment decisions because of higher or lower than normal catches, since surveillance data assumes standard calibrations.

As with many components used in mosquito surveillance programs, regulators are generally made for other industries. In this case, regulators are most available from beverage and welding markets, which are generally indoor applications. Unfortunately, the environmental tolerances of these pre-fabricated models in the field are entirely undescribed in literature. Beyond the effects on the gas itself, questions may arise regarding whether or not the regulator is more reliable in hot or cooler temperatures, or if widespread logistical failures from seasonal changes may compromise the equipment or offset calibrations. To test this, we acquired a subset of off-the-shelf models below $120 USD in online retail (as of 2024) so as to meet a reasonable price point for upscaling. We stress tested the equipment with artificially induced temperature swings and monitored changes to the flow rate calibrations. We then contrasted this with in-use field validation of over 50 trap nights across spring, summer, and fall within the Salt Lake City Mosquito Abatement District (SLCMAD) jurisdiction.

MATERIALS AND METHODS

Tolerance tests—general procedure

Five single-stage gas regulators were acquired from online-accessible vendors, labeled A (Model 201 Sku 3002260, Harris Products Group, Monroe, OH), B (3741-br, Taprite Micro Matic, Inc., San Antonio, TX), C (Series 30, Miller Electric Mfg, LLC, Appleton, WI), D (Model 841, Micro Matic USA, Inc., Brooksville, FL), and E (Model 810, Micro Matic USA, Inc., Brooksville, FL) (Fig. 1a-1e). Regulator E was a discontinued model that was no longer available for purchase, but has served as the historical regulator model already deployed for operational surveillance by SLCMAD). All models were fitted with the adaptors and 0.0075" choke as previously described (Bibbs et al. 2024). Each of the five regulator types were calibrated to 300 ml/min at

Fig. 2. (a) A field-deployed Salt Lake City (SLC) mosquito trap with contained transport and housing for gas cylinders. This unit is functionally equivalent to miniature CDC-style traps. (b) Regulator attachment to gas cylinders are fed through transport housing. (c) Cargo of battery, trap, trap net, cylinder, and attached regulator are packaged into the housing for transport.

the beginning of each trial, with stressors labeled as either "cold" or "hot" based on the extremity of the temperature the regulators were housed in. All calibrations and performance checks were made using 1 kg-capacity CO_2 cylinders and a flowmeter (Gas Flowmeter w/Copper Connector, JIAWANSHUN td., China). The theoretical release for calibrated regulators should reach 847 g per day [24 h $\times$ 60 min $\times$ 0.3 liter/min $\times$ 1.96 g/L of CO_2 at standard temperature and pressure (STP)].

Separately, a cohort of regulators was stressed and recalibrated only when the regulator completely failed to show the progressive degradation in performance. The logic was that, for operational usage, regulators would only be recalibrated at regular intervals that may not be daily. But if a total failure is detected, such as by a prematurely empty CO_2 cylinder or the confirmation of zero gas flow, then units would be recalibrated ad libitum to keep regular surveillance in operation. In all trial types, cylinder valves were fully opened, and the unit was allowed to flow for 24 continuous h within the prescribed assay conditions. Flow rates were measured and recorded after occupying an initial temperature (phase 1) for 16 h and again after occupying the final temperature for the remainder of the observation window (phase 2). Cylinders were replaced after each phase 2 measurement regardless of trial type. Tests were conducted with the stipulation that a useful regulator must be resilient in both the "cold" and the "hot" trials to be carried forward to field validation. In all cases, whether screening or doing quality control assessments, measurements were repeatedly taken at the end of each phase over 9 replicates.

Tolerance tests—model screening, changing temperature high to low

The "cold" trial reflects temperature extremes similar to those in the field during the spring and fall

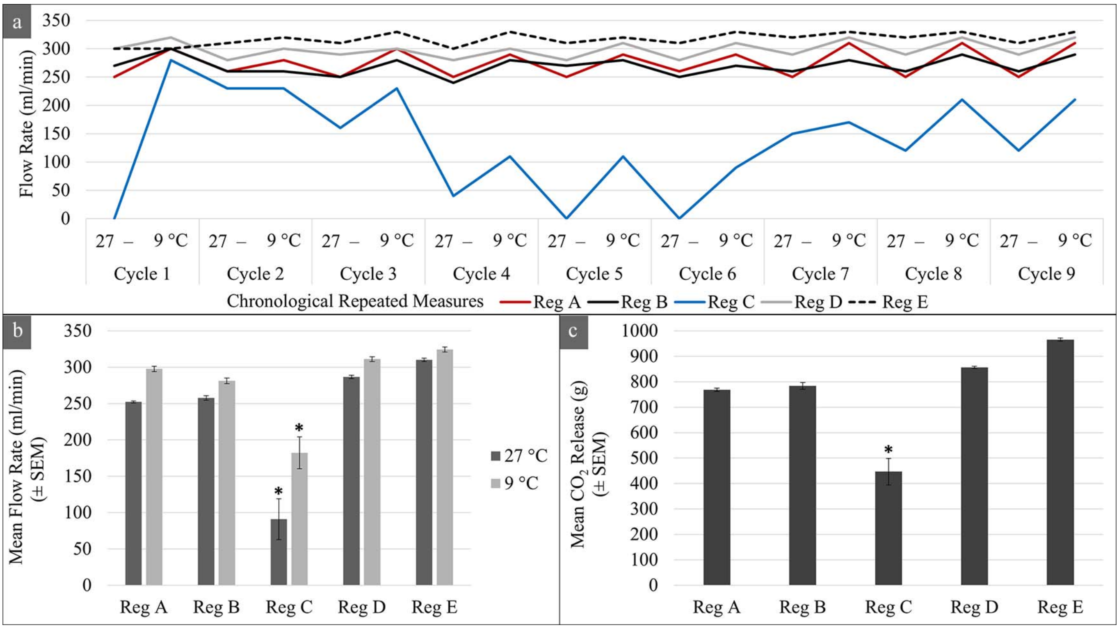

Fig. 3. Varying models of regulator were screened by acclimating to 27°C for 16 h (phase 1), then brought down to 9°C for 8 h to simulate a nightly temperature drop during spring/fall. Flow rate measures were taken on regulators that were continuously oscillated for 9 cycles (a) ($F_{4,44} = 67.72$, $P < 0.001$). Mean flow rates were assessed on units that were recalibrated each trial (b) ($F_{4,44} = 45.79$, $P < 0.0001$). Mean CO_2 release was also taken after a 24-h total cycle (c) ($F_{4,44} = 62.45$, $P < 0.0001$). Model C failed to retain calibrations during study and had significantly varying outputs.

season; cold nights may be as low as 0°C with warm day time temperatures reaching close to 21°C (NWS 2024). The cylinder-regulator setup (Fig. 2a-2c) was placed in an environmental chamber (Thermo Scientific 3920 Large Capacity Environmental Chamber) maintained at 27°C overnight during phase 1. After recording the flow rates following the 16-h acclimation, each setup was chilled to 9°C for the second phase of the "cold" trials. The flow rate was measured for each regulator at the end of each stage and the total mass of CO_2 expelled in the 24-h period was calculated with a before and after weight measurement of each cylinder after phase 2 measurements. Regulator C was not carried forward to the "hot" tests because of inability to maintain calibrations when chilled (Fig. 3a).

The "hot" trial reflects temperature extremes similar to those in the field during the summer season with daytime temperatures as high as 41°C and cooler nighttime temperatures reaching below 21°C (NWS 2024). Phase 1 for this cylinder-regulator setup was a 16-h acclimation at 42°C, after which each setup was brought down to 21°C during phase 2 of the "hot" trials. The flow rate was measured for each regulator at the end of each phase and the total mass of CO_2 expelled in the 24-h period was again calculated with a before and after weight measurement of each cylinder after phase 2. Regulator A was not carried forward to the quality control tests because of consistently irregular flow rates only when hot (Fig. 4a).

Tolerance tests—quality control, changing temperature low to high

To streamline effort in the field, additional quality control replicates were conducted on regulators B and D to verify their consistency for use in field validations. Quality control from the manufacturer of the regulators may play a role in the observed outcomes with tested regulators. To control for this, a second round of "cold" and "hot" trials was conducted with five duplicated regulators of models B and D. Regulator E was omitted from this test because over 30 units have already been in use with SLCMAD for more than five years. For regulators B and D, the 10 duplicates were labeled as D1, D2, D3, D4, D5, B1, B2, B3, B4, B5 for convenience, where B1/D1 were the same regulators used in the screening trials. The same methods were used to calibrate each regulator as with the first set of trials, whereby initial calibrations were made and then repeated measurements on flow rate were taken for a 9-wk duration.

However, during this round of quality control trials the 10 regulators were stressed by reversing the temperature sequence for "cold" and "hot". For "cold" trials this meant acclimating phase 1 at 9°C and then heating the assemblies to 21°C during phase 2. For "hot" trials this meant acclimating phase 1 at 21°C and then heating the assemblies to 41°C. All other testing details were conducted identically to the screening portion, with the addition of the aforementioned regulator duplicates. As before, flow rate was measured after each phase and before/after CO_2

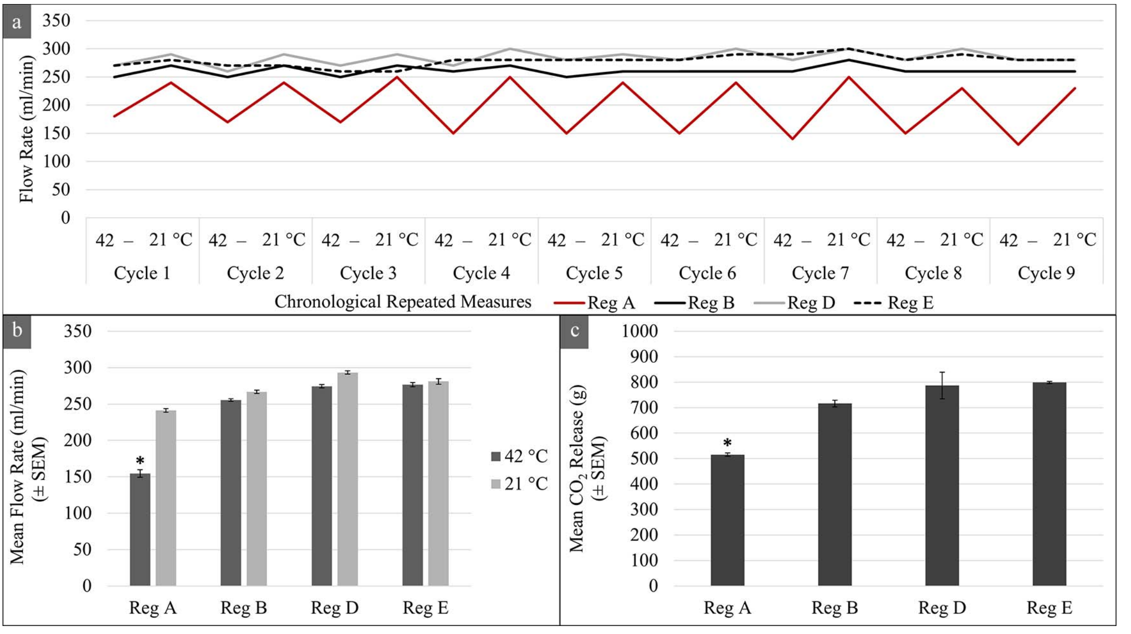

Fig. 4. Varying models of regulator were screened by acclimating to 42°C for 16 h (phase 1), then brought down to 21°C for 8 h to simulate a nightly temperature drop during summer. Flow rate measures were taken on regulators that were continuously oscillated for 9 cycles (a) ($F_{3,51} = 60.18$, $P < 0.001$). Mean flow rates were assessed on units that were recalibrated each trial (b) ($F_{3,35} = 296.59$, $P < 0.0001$). Mean CO_2 release was also taken after a 24-h total cycle (c) ($F_{4,44} = 61.06$, $P < 0.0001$). Model A fluctuated significantly in flow rates only while hot.

masses were taken after phase 2 for both sets of environmental conditions.

Field validations

Consistency of measures during quality control testing supported carrying forward both regulators B and D. Regulator E was included as a comparison group since SLCMAD already used these as their main regulator for more than 5 years. A total of fifteen duplicate regulators of B (#1-15), D (#16-30), and E (#31-45) were simultaneously deployed within the preexisting surveillance network of the SLCMAD, spanning a geography that includes urban/residential tracts, rural wetland, and industrial transition zones (Fig. 1f). From April 1 to October 31, 2024, a total of 56 trap-nights were conducted across each of 45 surveillance locations, yielding a total effort of 2,520 deployments of regulators into the field. Regulators were assigned with a random sequence generator (no duplicated numbers) across this network during each trap night for the duration of the study (Fig. 2a). Regulators (Fig. 2b) were paired with the SLC Trap and transport container developed in Bibbs et al. (2024) (Fig. 2c). High and low temperatures were recorded in the area for each trap night. Trap failures because of regulator malfunctions, such as by CO_2 not flowing or CO_2 excessively dispensed, were recorded for every deployment. Failure events were corrected by recalibrating the regulators at the SLCMAD facility and then redeploying on the next trap night.

Data analysis

Statistical testing on continuously tested flow rates for phase 1 and phase 2 measurements were calculated using a repeated measures ANOVA test with a paired t-test and Bonferroni correction. Zero flow rate values were transformed to 0.0001 ml/min for calculations. Independently measured means of CO_2 release and phase 1/phase 2 flow rates were analyzed using ANOVA/Tukey HSD. Mean flow rates and CO_2 release from the quality control tests of regulator B and D were analyzed with paired t-tests within measurement groups. Flow rates from tolerance tests and failures in the field were summarized with negative binomial regressions with the temperature data collected for the cycle of use. All statistical analyses were conducted using R v. 4.2.0 (R Core Team 2022).

RESULTS

In "cold" trial tolerance tests, regulator C failed to maintain calibrations throughout continuously cycling temperatures (Fig. 3a). Degradation of flow calibrations were significant across regulators ($F_{4,44} = 67.72$, $P < 0.001$), with ranking from high to low outputs reflecting E > D > A = B > C ($\alpha = 0.005$). Flow rates for both the 27°C phase 1 ($F_{4,44} = 45.79$, $P < 0.0001$) and the 9°C phase 2 ($F_{4,44} = 30.11$, $P < 0.0001$) were significantly reduced from the other models (Fig. 3b). The mean CO_2 released was significantly less for model

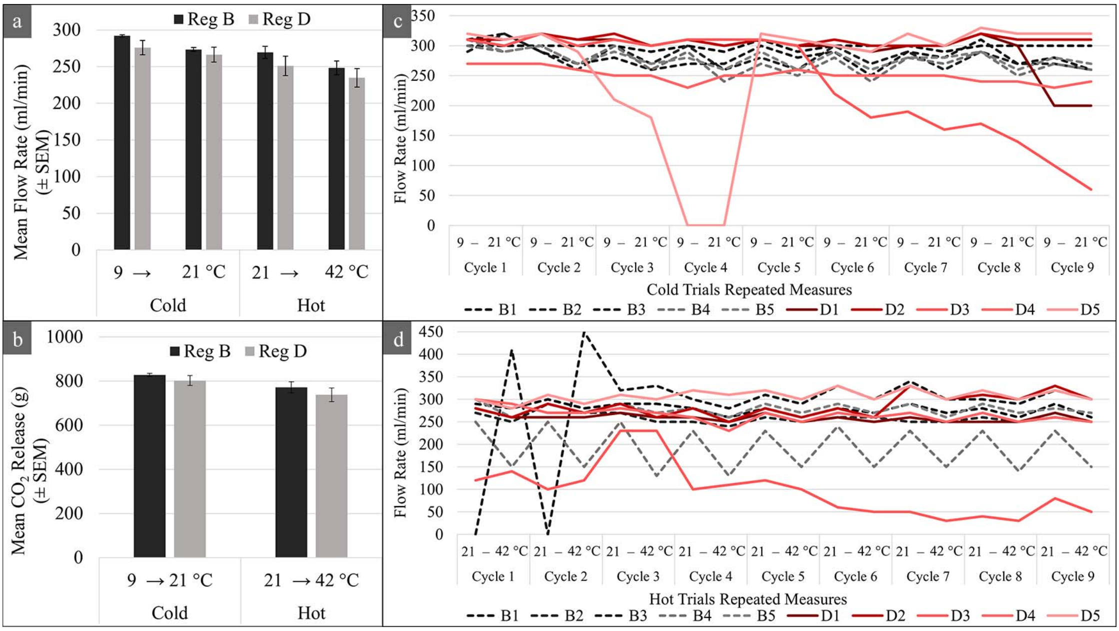

Fig. 5. Regulators of models B and D, chosen from the prior screenings, were quality checked by acquiring 5 identical units of each model (B or D, #1-5). Tests were conducted by acclimating to "cold" conditions of 9°C for 16 hours (P1), then brought up to 21°C for 8 h to simulate a temperature increase following a spring/fall night. A second series was conducted by acclimating to "hot" conditions of 21°C for 16 h (P1), then brought up to 42°C for 8 h to simulate a temperature increase following a summer night. Mean flow rates were assessed on units that were recalibrated each trial (a). Mean CO_2 release was also taken after a 24-h total cycle (b). Flow rate measures were taken on regulators that were continuously oscillated for 9 cycles in either the "cold" (c) or hot (d) conditions. Mean performance was not significantly different between regulators. Individual regulator performance indicates observable "cold" condition failures for model D and "hot" condition failures for both B and D.

C than the other types (Fig. 3c; $F_{4,44} = 62.45$, $P < 0.0001$). As a result, model C was considered a total loss and omitted from further testing.

In "hot" trial tolerance tests, regulator A consistently released less CO_2 only while heated but resumed acceptable calibration points once coming down to room temperature (Fig. 4a). Degradation of flow rates were significant across regulators ($F_{3,51} = 60.18$, $P < 0.001$), with ranking from high to low outputs reflecting E = D ≥ B > A ($\alpha = 0.0083$). Correspondingly, the flow rates for regulator A were significantly lower than the models B, D, and E during the 42°C phase 1 ($F_{3,35} = 296.59$, $P < 0.0001$), but not during the 21°C phase 2 (Fig. 4b). Similarly, the mean CO_2 released was also significantly less for model A as compared to the other models (Fig. 4c; $F_{4,44} = 61.06$, $P < 0.0001$). Model A was not selected for further testing as a result.

Performance was not significantly different with mean flow rates (Fig. 5a) or mean CO_2 release (Fig. 5b) between regulators B and D when conducting quality control replicates with five duplicates of each model. When parsing out the individual performance of each duplicate, regulator D had three of five regulators lose calibrations when oscillating between a 9°C phase 1 and 21°C phase 2 (Fig. 5c). When conducting a 21°C phase 1 and 42°C phase 2, regulator B had two of five units lose calibration, whereas regulator D had one of five units unable to maintain calibration (Fig. 5d). Across all testing, both during screening and quality control assessments, there was a general trend of lower flow rates whereas in hot conditions and higher flow rates after cooling (relative to the prior acclimated temperature).

Field validations were devised from total failures out of 15 duplicates for each of regulator B, D, and E per night of use. The mean failure rate across the entire season was less than 5% for all models (Fig. 6a), but model E was observed to fail twice as frequently as the others ($F_{2,55} = 296.15$, $P < 0.001$). Across the season, 10, 13, and 24 failures were observed among regulators B, D, and E, respectively. There was no particular trend across the failures from the field, whether correlating with the difference between daily high and low temperatures (Fig. 6b), nightly lows (Fig. 6c), or daily highs (Fig. 6d). This is likely confounded by the low overall number of failures relative to the total number of trap nights.

DISCUSSION

Overall, commercially pre-fabricated regulators can work within an acceptable tolerance of extreme temperatures and maintain a reasonably low rate of overall failure in the field despite not being manufactured for use in mosquito abatement operations. It was notable to

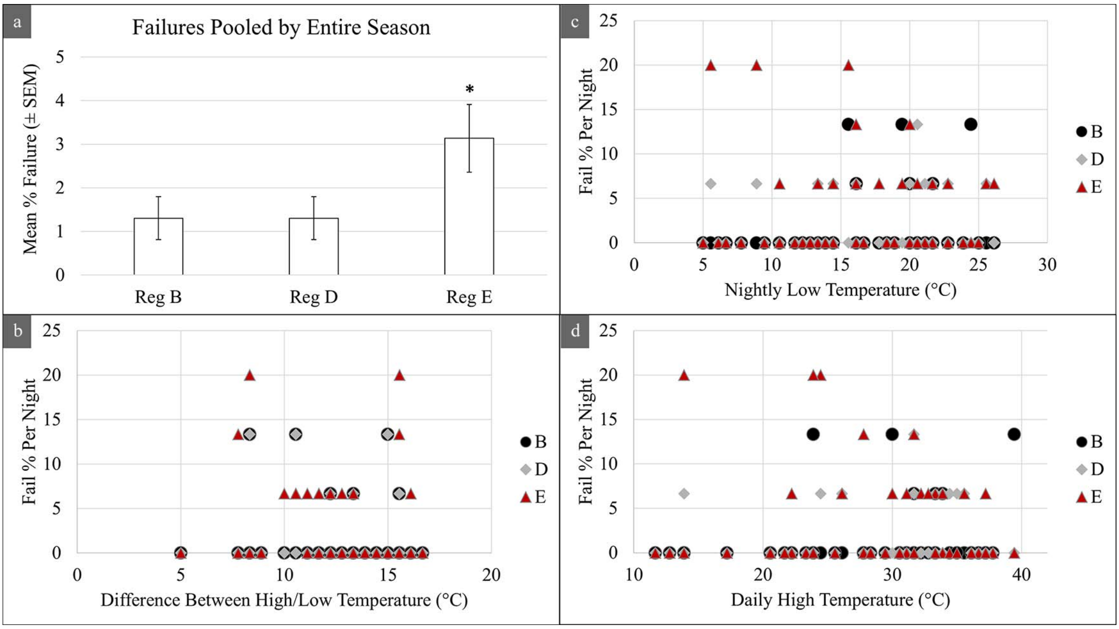

Fig. 6. During field validation, 15 units of regulators B, D, and E (the benchmark already in use) were deployed for 2,520 trap events across an established mosquito surveillance network within the Salt Lake City Mosquito Abatement District. The cumulative mean failure rate of each regulator was taken for the entire season (a). The nightly failure rate percentages were plotted for the daily difference in high-to-low (b), daily low (c), and daily high (d) temperatures across the monitoring period. No specific correlations to temperature were observed in the field. Regulator E had significantly higher overall rates of failure ($F_{2,55} = 296.15$, $P < 0.001$) than the other models, but all models were below an average fail rate of 5% of uses during the season.

SLCMAD staff that their default regulator E that is already used in our surveillance network had the worst reliability in the field. It is possible that this result is partially because of the preexisting age and wear on these regulators from routine field usage. However, this regulator is discontinued from sale from Micromatic, and so may be a moot point in the future operations of their program. However, this result highlights the importance of periodically evaluating a program's tools, even down to the individual manufacturers or suppliers. A variable CO_2 release rate, whether by dry ice or an improperly tuned regulator set-up, may create an inaccurate perception of mosquito activity and pathogen transmission risk (McPhatter and Gerry 2017).

The mosquito surveillance literature provides little advice to find or test regulators for deployment with adult mosquito traps, despite the casual mentions of their use as a default part of surveillance equipment (Reisen et al. 2000, Silver 2007, McPhatter and Gerry 2017). Regardless, there are some quality metrics that may be helpful for identifying the working models for a program's surveillance needs. Simulating temperature flux relative to seasonal use patterns stresses regulators to the point of failure. Furthermore, continuous measurements over repeated cycles of temperature can eliminate models that are not suitable for high-stress use. In addition, testing duplicates of the same model of interest can help reduce errors in judgements. For example, in our data we eliminated regulator A after the first sequence of "hot" tests. Yet one of the duplicates for regulator B mirrored the flow rate errors. This could mean that our exclusion of model A was not necessary, if we had tested more manufacturing duplicates of that particular regulator.

Our field validations were performed in the hot, arid, and high elevation area of Salt Lake City. However, humidity and high-low pressure fluctuation, such as in the southeastern United States, could easily result in different sources of error in potentially suitable regulators. Fortunately, these conditions can be recreated in an environmental chamber. We recommend that using evaluation methods as demonstrated in this study can be a valid screening tool. We also encourage mosquito surveillance/control programs to be cognizant of their particular environmental stressors when evaluating equipment. One piece of guidance that may be useful is our observation across several iterations of these trials that regulators tended to error toward lower flow rates while under hot conditions and higher flow rates after cooling (relative to the prior acclimated temperature). This could allow some anticipation of the type of failure one could expect given local seasonal conditions. For example, a chilled regulator may yield an empty CO_2 cylinder more often whereas a sun-heated regulator may be more likely to restrict flow in spite of the calibrations. Such failures with lures are also observed in dry-ice baited traps as well (McPhatter and Gerry

2017), but the complexity of regulators, and users greater demand for consistency may increase noted failure rates (Ritchie et al. 2008, Chen et al. 2011, Crepeau et al. 2013).

Gas cylinders are already a widely accepted tool in mosquito surveillance (Silver 2007). However, it is often overlooked that evaluation of surveillance equipment is necessary to better understand the reliability of those tools. Ultimately, the data presented suggests that off-the-shelf regulators from beverage and welding suppliers, even when limited in scope to lower cost models, can be reliable for field deployment in surveillance programs. Consistency and reliability of surveillance data is paramount for public health protection and data interpretation.

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