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

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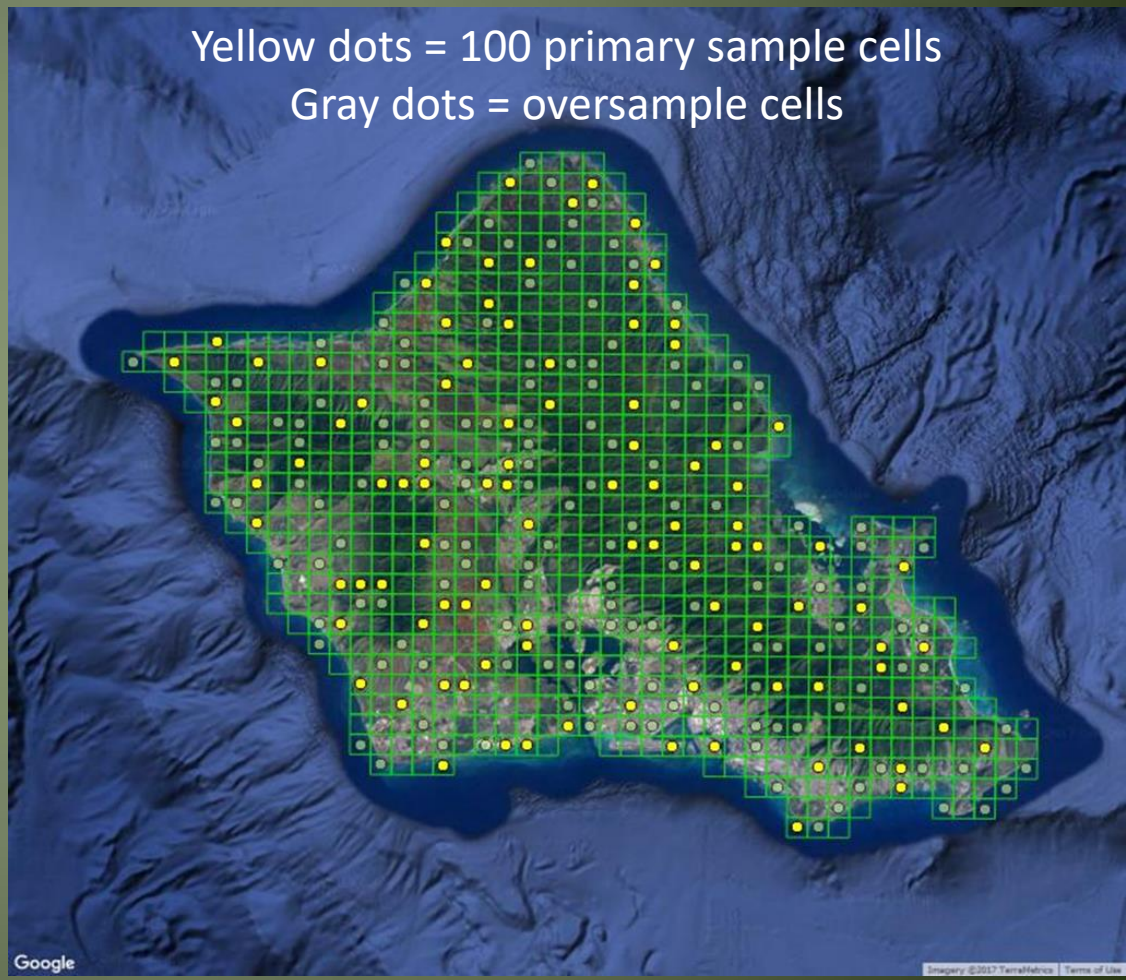
OBJECTIVES AND STUDY DESIGN

- 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

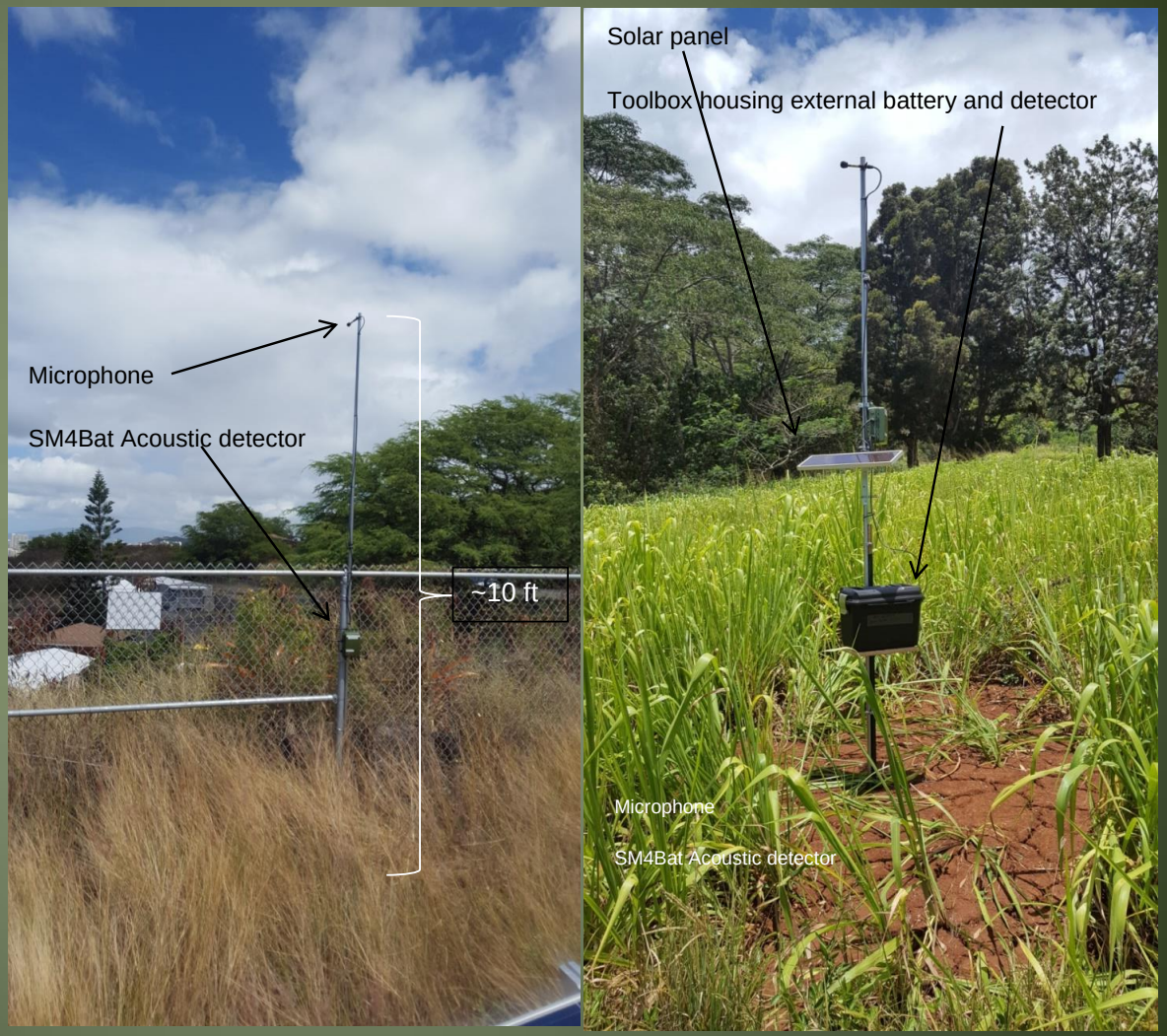


Figure 2. Examples of commonly used set-ups of the Wildlife Acoustics SM4Bat detectors used in the Hawaiian hoary bat Occupancy and Distribution study on Oahu, June 2017 – July 2018.

YEAR 1 OBJECTIVES - SEASONAL DISTRIBUTION ACROSS OAHU

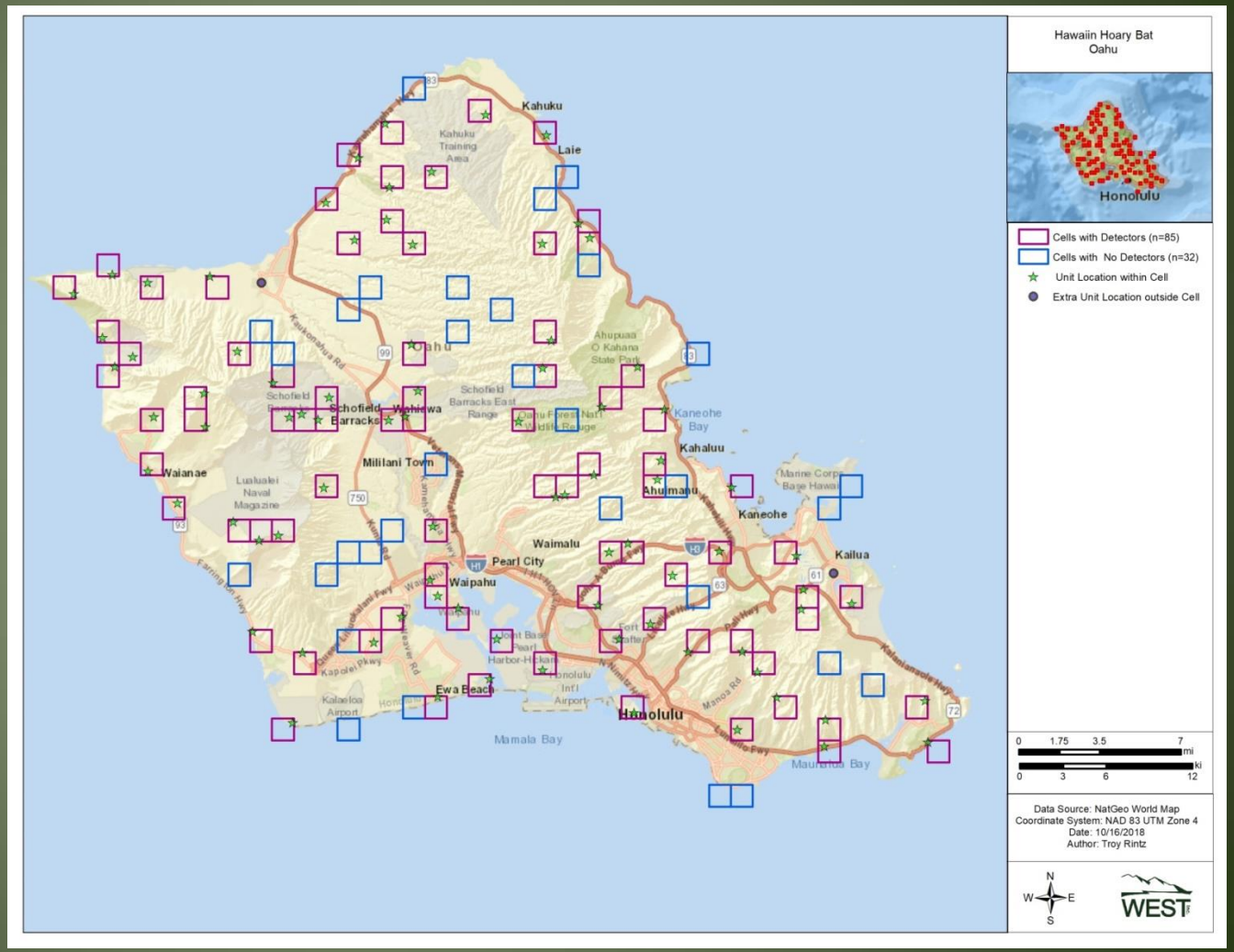
- Basic information – where, when, how often
  - Where were bats detected and during which season
  - Average number of detections per detector night
  - Proportion of detector nights bats were detected at individual sites
- Seasons were defined based on reproduction periods (Menard 2001 and Gorresen 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

- Examined two main models:
  1. **Single-season occupancy model** assuming population closure across seasons within a year, but seasonal differences in detection
  2. **Multi-season occupancy model** where site-level occupancy is expected to change for at least one season
- Single-season models used to estimate occupancy (Ψ) and detection (p) as a function of Month or Season
- Multi-season models parameterized changes in occupancy as a function of extinction (ε) and colonization (γ) which are also modeled as a function of Month or Season
- Occupancy analysis conducted with *unmarked* package (Fiske and Chandler 2011) in R and in Program PRESENCE (Hines 2006)

RESULTS - DISTRIBUTION

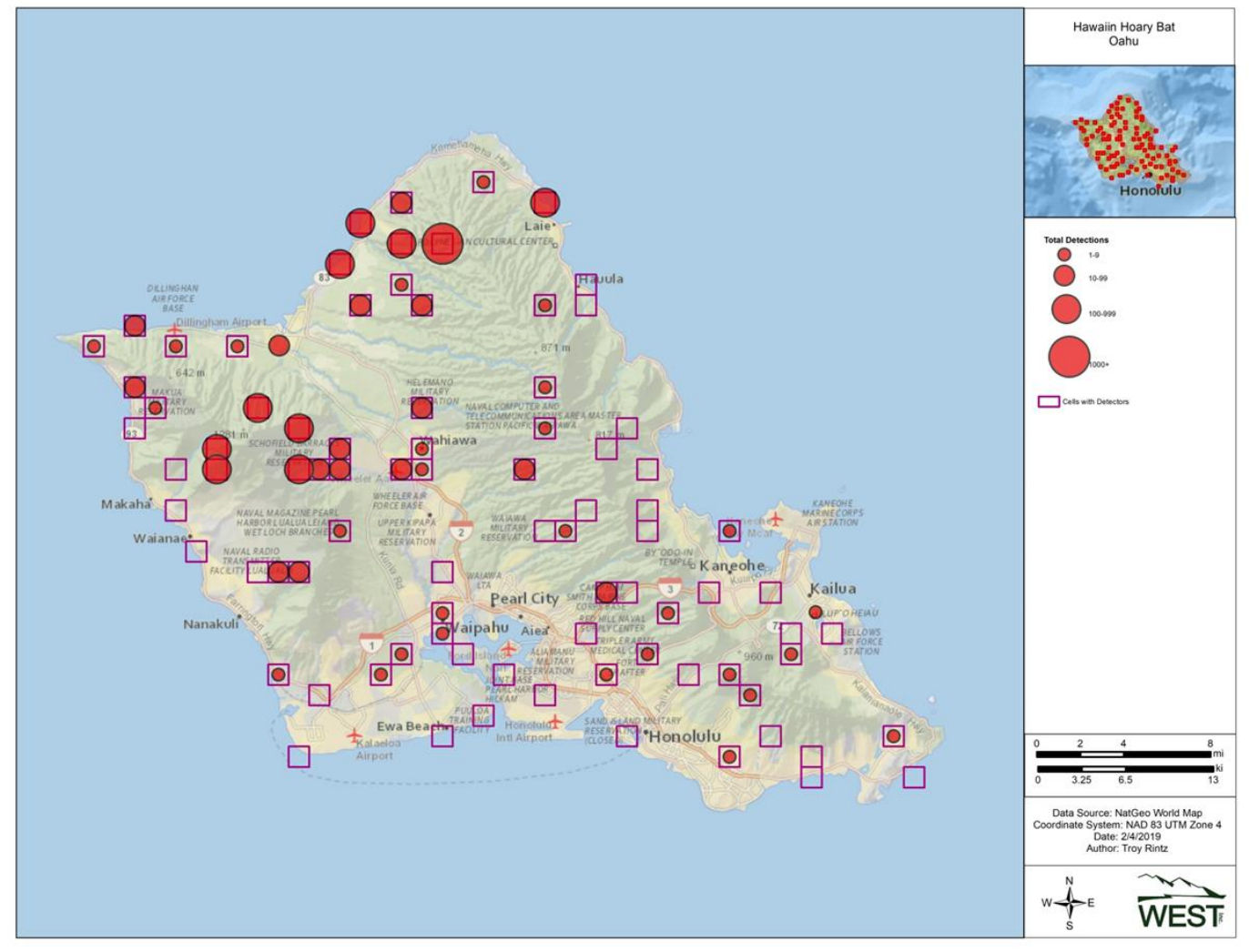
- 87 detectors in the field
- 85 detectors in GRTS cells
- Data from 83 detectors in Year 1 analysis (June 2017 – June 2018)



RESULTS - DISTRIBUTION

June 2017 – June 2018

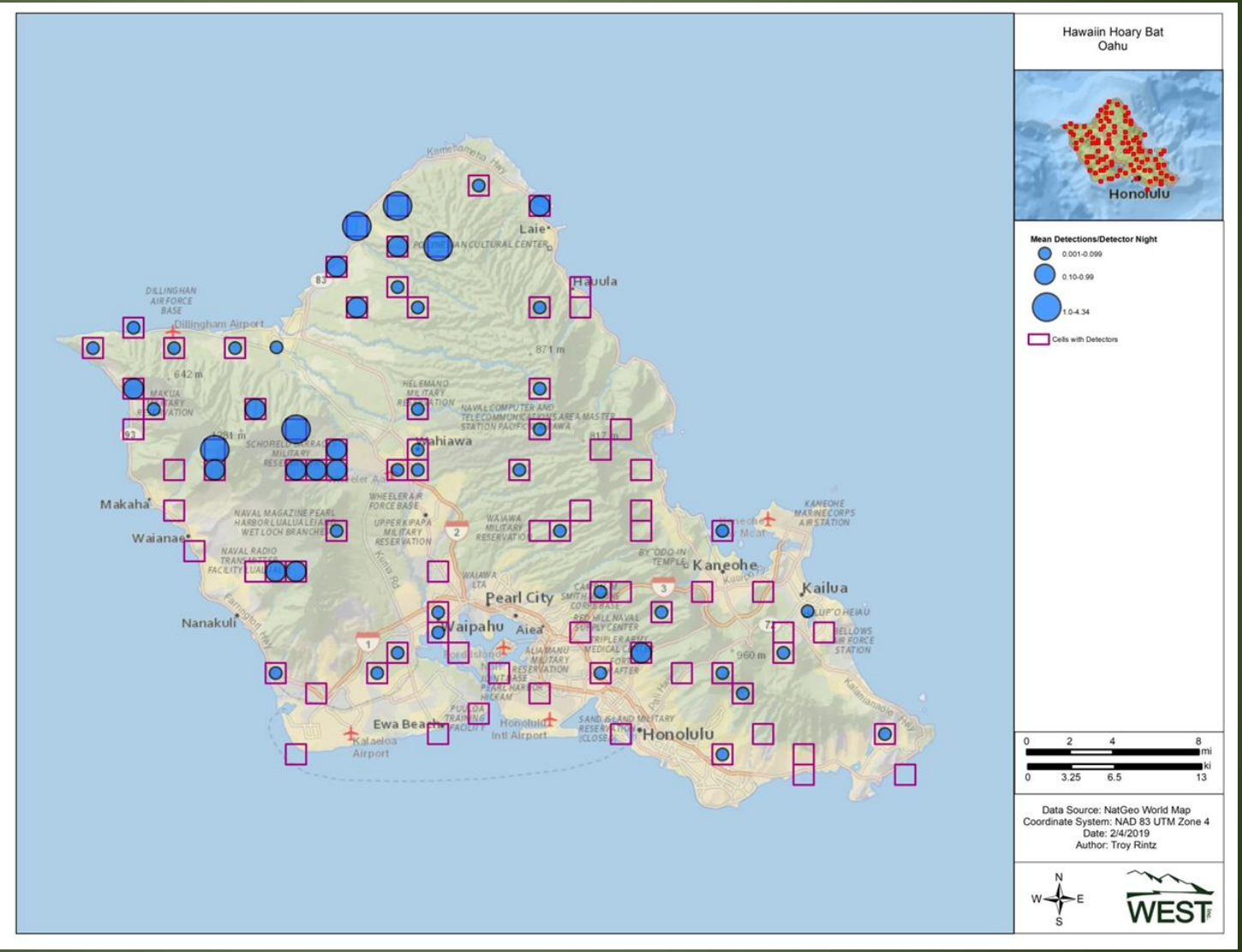
- 18 - 356 detector nights
- 4,808 detections
- 0 – 1,512 detections per site
- 51 of 83 (61%) detectors with ≥1 detection



RESULTS – MEAN DETECTIONS PER NIGHT

Mean detections / detector night

- 0 - 4.34 across all seasons



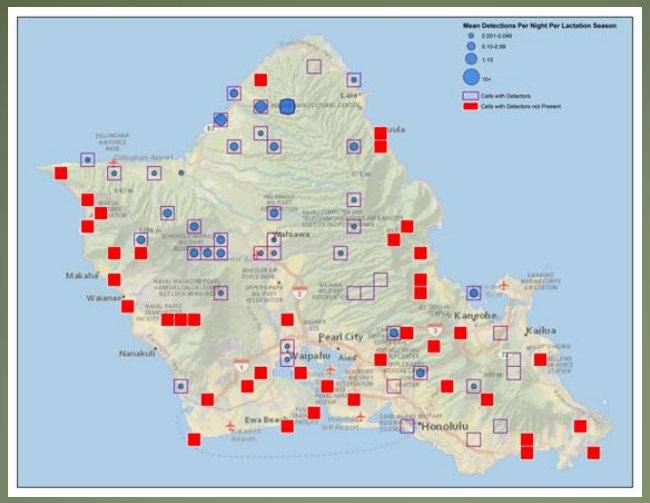
RESULTS : TOTAL CALLS TOP 20

Site ID	Site Name	Detections	Nights with Detections	Detector Nights‡	Mean Detections Per Detector Night	Proportion of Detector Nights with Detections
Site-039	Pupukea	1,512	102	348	4.3448	0.2931
Site-053	Kumaipo LZ	906	80	242	3.7438	0.3306
Site-103	Schofield Forest	418	84	328	1.2744	0.2561
Site-075	Peerson	395	112	343	1.1516	0.3265
Site-115	Waianae Valley	215	32	258	0.8333	0.124
Site-013	KAW Gate	188	79	352	0.5341	0.2244
Site-023	Waimea Valley	168	69	322	0.5217	0.2143
Site-097	Malaekahana SP	151	8	248	0.6089	0.0323
Site-061	Mt Kaala	150	91	307	0.4886	0.2964
Site-041	Schofield 3	105	29	332	0.3163	0.0873
Site-025	Schofield	82	56	332	0.247	0.1687
Site-079	Makua Ridge	58	34	286	0.2028	0.1189
Site-057	McCarthy Field	58	37	332	0.1747	0.1114
Site-083	Lualualei 2	56	24	220	0.2545	0.1091
Site-101	Pupukea Paumalu	45	11	18	2.5	0.6111
Site-087	Schofield 1	35	28	332	0.1054	0.0843
Site-029	KAW Rd	28	25	253	0.1107	0.0988
Site-021	Lualualei 1	24	16	220	0.1091	0.0727
Site-035	Helemano	21	20	332	0.0633	0.0602
Site-081	KAW 2	21	20	352	0.0597	0.0568

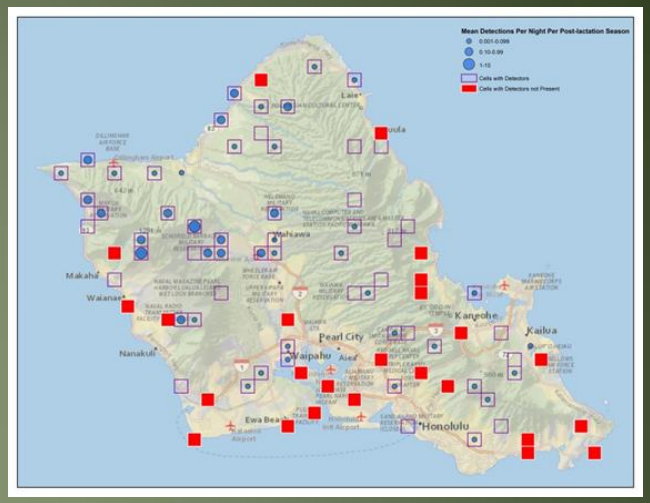
RESULTS – Detections / Detector Night

Mean detections / detector night

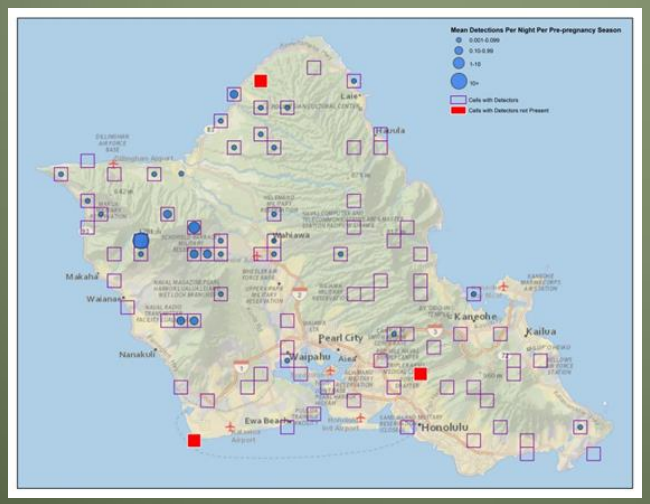
- 0 - 4.34 all seasons
- 0 – 21.54 w/i seasons



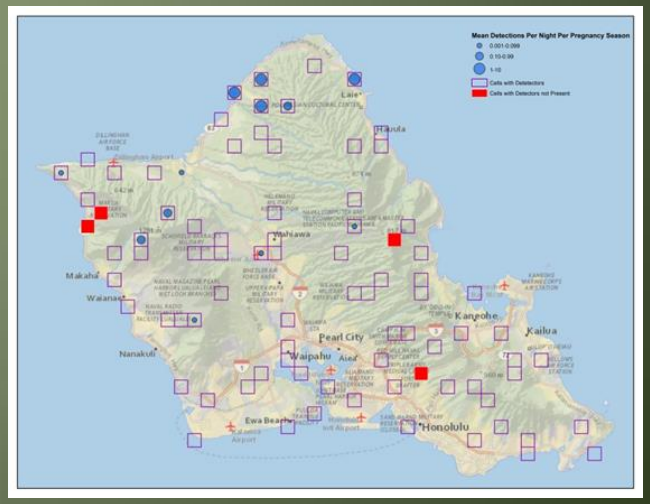
Lactation



Post-Lactation



Pre-pregnancy

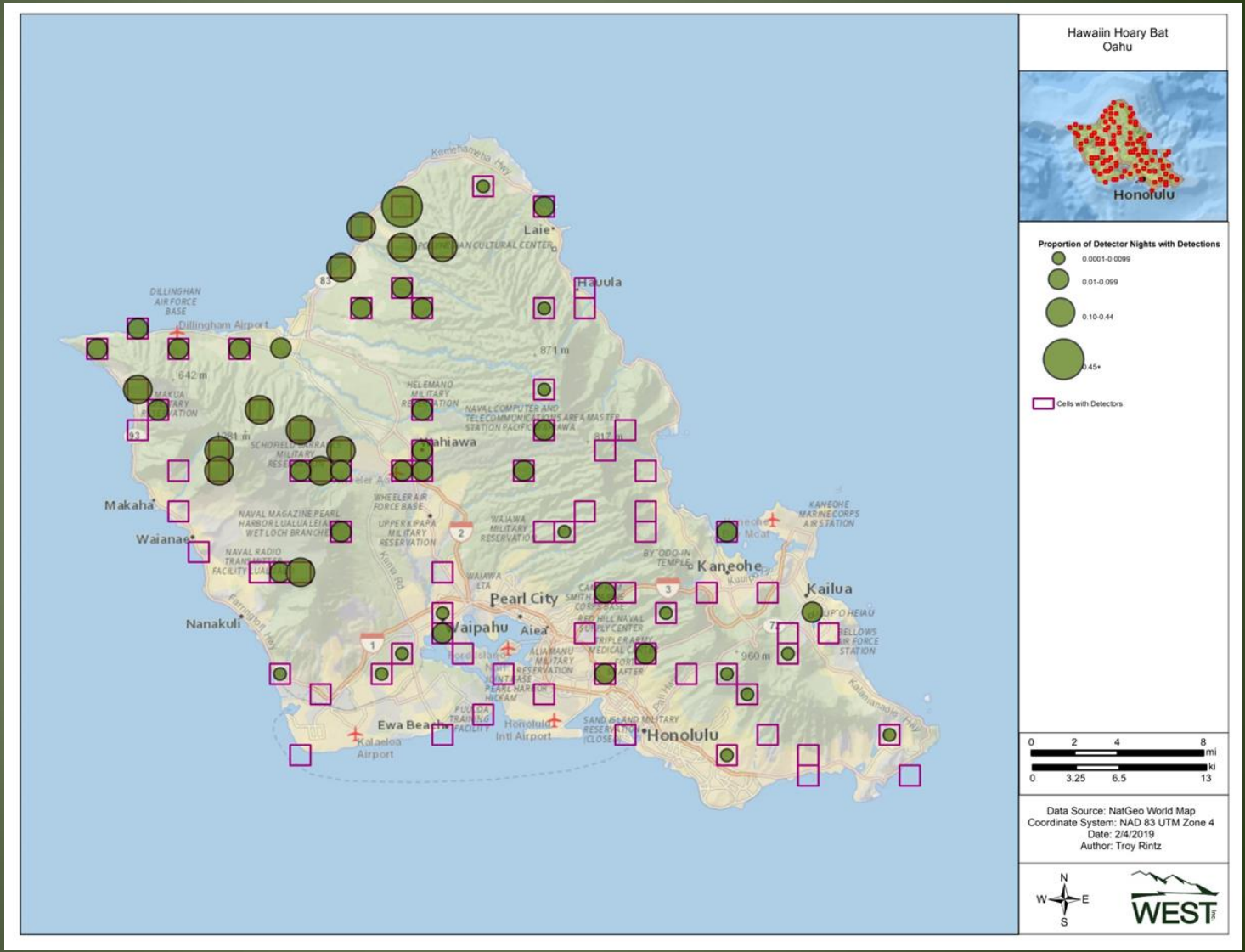


Pregnancy

RESULTS – Proportion of Nights With Detections

Proportion of Detector Nights with Detections

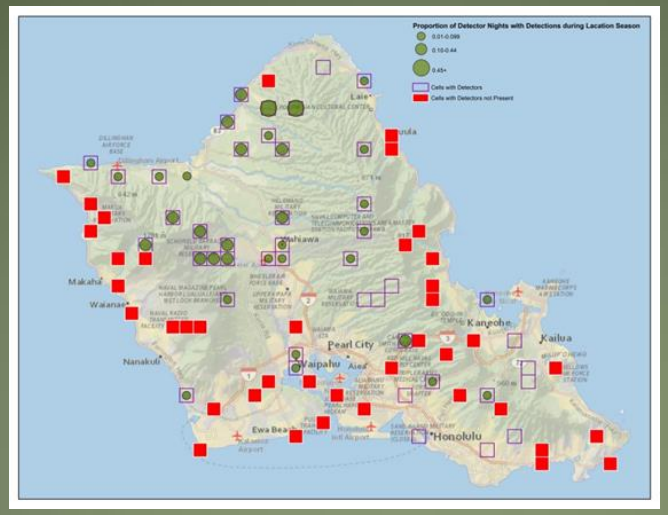
- 0 – 0.33 across all seasons (>1 season of data)



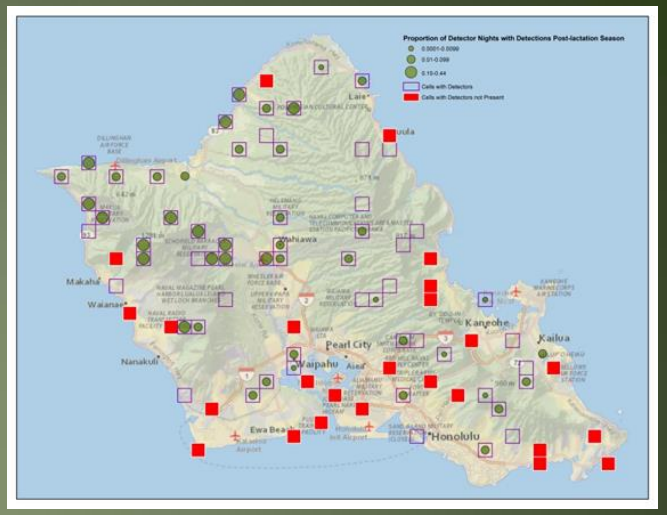
RESULTS – Proportion Nights With Detections

Proportion of Detector Nights with Detections

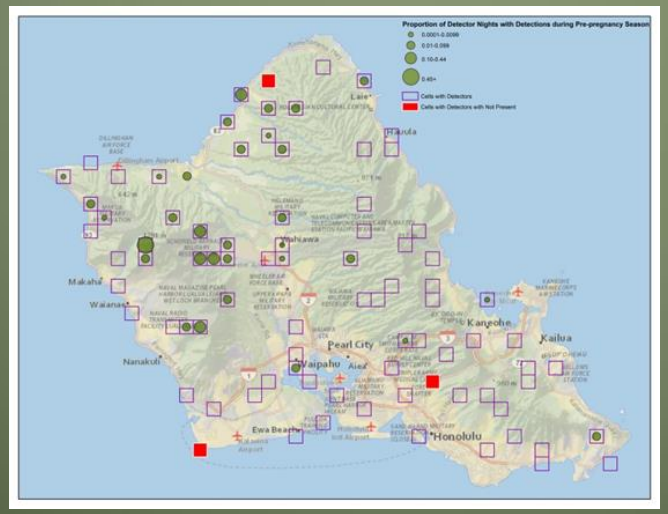
- 0 – 0.33 across all seasons (>1 season of data)
- 0 – 0.84 within seasons



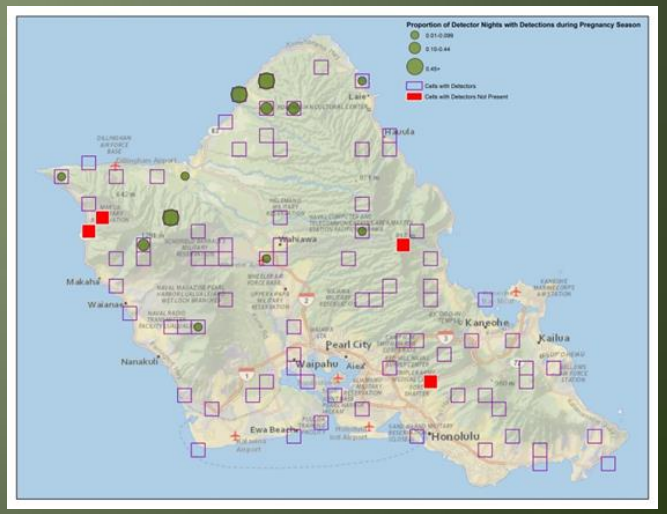
Lactation



Post-Lactation



Pre-pregnancy



Pregnancy

OVERVIEWS OF SITES

- Pictures of Some of the higher use sites.

Site 39- Pupukea

023- Waimea Valley

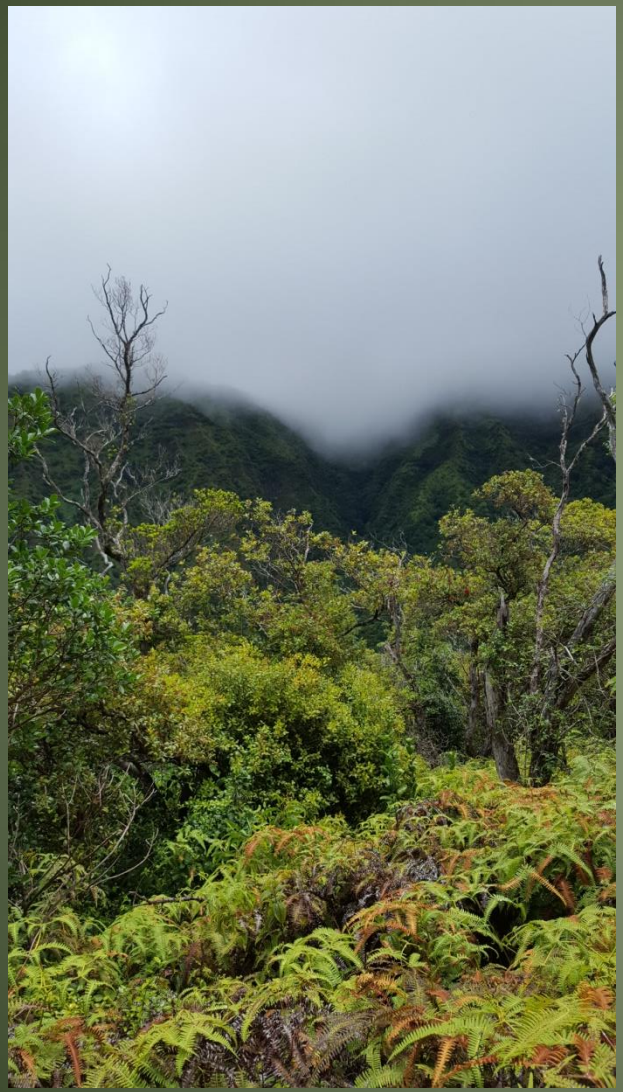
13- Kawailoa Gate

29- Kawailoa Rd

75- Peerson (Pupukea)

97- Malaekahana State Park

Site- 53 Kumaipo Landing Zone



115 Waianae Kai Forest Reserve

83- Lualualei Ridge

79- Makua Ridge

41 Schofield 3

57- Schofield McCarthy Area

87 Schofield 1

OCCUPANCY ANALYSIS – INDEPENDENCE OF DATA

Temporal correlation test results for join count χ^2 tests.

Interval	Markov Model	Lactation		Post-Lactation		Pre-Pregnancy		Pregnancy	
		Join count χ^2	p-value	Join count χ^2	p-value	Join count χ^2	p-value	Join count χ^2	p-value
4 days	No	14856.64	<0.0001	--	--	--	--	9.96	**0.234**
7 days	No	4.80	**0.5260**	4.81	**0.316**	6.01	**0.176**	13.93	0.024
10 days	No	11.04	0.0140	1.59	**0.624**	1.72	**0.694**	2.58	**0.826**
14 days	No	1.68	**0.8420**	1.11	**0.648**	1.16	**0.218**	0.95	**0.852**
4 days	Yes	450.75	<0.0001	--	--	--	--	10.43	**0.636**
7 days	Yes	4.39	**0.6720**	4.60	**0.774**	3.93	**0.502**	7.70	**0.102**

OCCUPANCY RESULTS: 14-DAY INDEPENDENT DATA

Multi-season model with detection probability modeled by season generated the lowest AIC value based on the revised year-1 dataset

Occupancy model	Model covariates	Initial occupancy rate estimate (SE)	Detection probability (p) estimate (SE)	Extinction rate (SE)	Colonization rate (SE)
Multi-season	Ψ(.)ε(.)γ(.) p(Season)	0.43 (0.11)	Season: Lact. p=0.34 SE=0.08; Post-Lact. p=0.19 SE=0.04; Pre-Preg. p=0.13 SE=0.05; Preg. p=0.43 SE=0.13	0.53 (0.10)	0.03 (0.02)

DERIVED OCCUPANY ESTIMATES BY SEASON
14-DAY DATA

Derived occupancy estimates by Season and bootstrapped 95%-confidence intervals						
Season	**Est. Occupancy Rate**	**SE**	**95%-CI**	**Est. Detection Probability**	**SE**	**95%-CI**
Lactation	0.47	0.12	(0.23, 0.70)	0.34	0.08	(0.20, 0.51)
Post-Lactation	0.25	0.06	(0.14, 0.37)	0.19	0.04	(0.12, 0.28)
Pre-Pregnancy	0.11	0.04	(0.03, 0.18)	0.13	0.05	(0.06, 0.25)
Pregnancy	0.08	0.03	(0.02, 0.13)	0.43	0.13	(0.21, 0.68)

DISTRIBUTION OF OCCUPANY ESTIMATES – 14-DAY SUBSAMPLES (LACTION PERIOD)

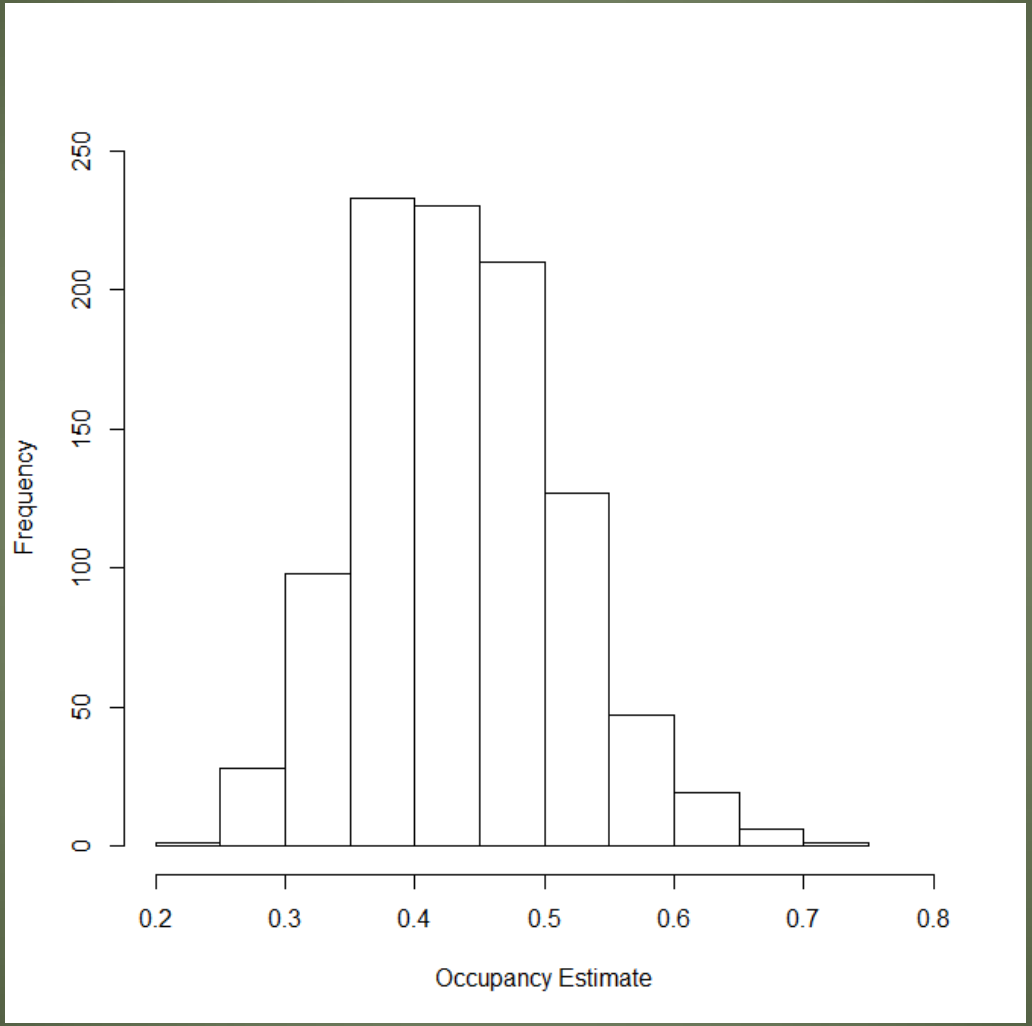


Figure 9: Distribution of occupancy estimates from 1,000 systematic random 14-day subsamples by site.

OCCUPANY ESTIMATES BY SEASON ACCOUNTING FOR CORRELATION - 7-DAY DATA

Occupancy estimates by season from the dynamic occupancy model for correlated detections						
Season	**Est. Occupancy Rate**	**SE**	**95%-CI**	**Est. Detection Probability**	**SE**	**95%-CI**
Lactation	0.54	0.10	(0.34, 0.72)	0.45	0.09	(0.28, 0.63)
Post-Lactation	0.26	0.06	(0.15, 0.37)			
Pre-Pregnancy	0.14	0.04	(0.06, 0.21)			
Pregnancy	0.08	0.03	(0.02, 0.14)			

SAMPLE SIZE ASSESSMENT

Sample size approximation for three levels of precision based on estimates of detection and occupancy rates for the Lactation season, three levels of desired relative precision, and 7- or 14- day sample intervals.

Interval	Est. Occupancy rate (Ψ)	Est. Detection rate (p)	Relative Precision	Sample size (α = 0.05)	Sample size (α = 0.10)
14-day	0.47	0.34	0.1	433	305
14-day	0.47	0.34	0.2	108	**76**
14-day	0.47	0.34	0.3	48	34
7-day	0.54	0.45	0.1	327	231
7-day	0.54	0.45	0.2	**82**	**58**
7-day	0.54	0.45	0.3	36	26

INSIGHTS FROM YEAR 1 ANALAYSIS

- Distribution (i.e., acoustic activity) most widespread during lactation and post-lactation periods (summer & fall)
- Lower AIC values obtained from models that assumed open populations between seasons
- The colonization rate near zero and the high extinction rate may indicate that HAHOBA distribution is more widespread during the lactation season, when our surveys began, and then becomes more restricted during the subsequent reproductive seasons
- An assessment of sample size indicates that the current sample size is sufficient to provide 90%- to possibly 95%-confidence intervals that are within 20% of the occupancy estimate

NEXT STEPS

- 2-3 more years of data to be collected and analyzed
- Revisit the same sites over time to ensure detection probability is accurately estimated and that habitat and detection variables are not confounded (MacKenzie 2006)
- Incorporate habitat variables in the occupancy analysis to assess HAHOBA habitat selection and explore use of Bayesian occupancy analysis methods
- Consider that detection probabilities (i.e., bat calling behavior) is responsible for apparent changes in seasonal distribution
- Investigate the correlation between acoustic data and #'s of bats present – count some bats

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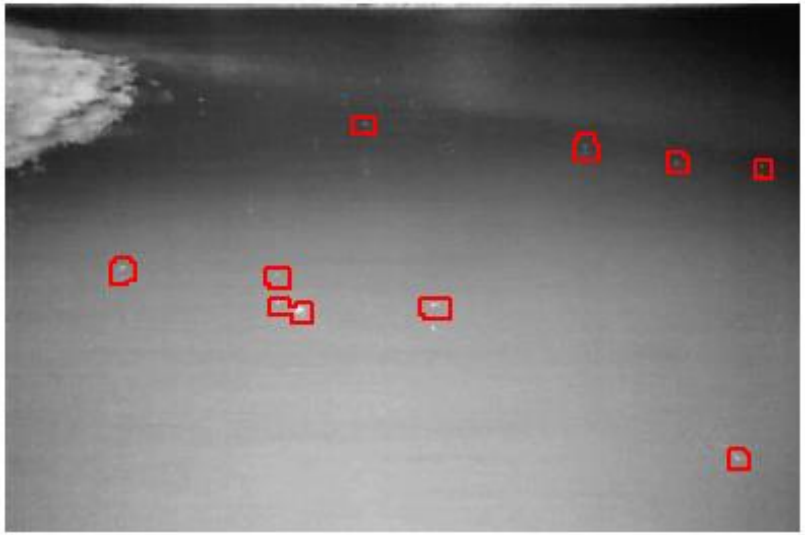
HABITAT COVARIATES

- Preliminary habitat analysis with 14-day interval data
  - Human population density
  - Percent tree cover
  - Elevation
- Classification above and below median
- Lactation season occupancy above/below 141m
  - 0.08 (95% CI: 0.01, 0.42) below 141m
  - 0.59 (95% CI: 0.35, 0.80) above 141m

COUNTING BATS

- Unmanned aerial vehicles and a high-resolution thermal camera
- Automated photo recognition
- Estimate density and abundance on a study area (e.g., within a cell)
- Fly transects within grid cell
- Transects optimized for coverage based on visual LOS
- Neural network and trained by machine learning techniques used to detect and count bats in thermal camera images
- Does density correlate with acoustic activity?

QUESTIONS - DISCUSSION



Special thanks to a number of helpful collaborators across the island that have allowed access and provided assistance to gain access to sample sites: DOFAW, State Parks, HECO, City/County of Honolulu, Water Supply Board, YMCA, DOD & Army Natural Resources Group in particular, Kahuku Wind, Kawailoa Wind, USFWS, and number of individuals and small businesses.

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