Environmental
& Statistical
Consultants

Hawaiian Hoary Bat Occupancy and Distribution on Oahu – Project Status Update

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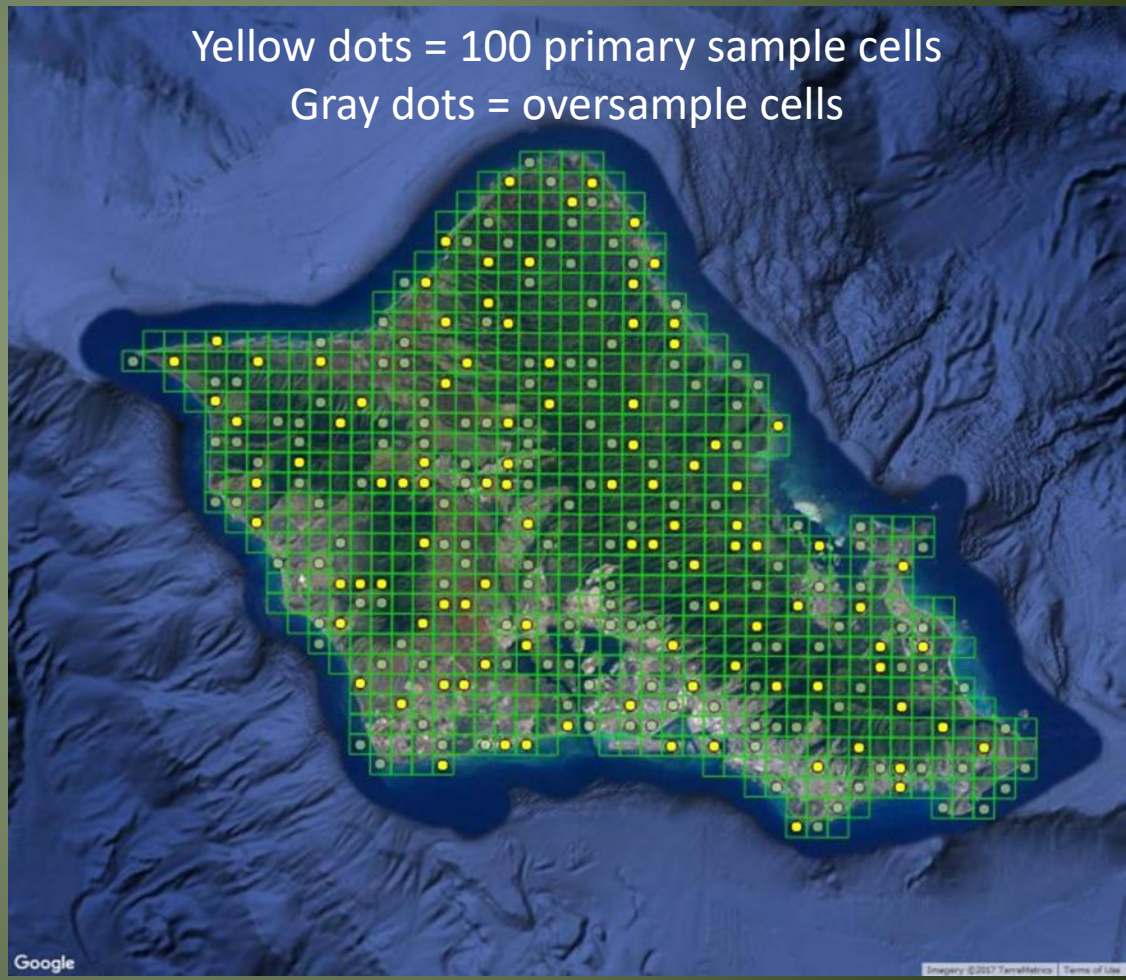
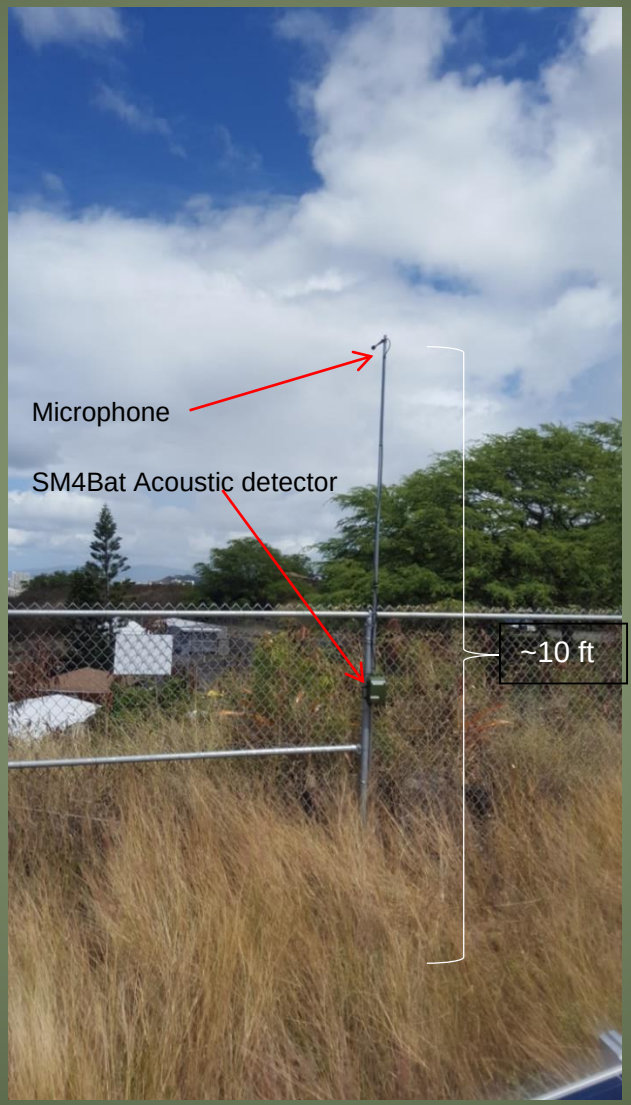
OBJECTIVES AND STUDY DESIGN

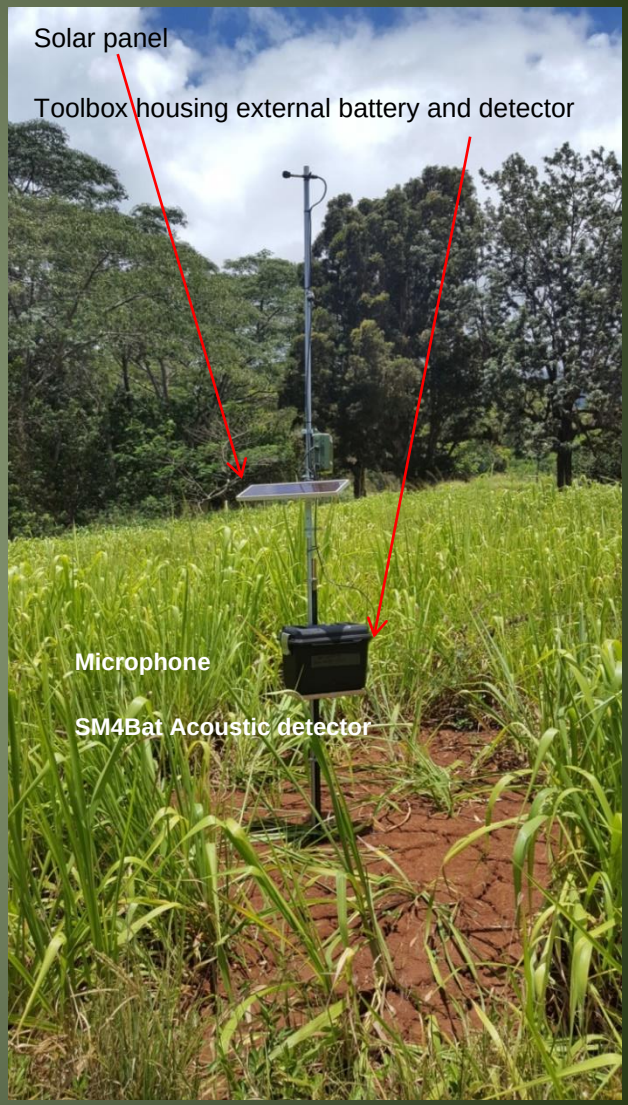
- 5-year study period to look at distribution and seasonal/annual changes in occupancy
- Designed for island-wide inference
- 2.3 km^2 grid cells across the island
- Spatially Balanced Generalized Random Tessellation Stratified Sample (GRTS)



ACOUSTIC SAMPLING METHODS

- Wildlife Acoustics SM4Bat detectors
- Monitored year round
- Checked at ~2-week to 2-month intervals (location dependent)
- Kaleidoscope Pro and Analook used to filter/analyze acoustic data
- Microphones updated From SMM-U1 to SMM-U2 in 2019





OBJECTIVES (Years 1-2): SEASONAL DISTRIBUTION ACROSS OAHU

- Basic information – where, when, how often
  - Where were bats detected and during which season
  - Average number of detections per detector night
  - Proportion of detector nights bats were detected at individual sites
- Seasons were defined based on reproduction periods (Menard 2001 and Gorresen et al. 2013)
  - lactation season = mid-June to Aug
  - post-lactation season = Sept to mid-Dec
  - pre-pregnancy season as mid-Dec to March
  - pregnancy season as April to mid-June

OCCUPANCY ANALYSIS

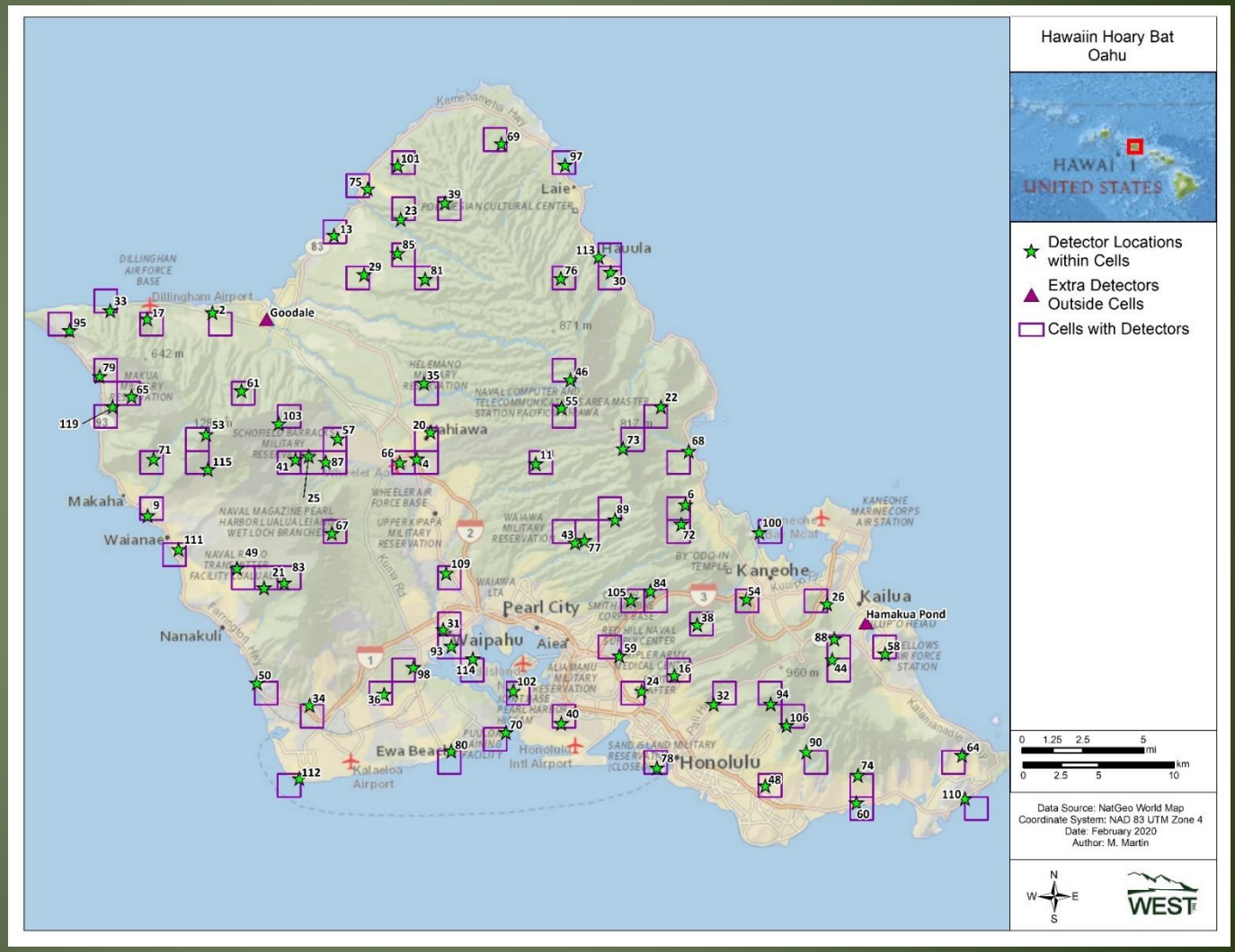
- Single season occupancy models not considered
- Examined two multi-season occupancy models:
  1. **Multi-season dynamic occupancy model** that assumes detections are independent (MacKenzie et al. 2006)
  2. **Multi-season dynamic occupancy model** that assumes detections are correlated (Hines et al. 2010, 2014)
- Multi-season models parameterized changes in occupancy as a function of extinction, colonization, and probability of detection
- Occupancy analysis conducted with *unmarked* package (Fiske and Chandler 2011) in R and in Program PRESENCE (Hines 2006)
- Site-level covariates: elevation, the percentage of trees, and human population density in each grid cell
- Visit-level covariates: season, month

OCCUPANCY ANALYSIS

- Assumption: detections for a given site during different survey occasions are independent
- Correlation among detections were assessed using the join count chi-square test (Wright et al. 2016)
  - Assuming independent detections
  - Assuming a first-order Markov model
- Nightly data highly correlated → took systematic random samples of 7, 10, 14, and 21 days and assessed correlation for each model
- Assessed separately by season

SAMPLE SIZE - DISTRIBUTION

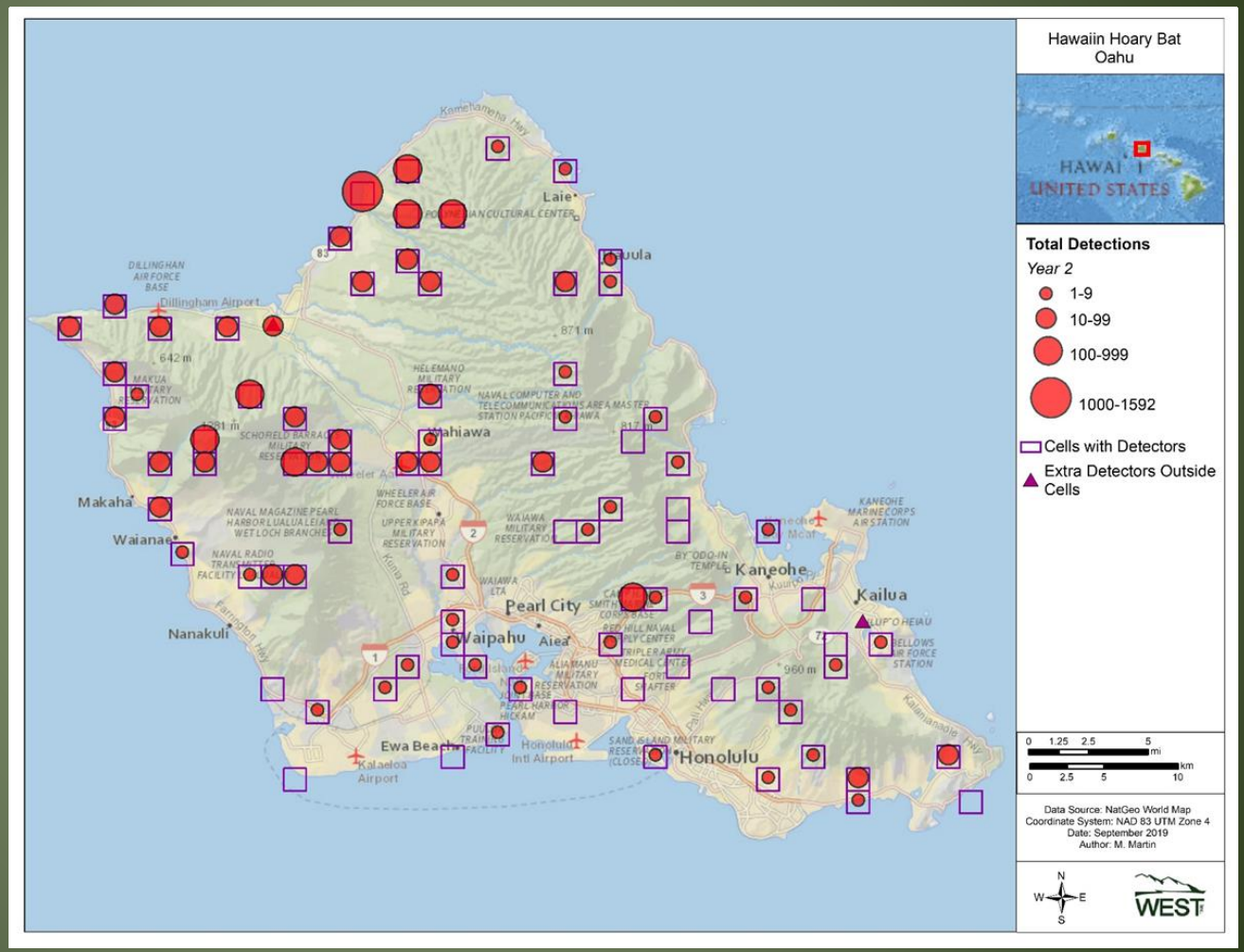
- 87 detectors in the field
- 85 detectors in GRTS cells
- Data collected from all 87 detectors during at least some portion of the study
- A few detectors lost due to theft and some data loss due to equipment malfunction



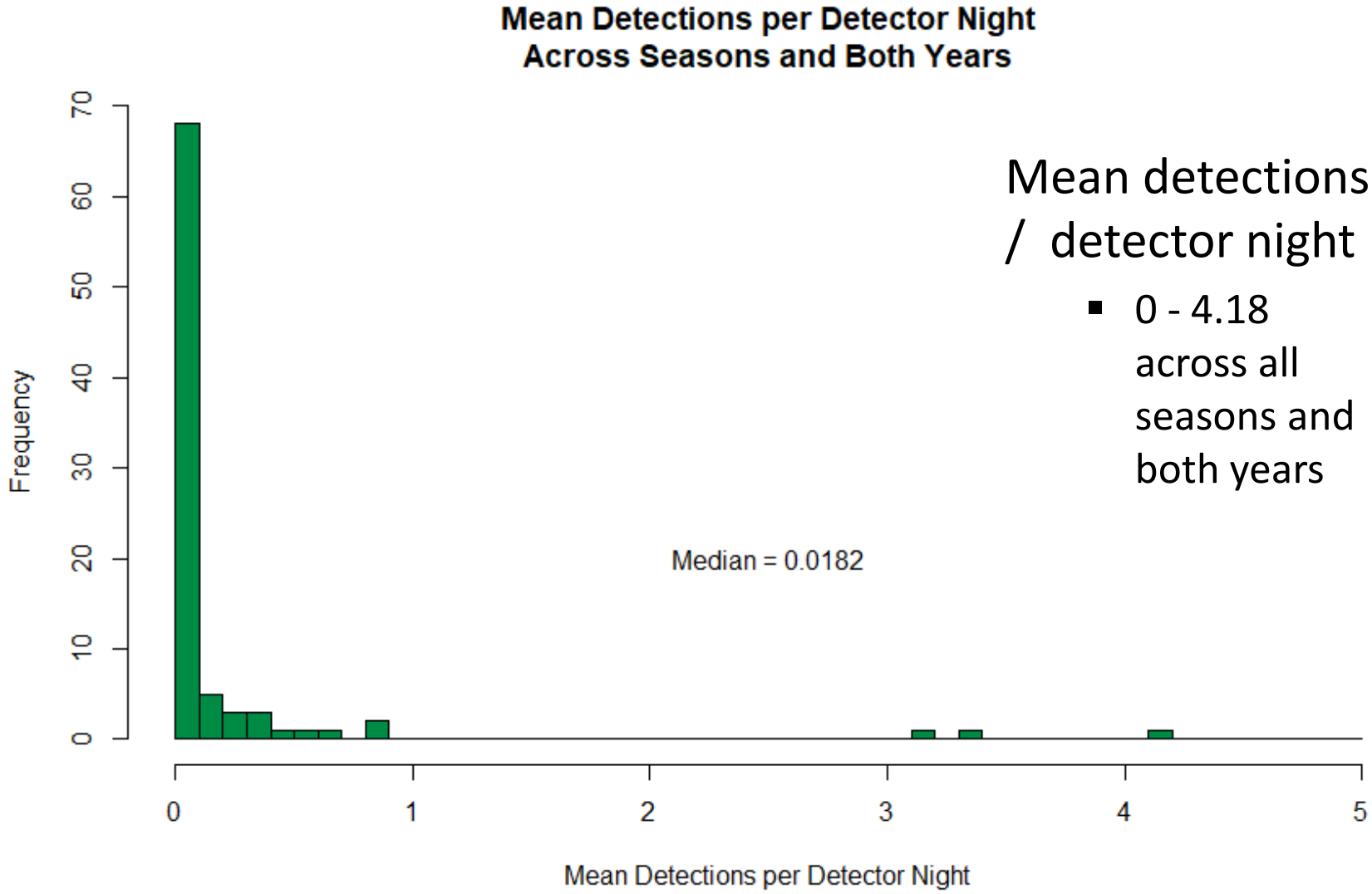
RESULTS - DISTRIBUTION

June 2017 – Oct 2019

- 106 - 800 detector nights
- >12,000 detections
- 0 – 2,551 detections per site (**median = 11**)
- 77 of 87 (89%) detectors with ≥1 detection



RESULTS – MEAN DETECTIONS PER NIGHT



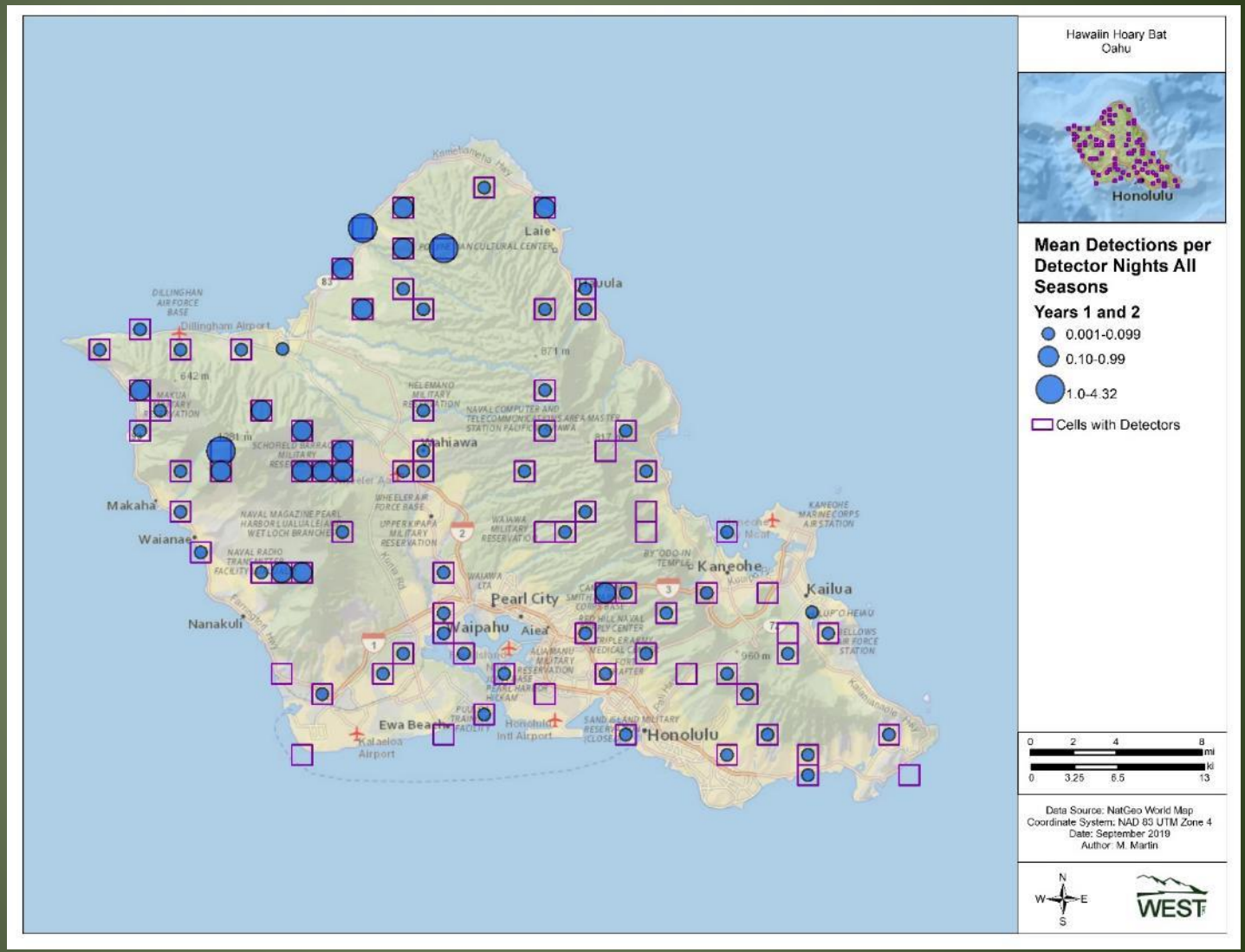
Mean detections / detector night

- 0 - 4.18 across all seasons and both years

DISTRIBUTION – ANNUAL DETECTION RATES

Mean detections per detector night

- Year 1
  - 0 - 4.37 across all seasons
- Year 2
  - 0 - 5.19 across all seasons



RESULTS : TOTAL CALLS TOP 20

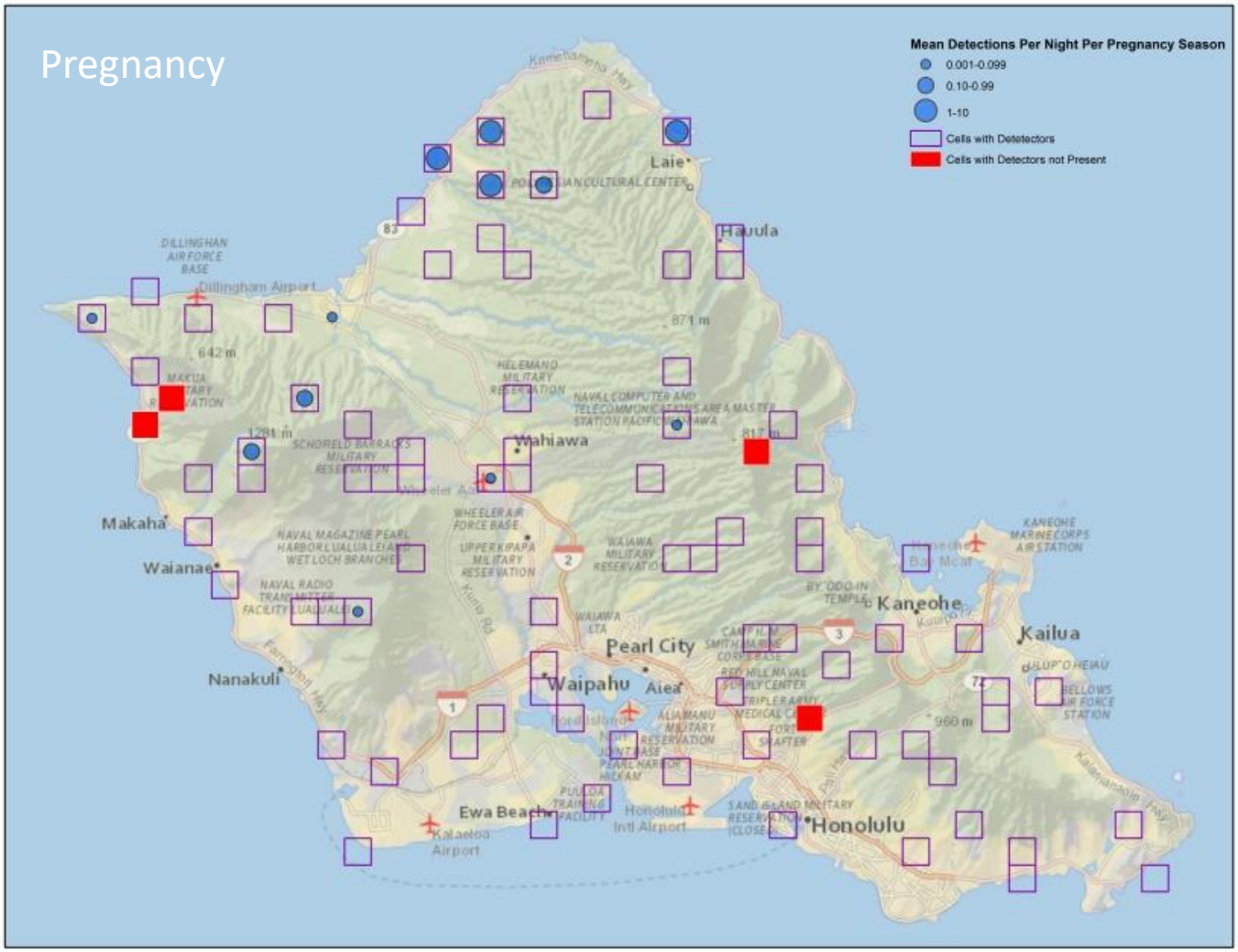
Site ID	Site Name	Detections	Nights with Detections	Detector Nights	Mean Detections Per Detector Night	Proportion of Detector Nights with Detections
Site-053	Kumaipo LZ	2551	247	610	4.18	0.40
Site-075	Peerson	2386	272	715	3.34	0.38
Site-039	Pupukea	2391	215	767	3.12	0.28
Site-101	Pupukea Paumalu	348	163	413	0.84	0.39
Site-023	Waimea Valley	630	241	754	0.84	0.32
Site-103	Schofield Forest	483	116	743	0.65	0.16
Site-013	KAW Gate	357	157	698	0.51	0.22
Site-041	Schofield 3	339	180	730	0.46	0.25
Site-115	Waianae Valley	274	63	714	0.38	0.09
Site-061	Mt Kaala	294	206	767	0.38	0.27
Site-079	Makua Ridge	229	113	724	0.32	0.16
Site-097	Malaekahana SP	152	14	509	0.30	0.03
Site-021	Lualualei 1	183	76	660	0.28	0.12
Site-105	Aiea Loop Trail 1	170	37	745	0.23	0.05
Site-057	McCarthy Field	147	109	767	0.19	0.14
Site-083	Lualualei 2	128	71	680	0.19	0.10
Site-025	Schofield	127	94	767	0.17	0.12
Site-029	KAW Rd	84	70	598	0.14	0.12
Site-087	Schofield 1	86	67	718	0.12	0.09
Site-081	KAW 2	66	60	710	0.09	0.08

DISTRIBUTION - SEASONAL DETECTION RATE

Year 1

Mean detections per detector night

- 0 - 4.37 all seasons
- 0 – 21.8 within seasons

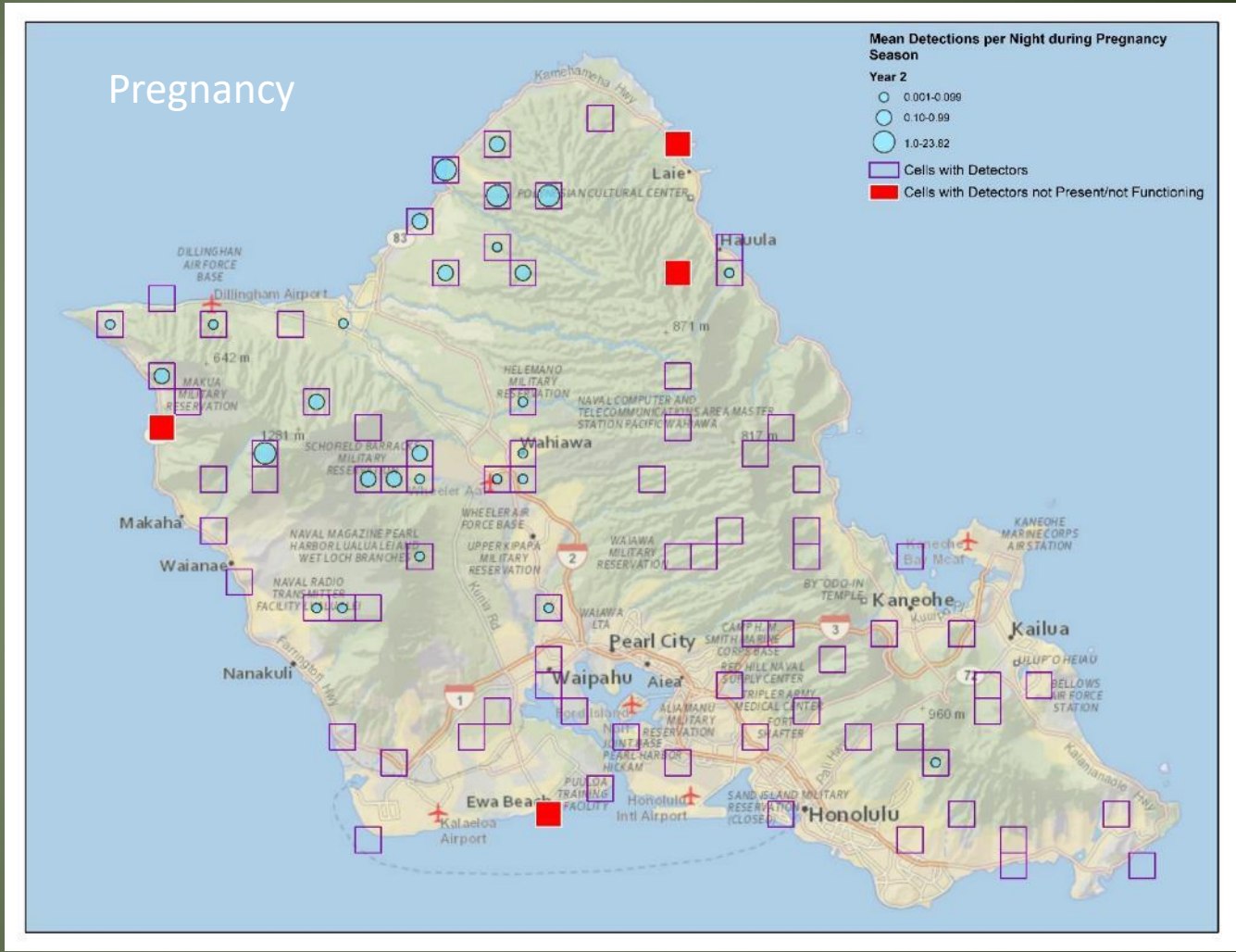


DISTRIBUTION – SEASONAL DETECTION RATE

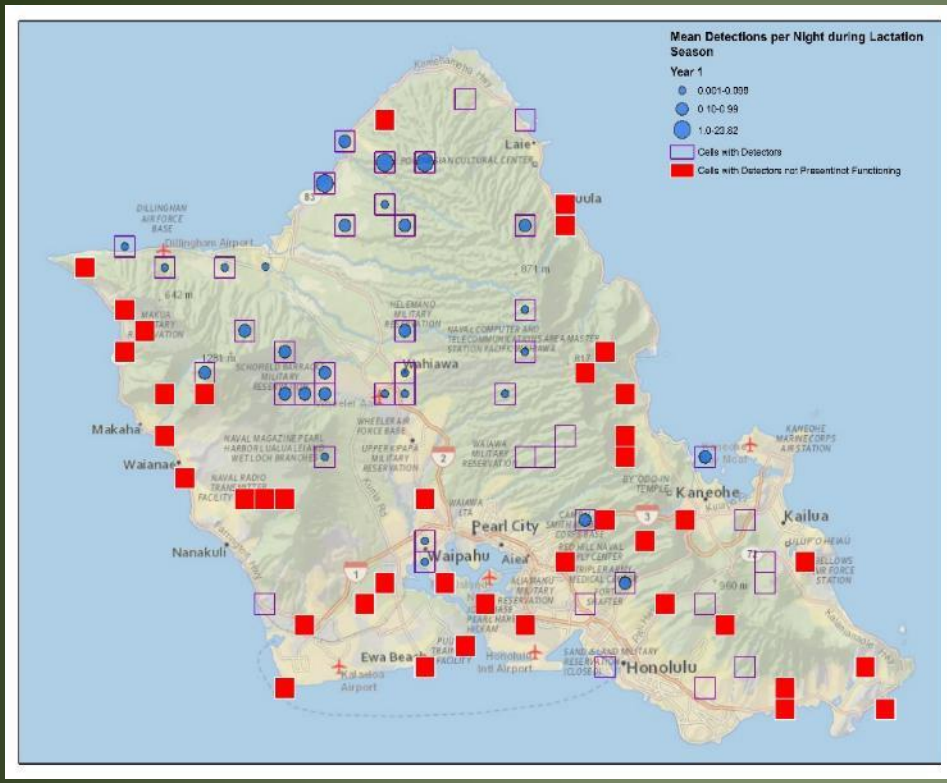
Year 2

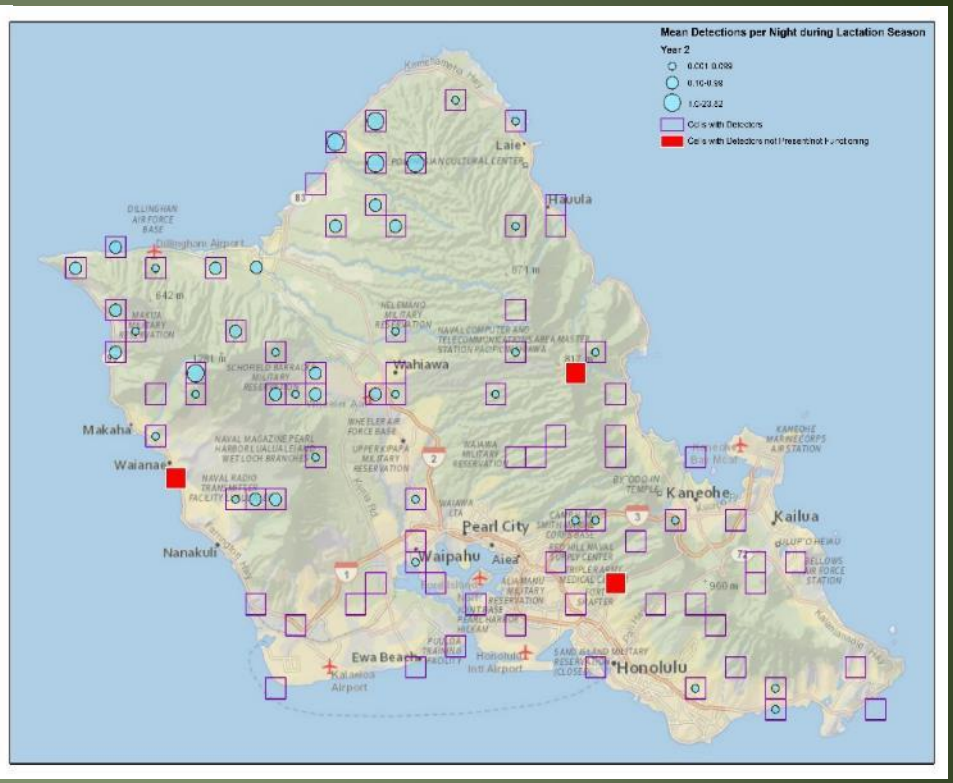
Mean detections per detector night

- 0 – 5.19 all seasons
- 0 – 23.82 within seasons



DETECTION RATE – YEAR TO YEAR SEASONAL COMPARISONS





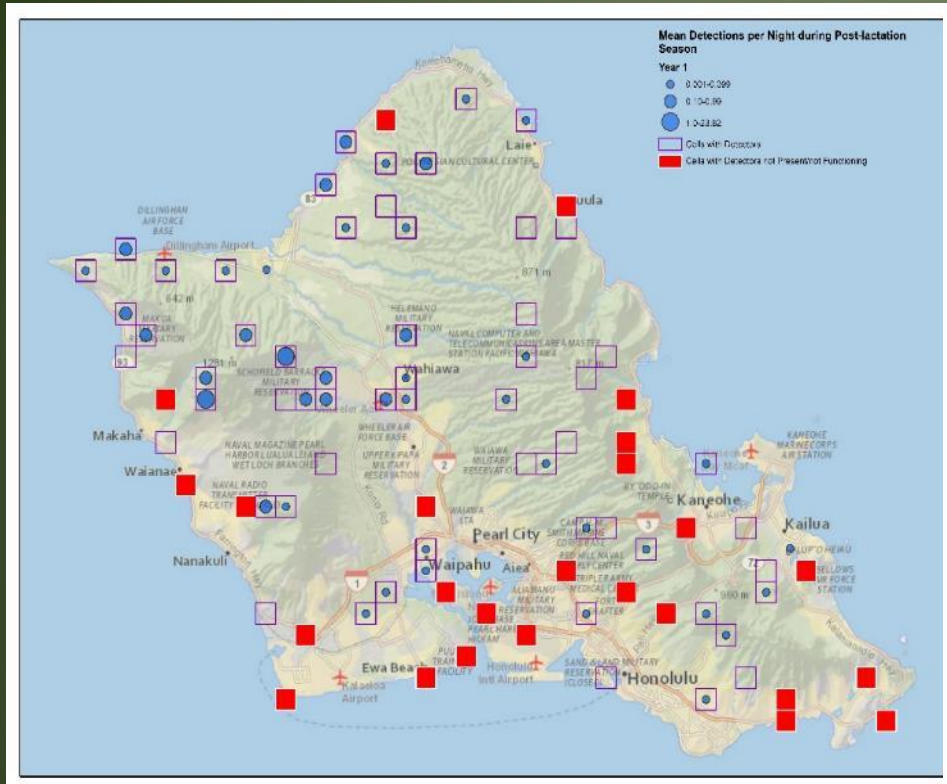
Lactation Year 1

Lactation Year 2

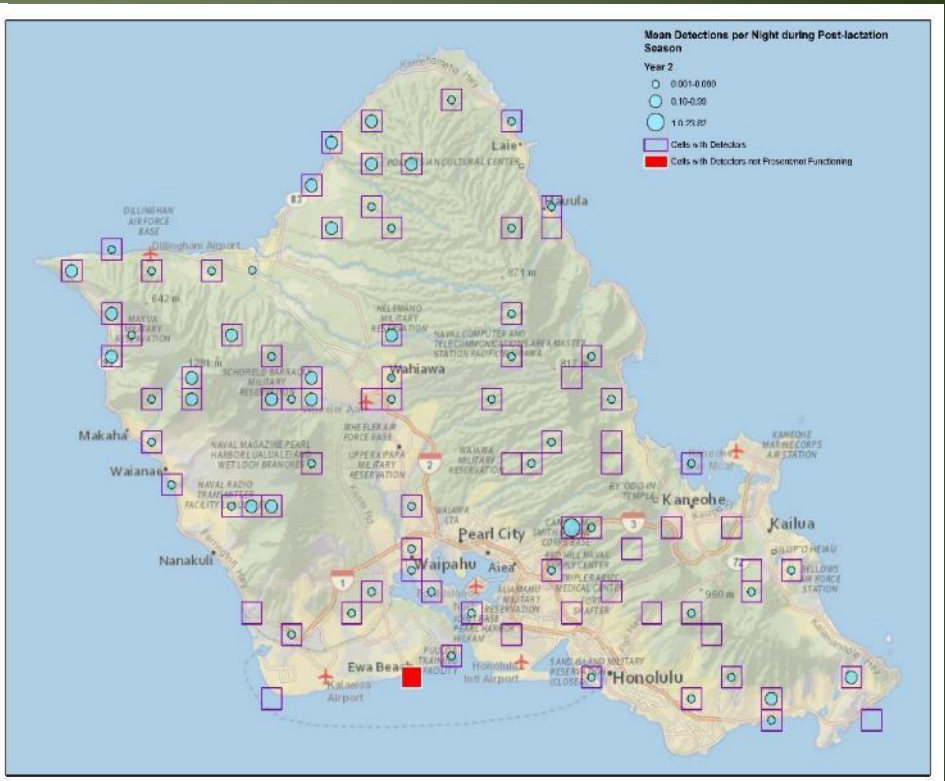
Mean detections / detector night

- Year 1: 0 – 21.8 (avg = 0.65)
- Year 2: 0 – 16.7 (avg = 0.46)

DETECTION RATE – YEAR TO YEAR COMPARISONS



Post-Lactation Year 1

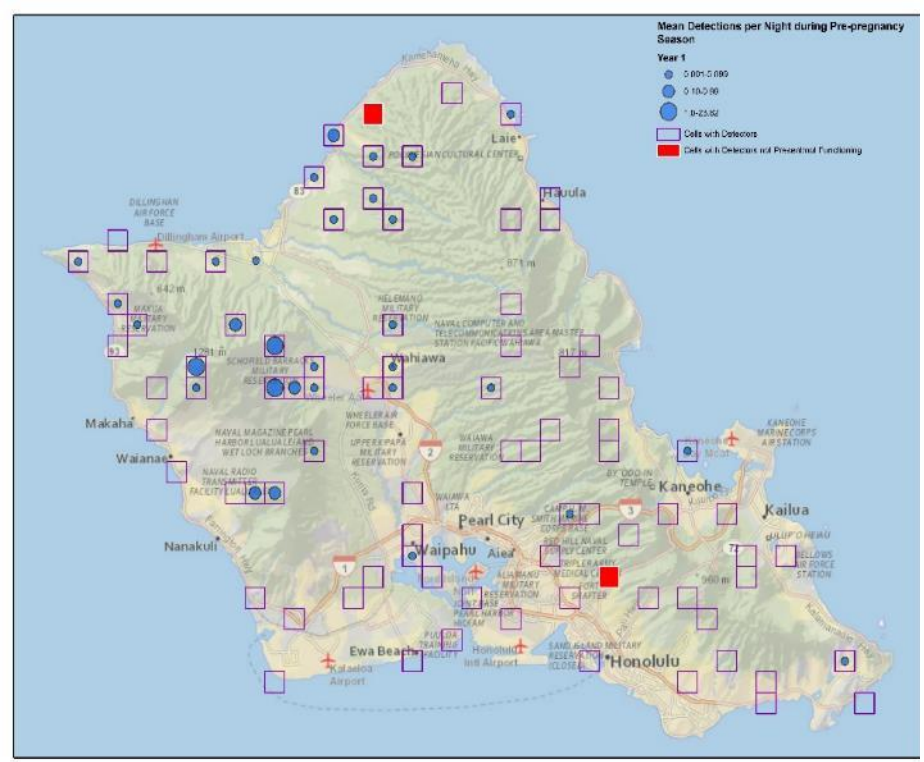


Post-Lactation Year 2

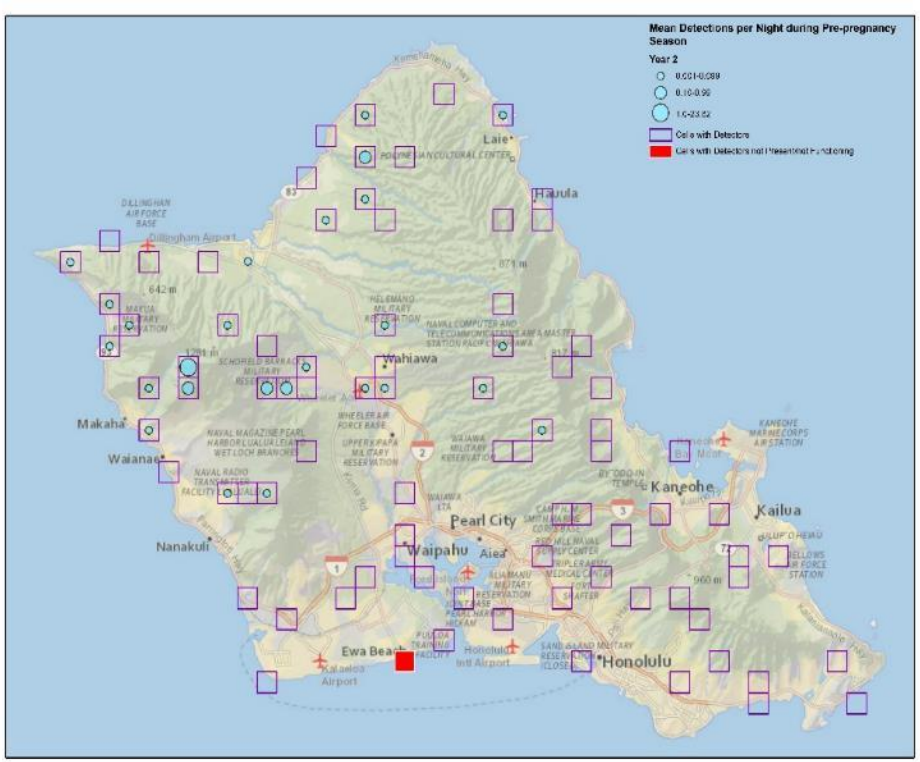
Mean detections / detector night

- Year 1: 0 – 2.96 (avg = 0.18)
- Year 2: 0 – 1.43 (avg = 0.11)

DETECTION RATE – YEAR TO YEAR COMPARISONS



Pre-Pregnancy Year 1

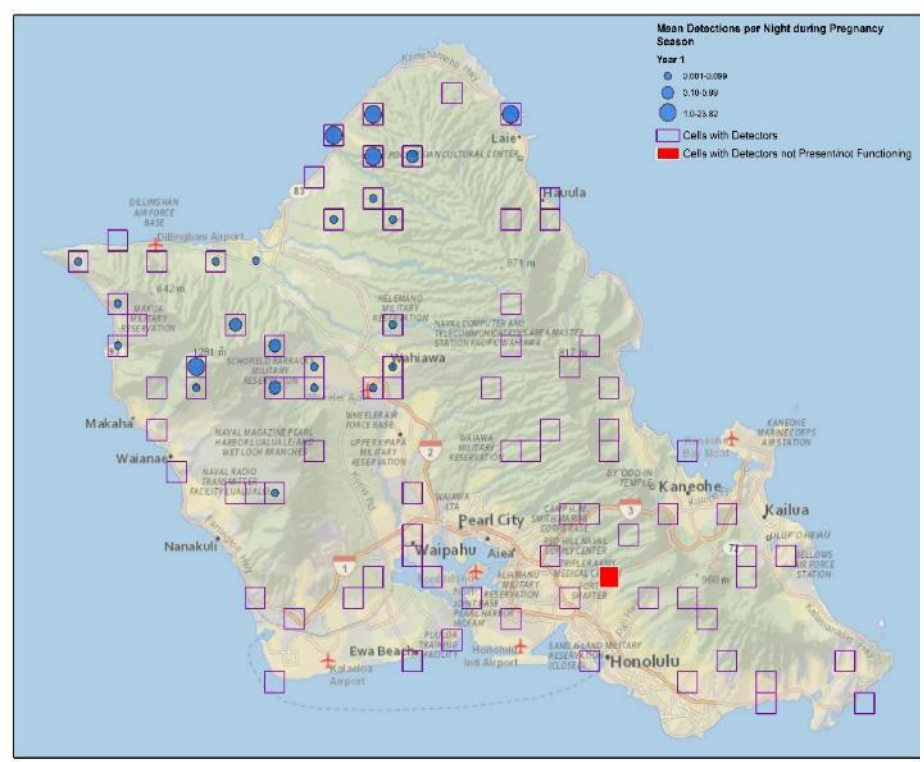


Pre-Pregnancy Year 2

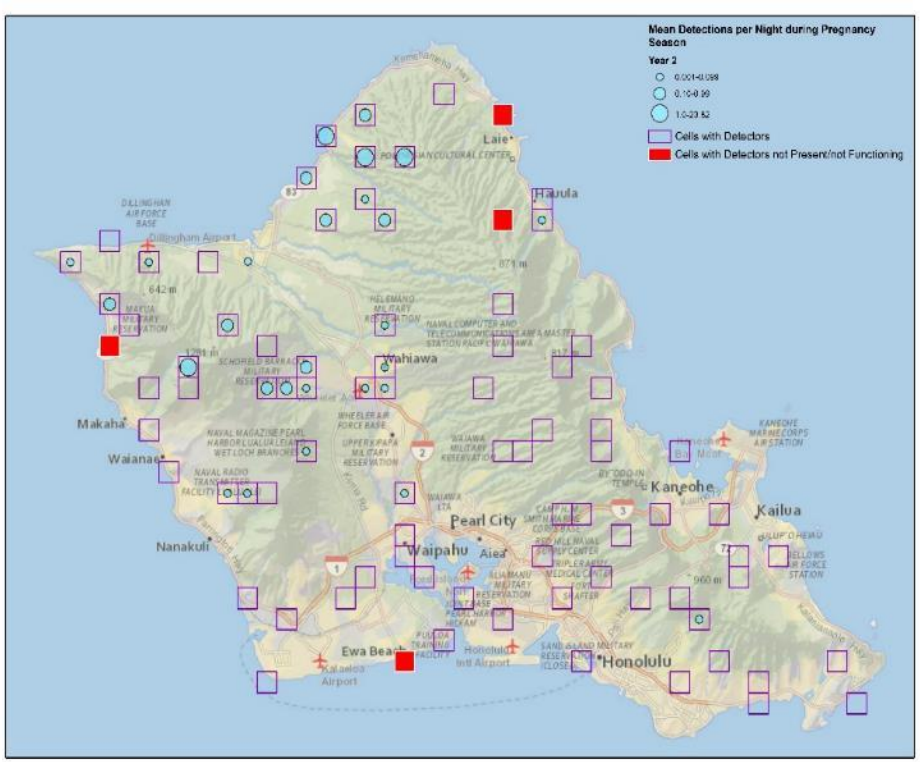
Mean detections / detector night

- Year 1: 0 – 13.1 (avg = 0.23)
- Year 2: 0 – 2.1 (avg = 0.04)

DETECTION RATE – YEAR TO YEAR COMPARISONS



Pregnancy Year 1

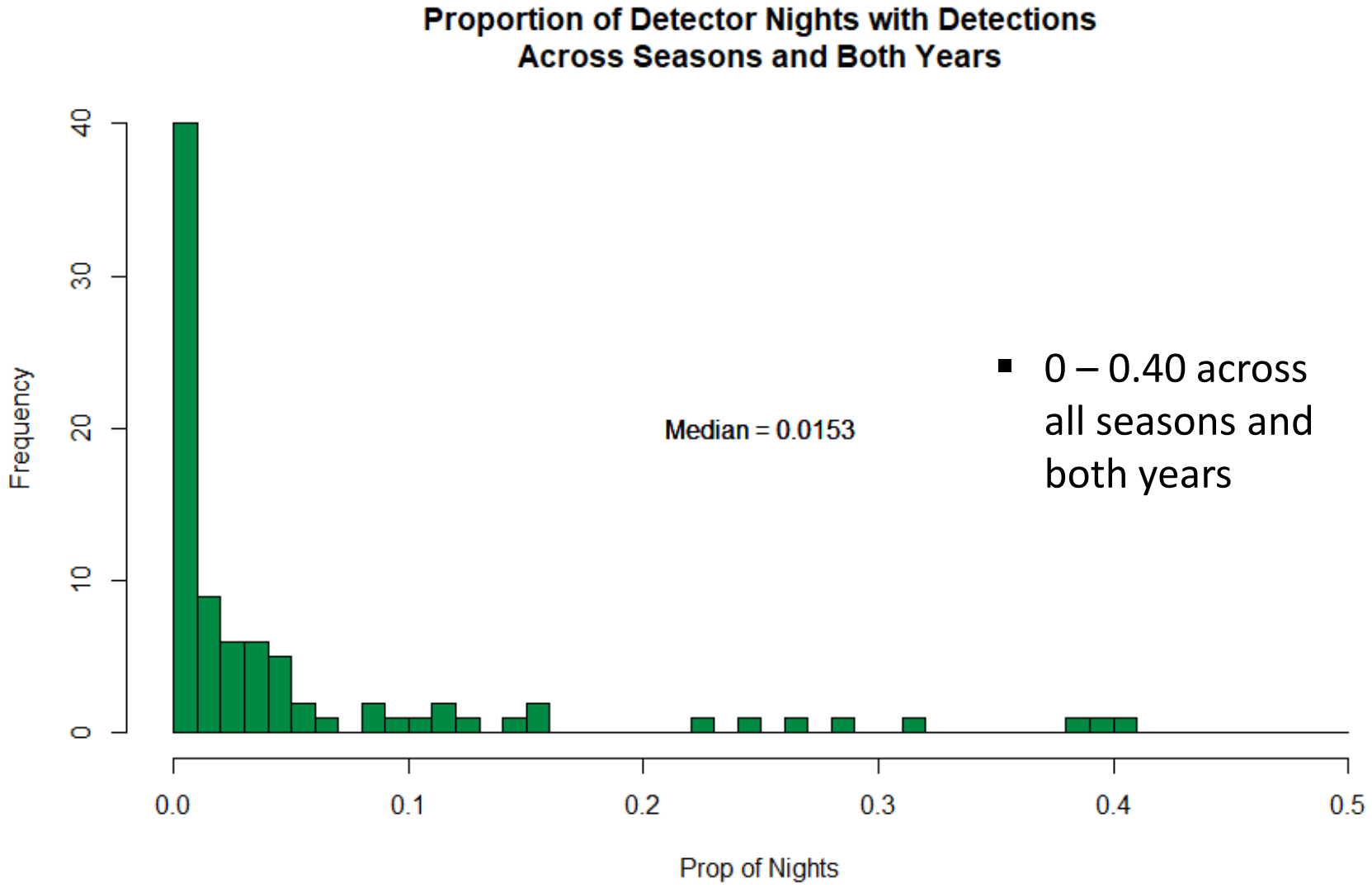


Pregnancy Year 2

Mean detections / detector night

- Year 1: 0 – 3.8 (avg = 0.15)
- Year 2: 0 – 7.9 (avg = 0.21)

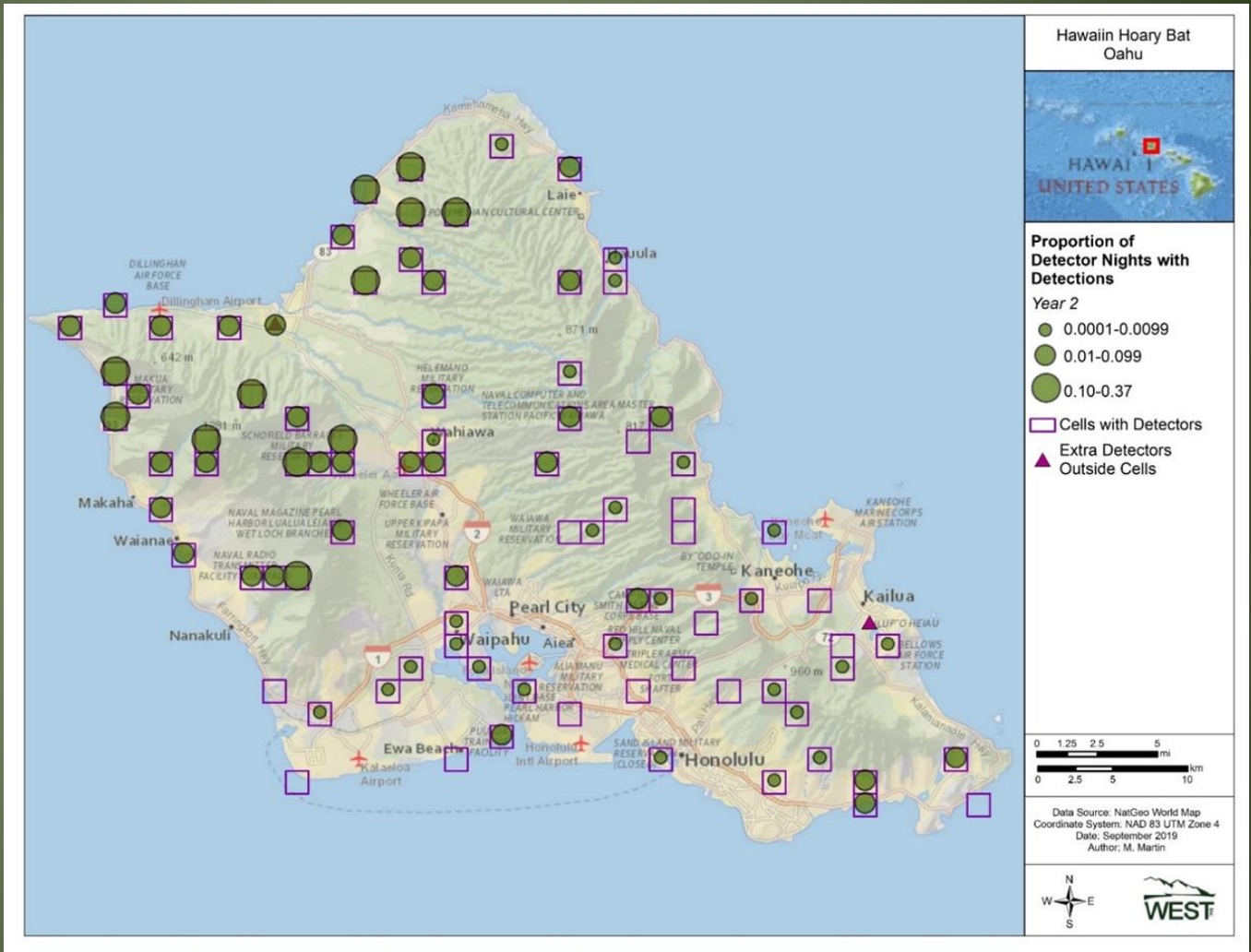
RESULTS – Proportion of Nights With Detections



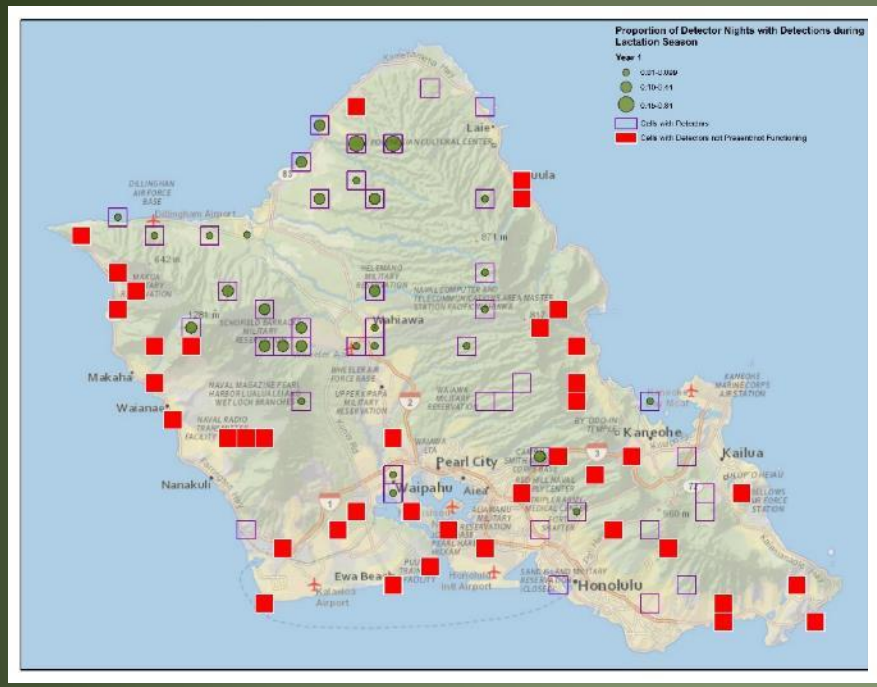
- 0 – 0.40 across all seasons and both years

PROPORTION OF NIGHTS WITH DETECTIONS

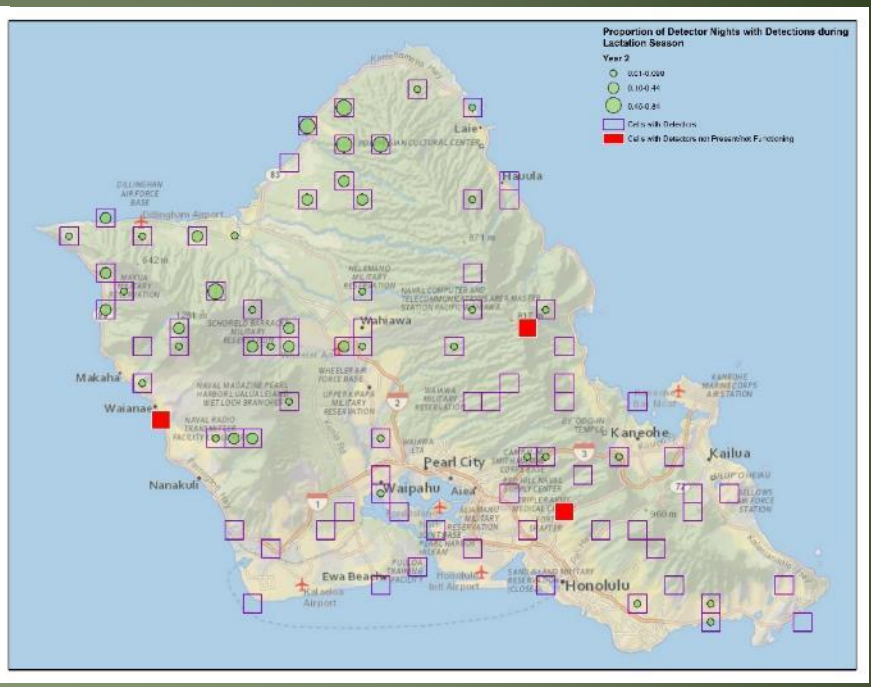
- Year 1
  - 0 – 0.52 across all seasons
- Year 2
  - 0 – 0.37 across all seasons



PROPORTION OF NIGHTS WITH DETECTIONS ANNUAL COMPARISONS



Lactation Year 1

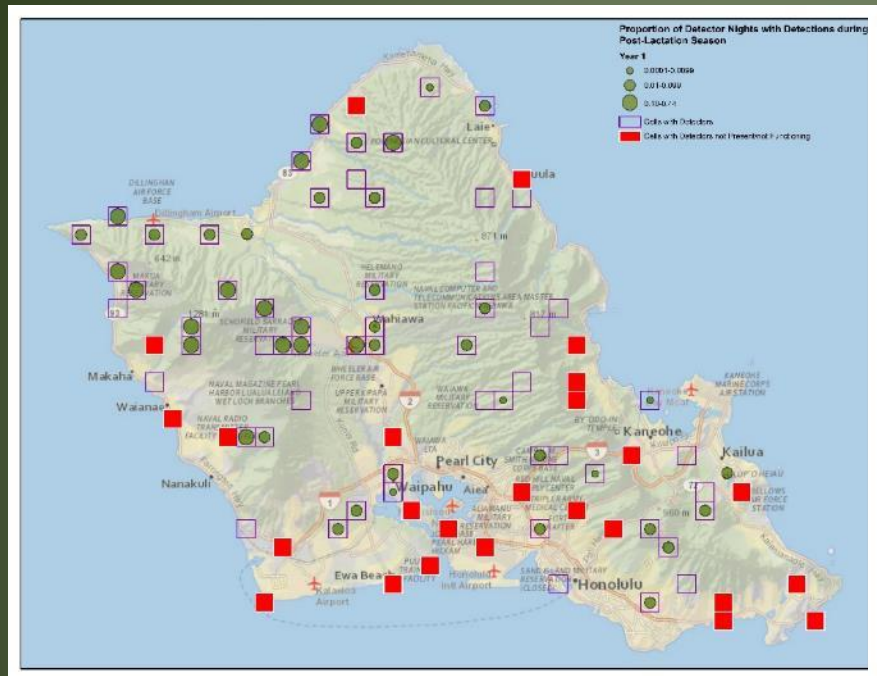


Lactation Year 2

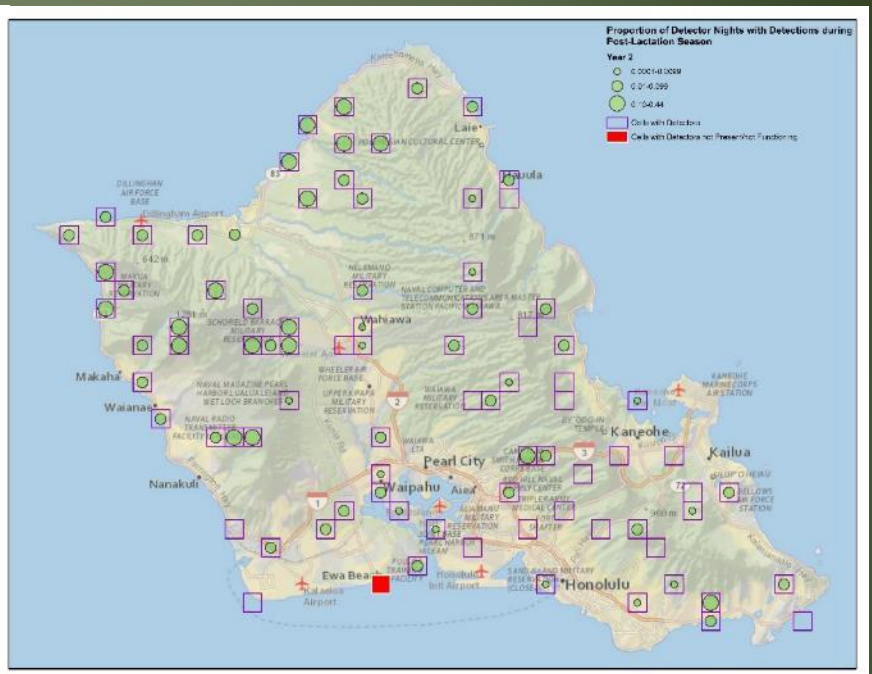
Proportion Nights With Detections

- Year 1: 0 – 0.84 (0.11)
- Year 2: 0 – 0.72 (0.08)

PROPORTION OF NIGHTS WITH DETECTIONS ANNUAL COMPARISONS



Post-Lactation Year 1

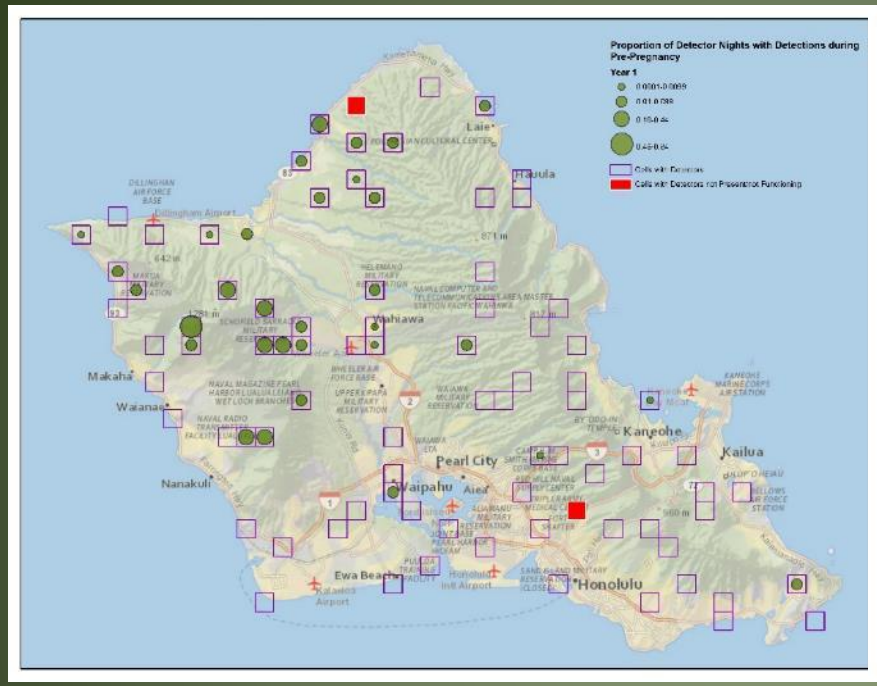


Post-Lactation Year 2

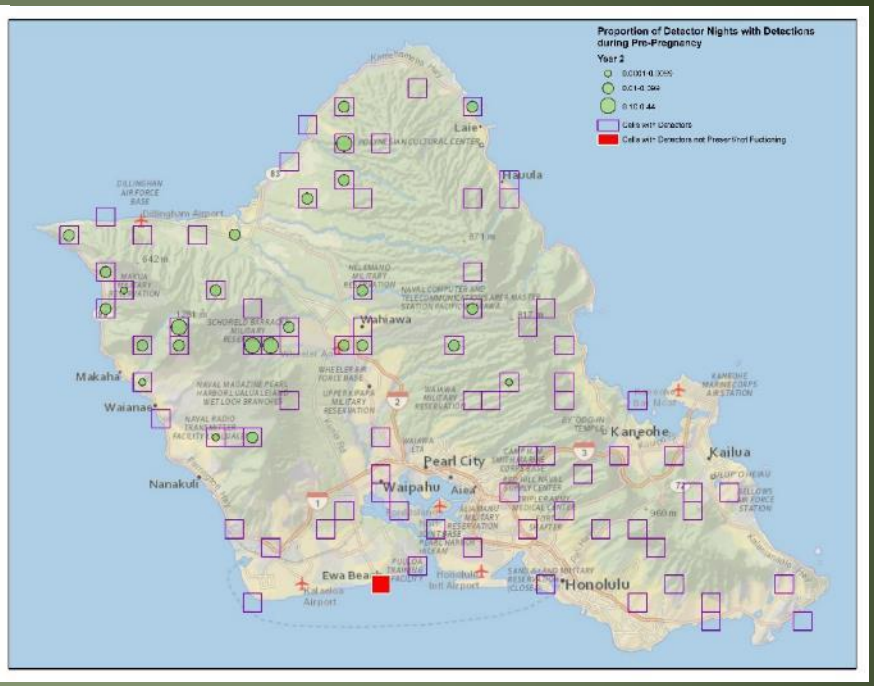
Proportion Nights With Detections

- Year 1: 0 – 0.45 (0.08)
- Year 2: 0 – 0.45 (0.06)

PROPORTION OF NIGHTS WITH DETECTIONS ANNUAL COMPARISONS



Pre-Pregnancy Year 1

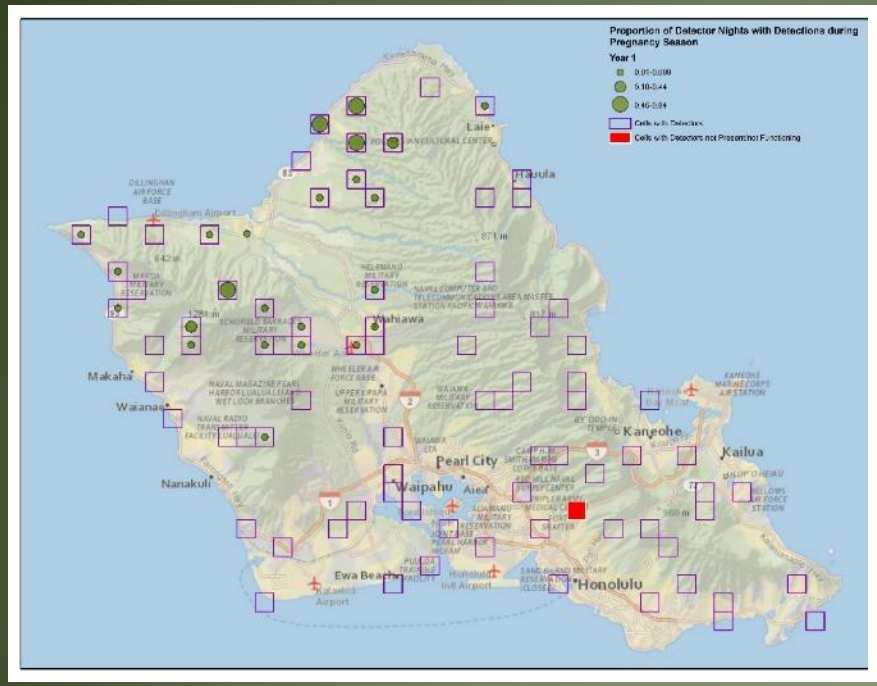


Pre-Pregnancy Year 2

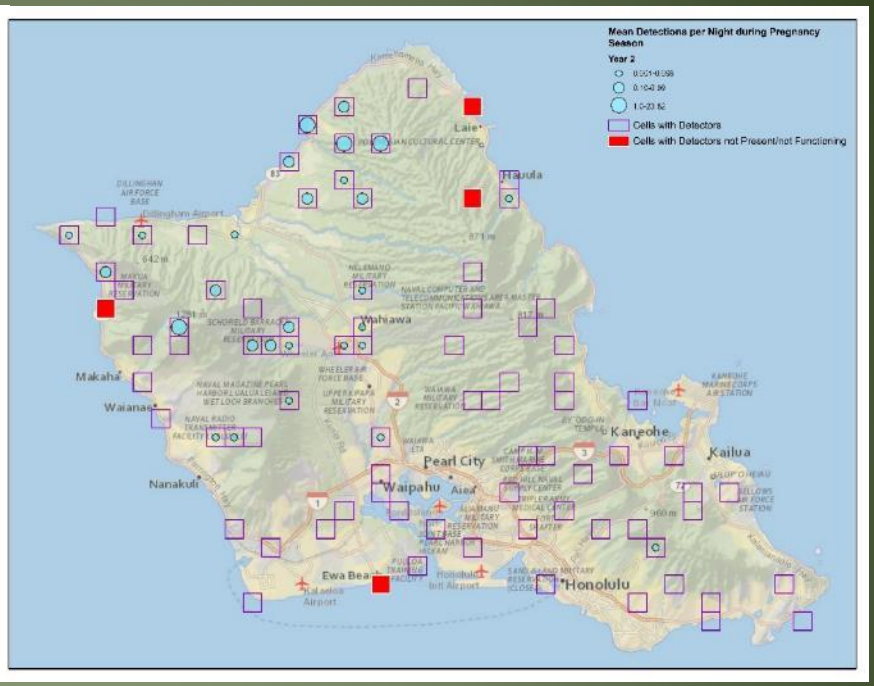
Proportion Nights With Detections

- Year 1: 0 – 0.57 (0.03)
- Year 2: 0 – 0.31 (0.02)

PROPORTION OF NIGHTS WITH DETECTIONS ANNUAL COMPARISONS



Pregnancy Year 1

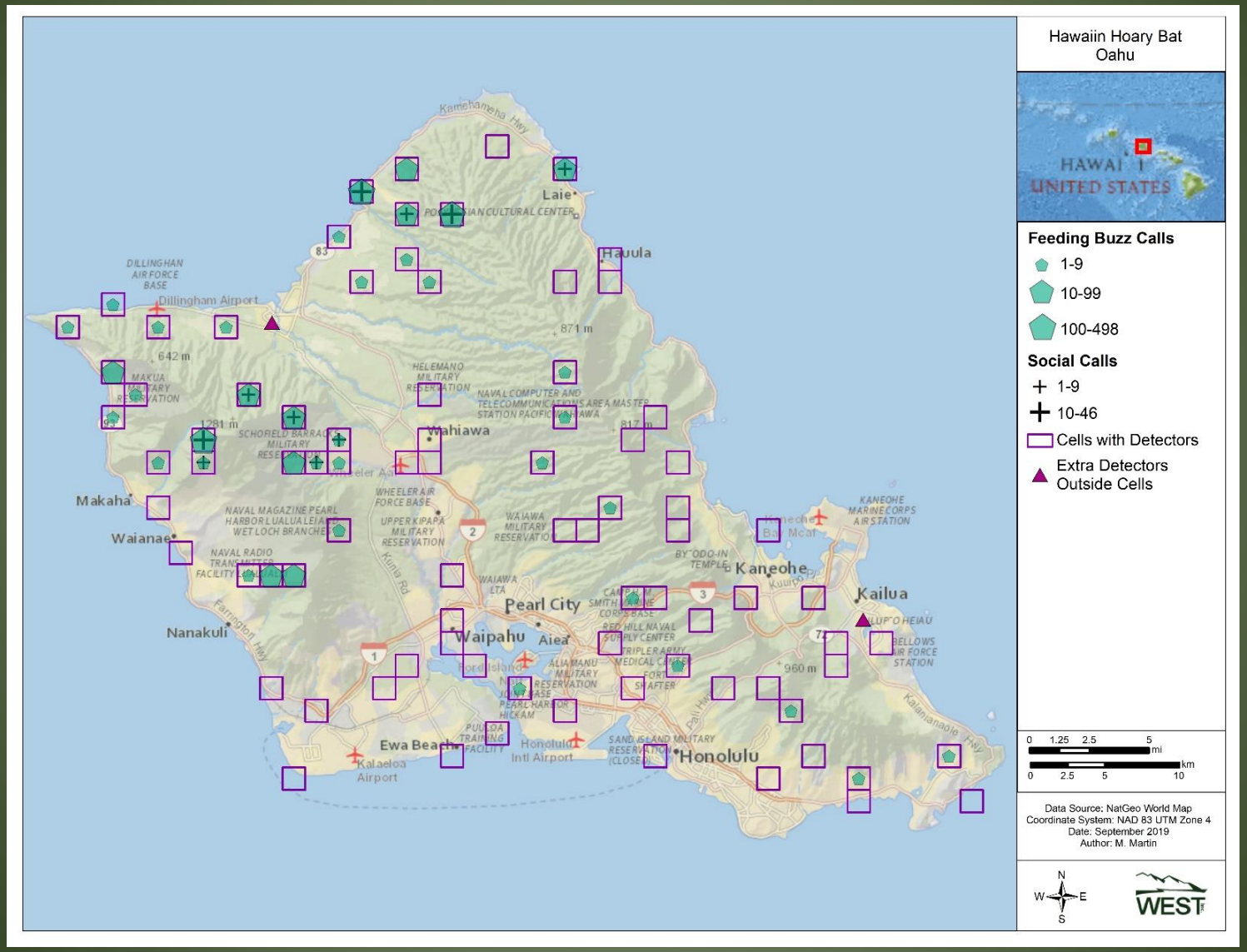


Pregnancy Year 2

Proportion Nights With Detections

- Year 1: 0 – 0.71 (0.04)
- Year 2: 0 – 0.50 (0.05)

FEEDING BUZZES and SOCIAL CALLS



Questions/Discussion regarding Distribution

OCCUPANCY ANALYSIS – INDEPENDENCE OF DATA

Join count test results for correlated detections, four seasons, and four sampling intervals across the first two survey years.

Season	Interval (days)	Model	Year 1		Year 2	
			Join count χ^2	p-value	Join count χ^2	p-value
Lactation	**7**	**Corr.**	**13.89**	**0.029**	**699.87**	**0**
	10	**Corr.**	**146.86**	**<0.001**	**11.65**	**0.062**
	14	Corr.	5.50	0.145	4.82	0.144
	21	Corr.	1.38	0.475	2.83	0.194
Post-Lactation	7	Corr.	4.06	0.436	1.28	0.906
	10	Corr.	5.56	0.152	2.15	0.627
	14	Corr.	2.09	0.395	0.94	0.402
	21	Corr.	0.30	0.590	4.22	0.054
Pre-Pregnancy	7	Corr.	2.79	0.893	0.08	0.367
	10	Corr.	7.73	0.094	0.94	0.415
	14	Corr.	1.51	0.382	0.49	0.694
	21	Corr.	1.65	0.303	1.54	0.848
Pregnancy	7	Corr.	10.48	0.187	4.82	0.417
	10	Corr.	2.32	0.625	2.28	0.313
	14	Corr.	3.69	0.412	0.43	0.880
	21	Corr.	0.21	0.990	0.81	0.715

SITE LEVEL COVARIATES FOR OCCUPANCE MODELING

Site-level Covariate	Description
PopSqMi	Human population per square mile (mi) in each grid cell.
PopSqMiClass	0 if population density <64.60 people per square mi, 1 otherwise.
Elev	Mean site elevation in meters in each grid cell.
ElevClass	0 if Elevation <141.43 m, 1 otherwise.
PctTrees	Percent tree cover in grid cell.
PctTreesClass	0 if percent tree cover <20.68%, 1 otherwise.

RESULTS – MULTI-SEASON DYNAMIC OCCUPANCY MODEL FOR CORRELATED DETECTIONS

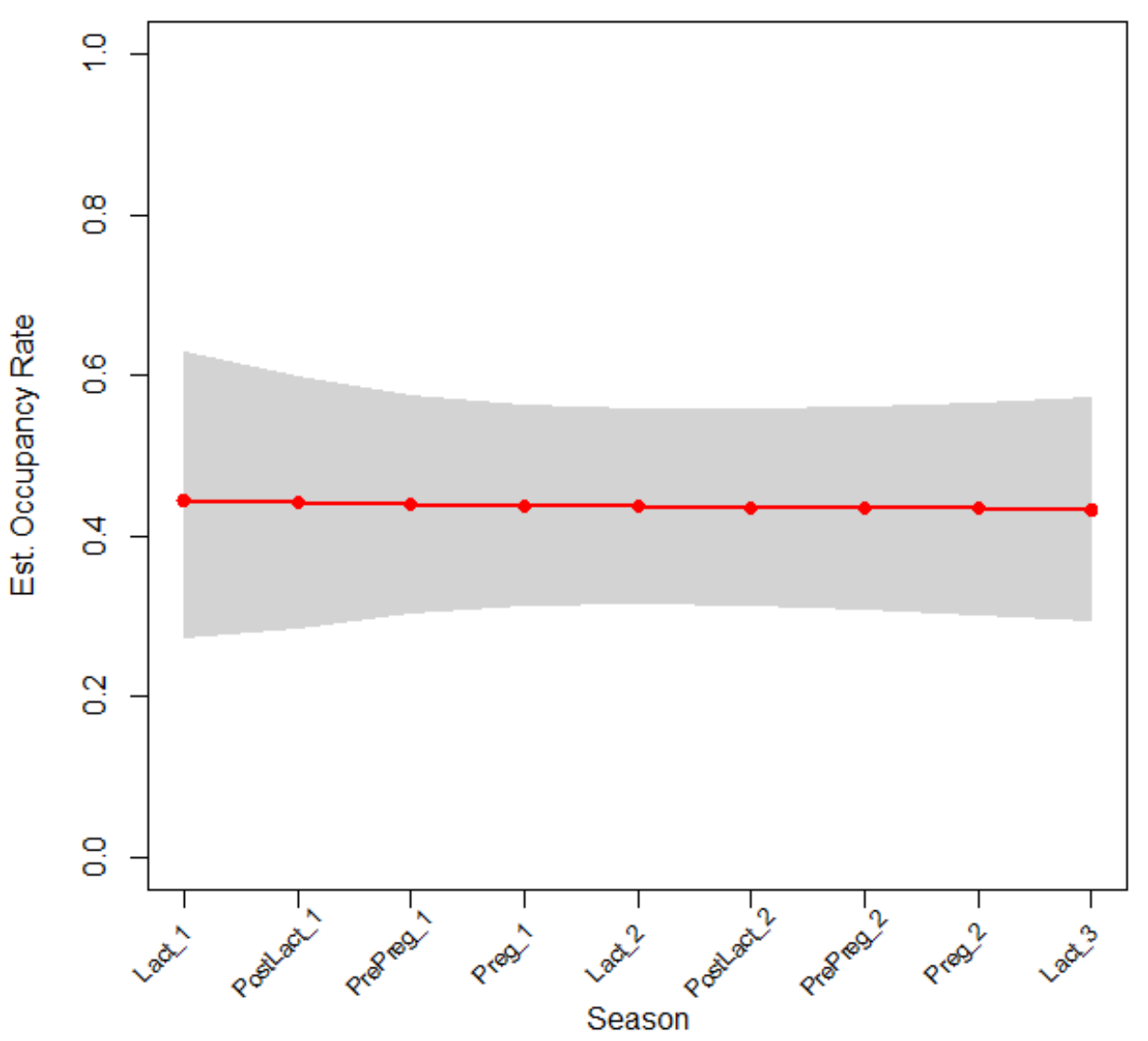
Multi-season model with detection probability modeled by season and PopSqMiClass generated the lowest AIC value based on the 2-year dataset

Model	AIC	Delta AIC	AIC wgt
psi,th0(),th1(),gam(),eps(),p(Season),th0pi(PopSqMiClass)	2120.24	1.06	0.3031
psi,th0(),th1(),gam(),eps(),p(Season),th0pi(PopSqMi)	2123.64	4.46	0.0554

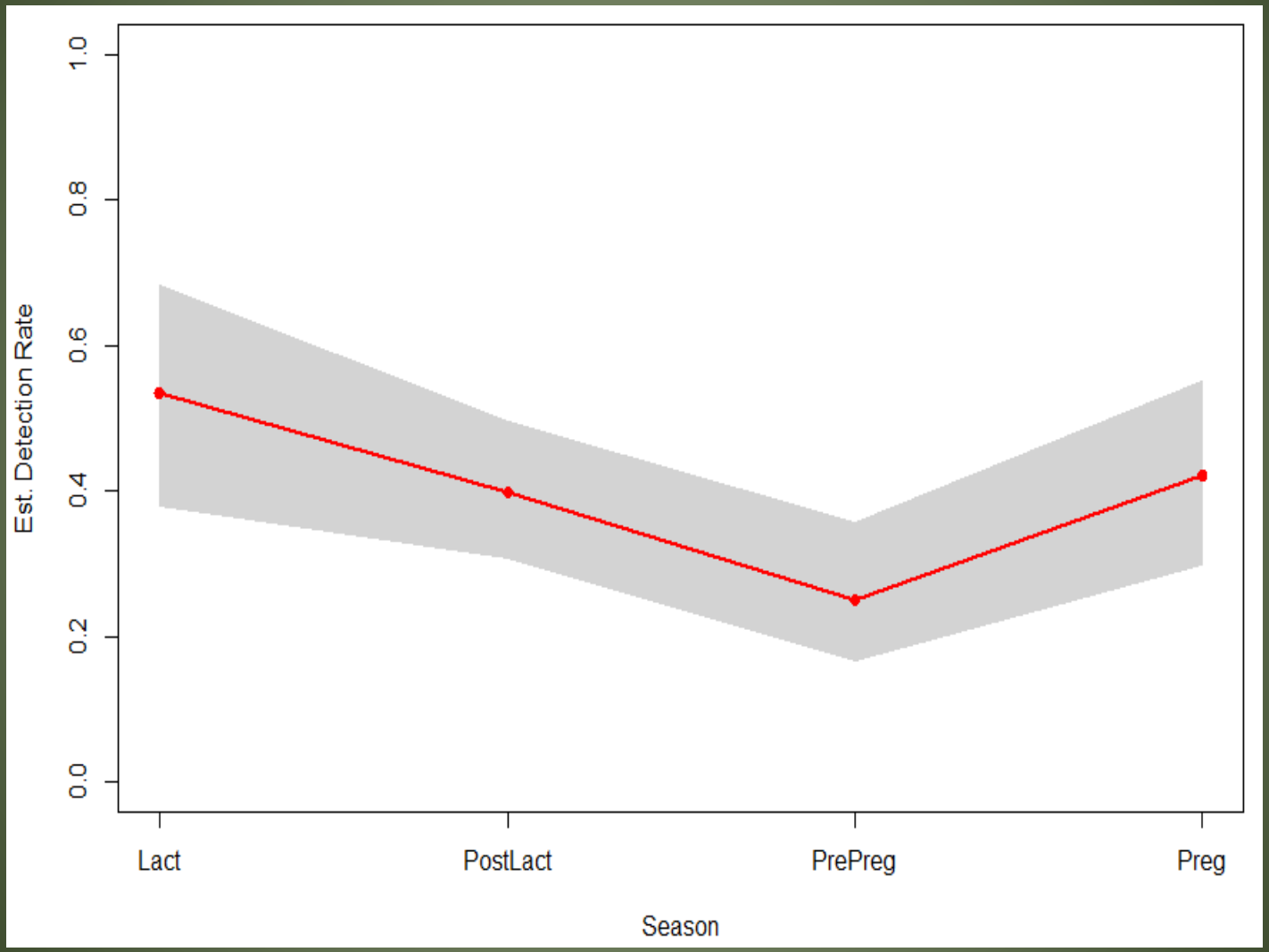
OCCUPANCY AND DETECTION PROBABILITIES FOR TOP MODEL

Year	Season	Est. Occ. Rate	SE	95% CI	Est. Detection Prob.	SE	95% CI
1	Lactation	0.4465	0.0951	(0.2750, 0.6317)	0.5347	0.0795	(0.3806, 0.6825)
1	Post-Lactation	0.4435	0.0798	(0.2872, 0.5999)	0.3977	0.0485	(0.3076, 0.4954)
1	Pre-Preg	0.4410	0.0693	(0.3051, 0.5769)	0.2500	0.0485	(0.1673, 0.3562)
1	Preg	0.4388	0.0635	(0.3145, 0.5632)	0.4204	0.0655	(0.2998, 0.5512)
2	Lactation	0.4370	0.0614	(0.3167, 0.5573)	0.5347	0.0795	(0.3806, 0.6825)
2	Post-Lactation	0.4354	0.0620	(0.3138, 0.5570)	0.3977	0.0485	(0.3076, 0.4954)
2	Pre-Preg	0.4340	0.0644	(0.3078, 0.5601)	0.2500	0.0485	(0.1673, 0.3562)
2	Preg	0.4328	0.0676	(0.3004, 0.5652)	0.4204	0.0655	(0.2998, 0.5512)
3	Lactation	0.4317	0.0710	(0.2925, 0.5710)	0.5347	0.0795	(0.3806, 0.6825)

OCCUPANY ESTIMATES AND 95% CONFIDENCE BANDS BY SEASON AND YEAR



DETECTION PROBABILITY AND 95% CONFIDENCE BANDS BY SEASON



SAMPLE SIZE ASSESSMENT

Sample size approximation for 20% relative precision based on estimates of detection and occupancy rates for the 14-day interval Lactation data season, 7-day sample intervals for the other three seasons.

Interval	Est. occupancy rate (Ψ)	Est. availability rate given previous availability	Est. detection rate given availability	Est. detection rate (p)	Sample size (α = 0.10)
Lactation	0.45	0.82	0.53	0.44	84
Post-Lactation	0.44	0.82	0.40	0.33	85
Pre-Preg	0.44	0.82	0.25	0.21	86
Preg	0.44	0.82	0.42	0.35	87

INSIGHTS FROM FIRST 2 YEARS OF STUDY

- Temporal correlation among acoustic data is high
- Distribution (i.e., acoustic activity) appears to vary by season, but consistently more widespread during lactation and post-lactation periods (summer & fall)
- Feeding buzzes and social calls most prevalent in areas of highest activity
- Occupancy rates are inversely associated with population density, but not with tree cover or elevation
- Probability of detection varies quite a lot across seasons, while occupancy estimates have been consistent
- High degree of consistency in seasonal and annual detection rates and occupancy estimates across years
- Additional data should continue to improve models as we gain another transition among seasons

NEXT STEPS

- 1-2 more years of data to be collected and analyzed
- Remove a few detectors initially deployed to assess distribution
- Continue to monitoring same sites to ensure detection probability is accurately estimated and that habitat and detection variables are not confounded (MacKenzie 2006)
- Assess seasonal distribution relative to extinction and colonization rates (i.e., are the bats there and not detectable or is there distribution changing)
- Assess Bayesian approach to occupancy analysis to see if it may allow for better inclusion of habitat variables

QUESTIONS - DISCUSSION

DRONE TRANSECT SURVEYS – PILOT STUDY

- Unmanned aerial vehicle and a high-resolution thermal camera
- Estimate density and abundance on a study area (e.g., within a cell) using line transect survey approach
- Transects optimized for coverage based on visual LOS
- Does density correlate with acoustic activity?

SURVEYS WITH DRONES – PILOT STUDY JULY 2019

- 1.5 nights flying with Marcos on the Big Island
  - Testing of heights and speed
  - Few bats detected and all were skylit (drone on ground or ascending)
- 4 nights flying on Oahu – 15-20 transects per night
  - 3 grid cells all on North Shore
  - Successful deployment at various heights and speeds
  - Few bats detected (only 1 or 2 on flights)
- Technique worked well in the field (consistent contouring automated flight)
- Multiple heights and speeds tested

DRONE TEST – BAT FROM GROUND (Big Island)

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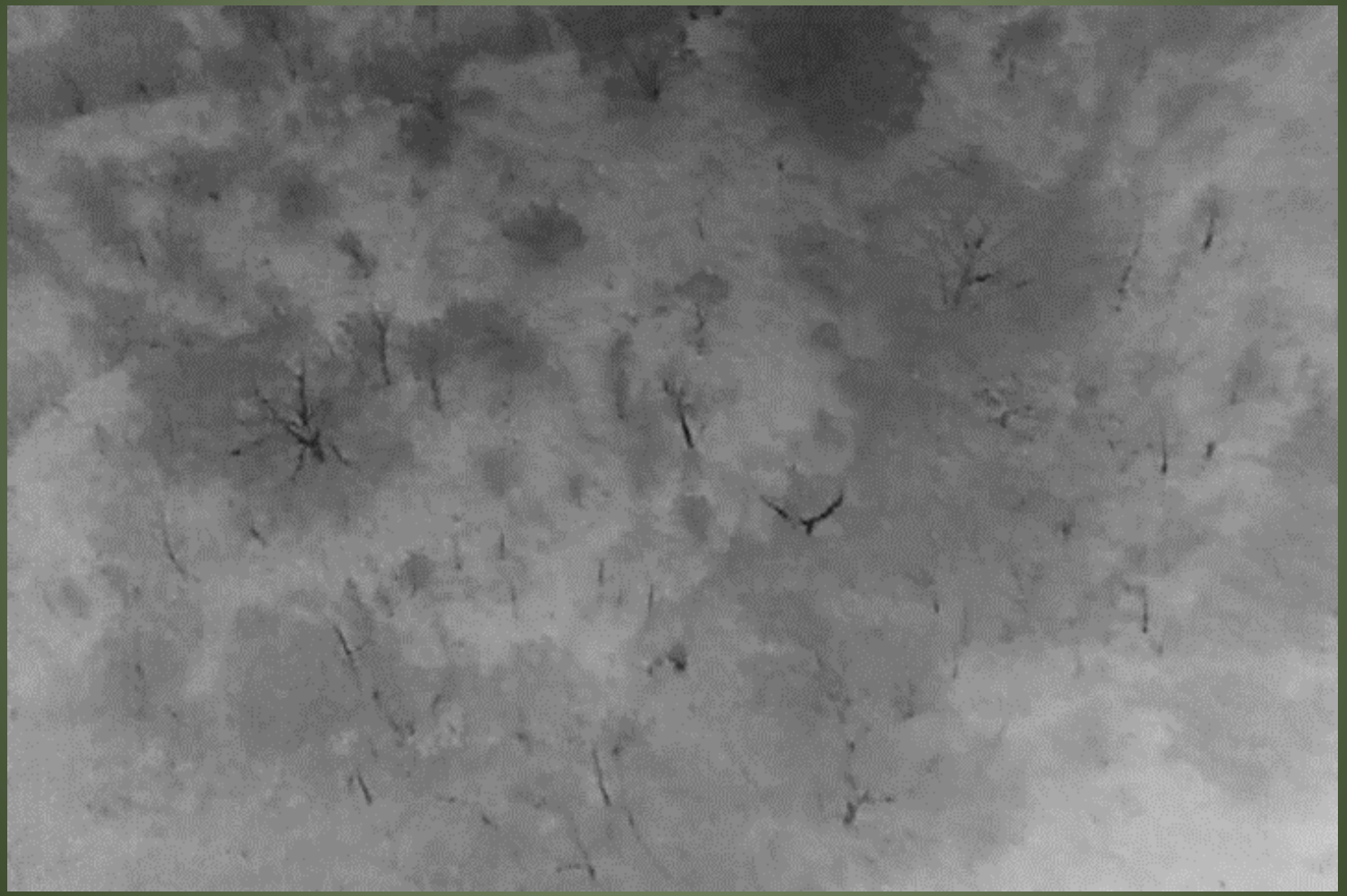
DRONE TRANSECT SURVEY – OWL (OAHU)

DRONE TRANSECT SURVEY – BAT (OAHU)

DRONE TRANSECT SURVEY – BAT? (OAHU)



QUESTIONS - DISCUSSION

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