Variable Circular Plots: Station Placement and the Independence Assumption

Master's Research Project

Matt Edwards

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Distance Sampling

Distance sampling is a method of population density estimation that considers the probably of observing the object of interest at the distance at which it was seen.

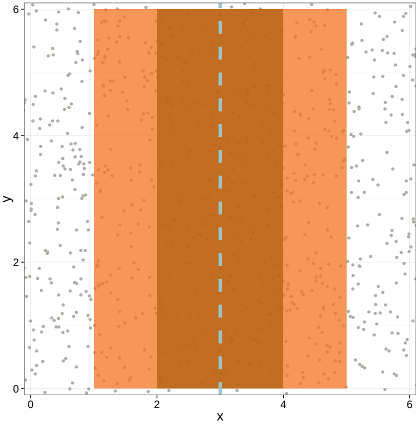
- Used often in Ecological Sciences
- Began with roadside surveys in early 1900s
- Theory developed through mid-1900s

Distance Sampling: History

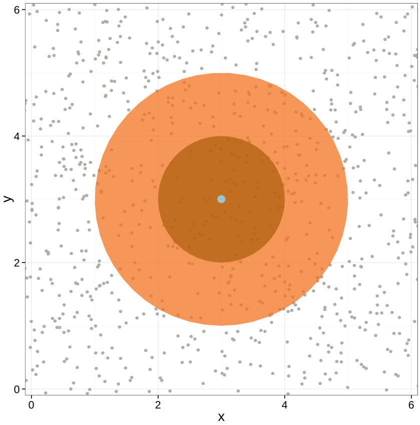
A selection of relevant papers:

- Emlen—1971
- Ramsey, Scott—1979, 1980 Papers
- Burnham, Anderson, and Jeffrey L. Laake—1980 Monograph
- Buckland et. al. 1993, 2001—text
- Continued Development into 2000s
    - Combined with Mark-Recapture Methods
    - Extended for use with underwater acoustics for estimates of krill populations
    - Combined with camera traps to estimate populations

Transect Examples



Line Transect



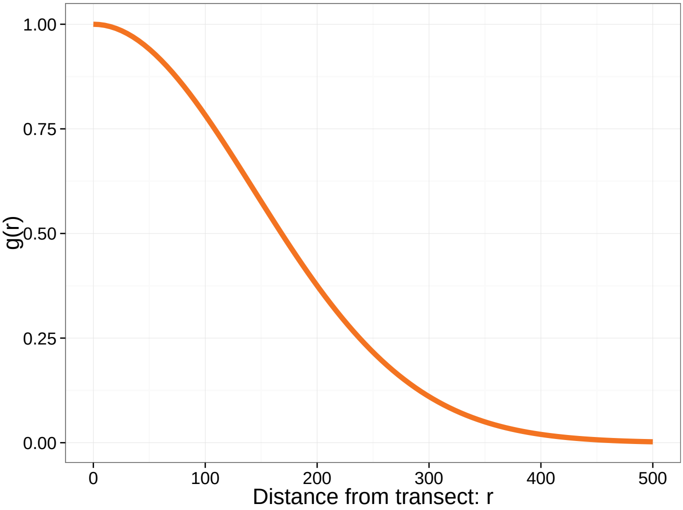
VCP/Point Transect

Line vs Point Transects

- Line transects are walked
  - Distances perpendicular to transect are recorded, as projected on ground
- Point transects: observer(s) stand at station, observe everything within 360°
  - Alternately: Variable Circular Plots (VCP)
  - Allow “cooling” period
  - Safer for observer
  - Straight line distance from Observer is recorded, as projected on ground
- Both: Observations can be from visual sightings, auditory clues, or a combination

Detection Curve: $g(r)$

The probability of detecting an object, give it is at distance r.



Density Estimation

$$\hat{D} = \frac{n}{\text{Area} * P(\text{observing object}|\text{distance } r)}$$

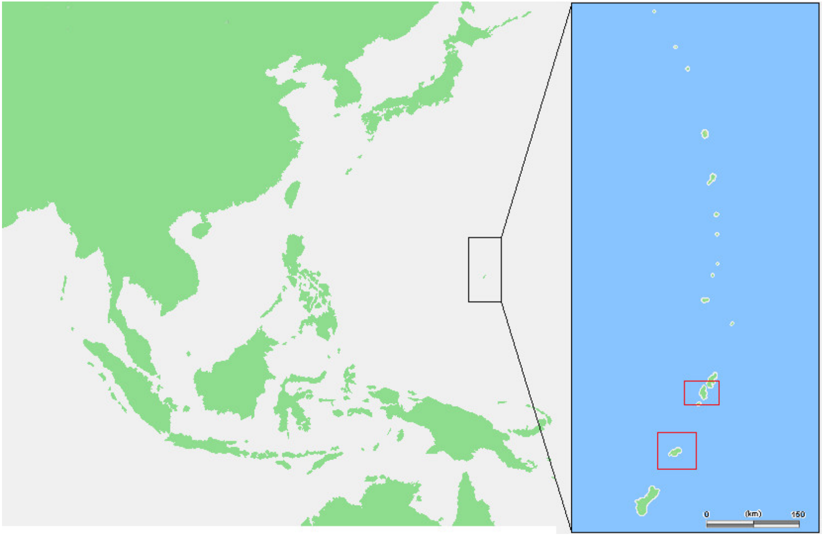
$$\hat{D} = \frac{n}{\text{Area} * g(r)}$$

- $\hat{D}$: Estimated Population Density
- n: number of objects observed
- *Area*: The area surveyed
- $g(r)$: $P(\text{observing object}|\text{distance } r)$

Micronesian Forest Bird Survey: 1982

- Engbring, Ramsey & Wildman (1986)
- Used VCP to survey several bird species in the Micronesian islands
- Each of 5 Islands divided into regions
- Transect randomly placed within region (angle & starting position selected randomly)
- Stations placed every 150 m along transect
- Additional transects placed 2 km parallel

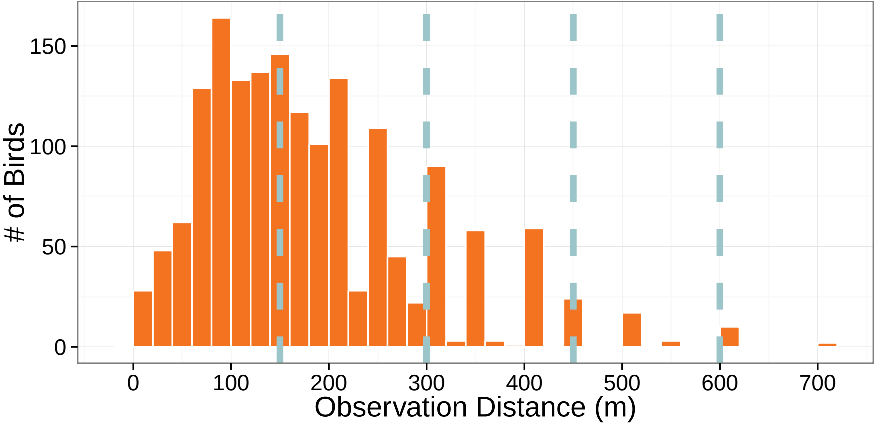
Micronesia



Mariana Islands, modified from work by M. Minderhoud, (public domain) via Wikimedia Commons

Collared Kingfisher Observation Data

Aggregated empirical observation distances from 1982 study.



Research Question

Do overlapping observation areas violate any underlying independence assumptions?

Will it make a difference in our final population density estimates if a bird is observed from more than one station?

VCP Indepencence

VCP Analysis assumes sightings of animals are independent events.

- Ramsey and Scott (1979), Buckland (1987), and Thompson (2012) discuss assumption that VCPs are randomly placed.
    - Implicit, but not explicit, possibility of overlap
- Reynolds, Scott, and Nussbaum (1980) state the possibility of observing the same bird from more than one station should be avoided.
- Buckland et al. (2001) states "Transects are normally spaced at a sufficient distance to avoid detecting an object from two neighboring transects, although this is not usually critical unless sampling a line changes the animal distribution at neighboring, as yet un-sampled lines."

Simulation Set Up

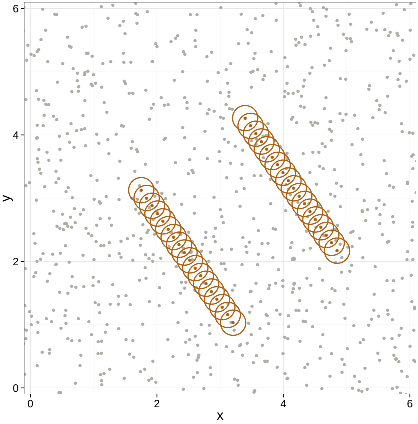
Modeled after Palie Region on Rota:

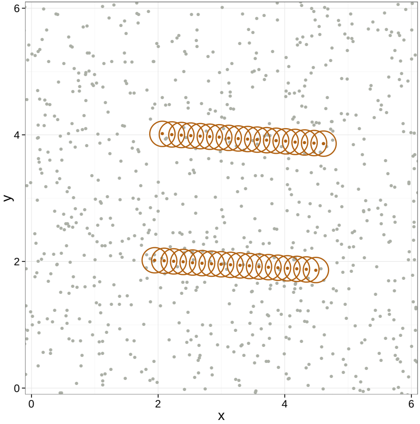
- 20 birds per km^2
- 9.41 km^2 Study Area
- Two transects, 16 & 17 stations each
- Truncation distance, w, taken to be 500 m

Transect Layouts

Examples of two random Transect layouts.

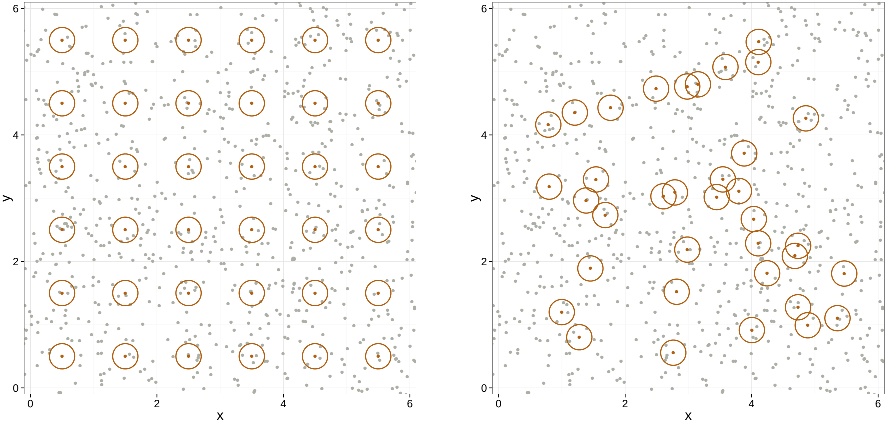
1 unit on graph = 1 km





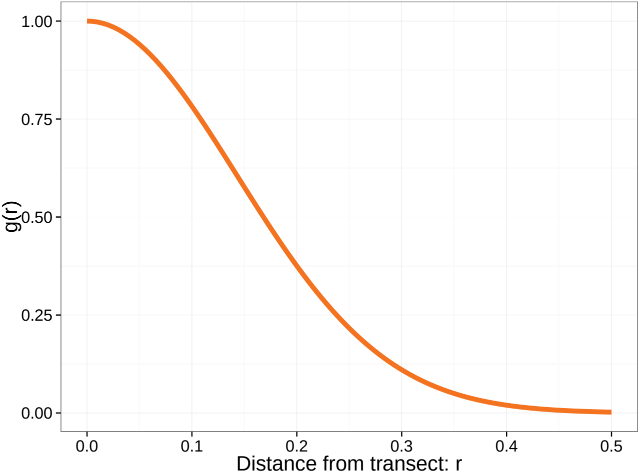
Structured and Random Layouts

Examples of Structured and Random layouts.
1 unit on graph = 1 km



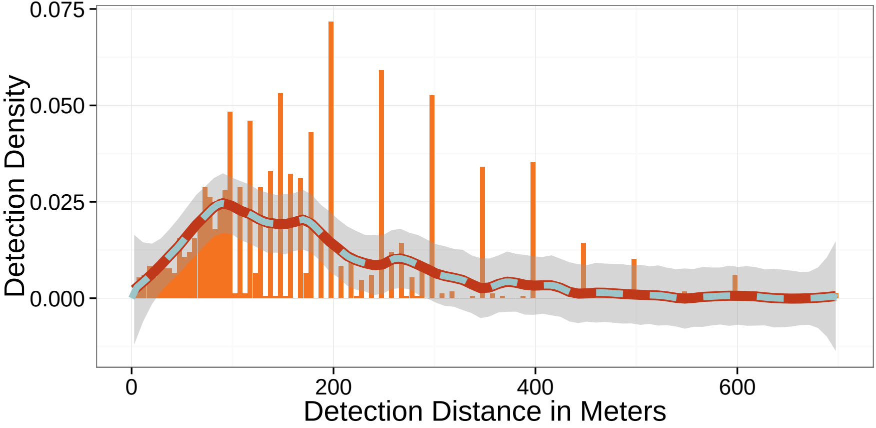
Detection Curve: Ideal

"Ideal" detection probability curve, maximum observation distance set to 0.5 unit (500 m) distance, and scaled so $g(0) = 1$



Detection Curve: Empirical

Detection probability curve from empirical data, shown unscaled.



Movement

The histogram of observed distances shows evidence of movement, so it was considered as an option for simulation.

Three Movement Options:

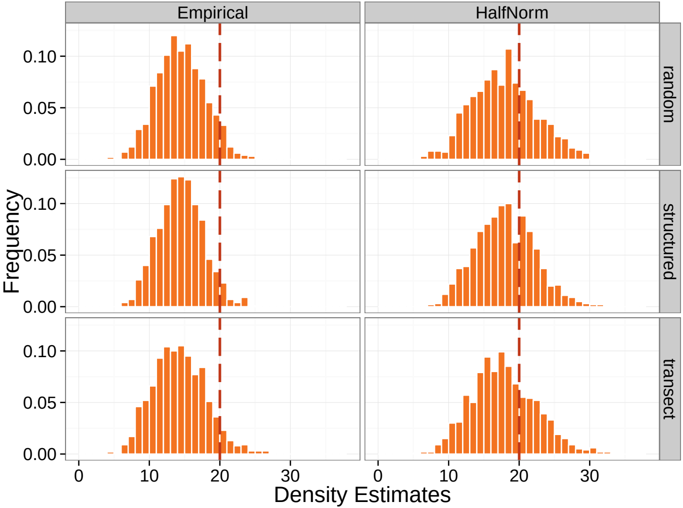
- No Movement: Objects stayed at origin point

- Temporary Movement: Objects would shift away from observer, but shift back to origin after observer “left”

- Compounded Movement: Objects would shift away from observer, would remain at new point after observer moved. (Movement could compound if object was within movement radius for more than one VCP)

Empirical vs. Half-Normal

1000 simulations, comparing Empirical vs Half-Normal detection probability, no movement,



Empirical vs. Half-Normal

Centers and Spread

$g(x)$	Layout	Mean	Std Dev	25th	Median	75th
Empirical	Random	14.47	3.37	12.08	14.38	16.73
Empirical	Structured	14.49	3.15	12.27	14.47	16.59
Empirical	Transect	14.26	3.66	11.65	14.14	16.80
Half-normal	Random	17.90	4.57	14.67	17.86	20.88
Half-normal	Structured	18.03	4.16	15.05	17.91	20.82
Half-normal	Transect	17.80	4.64	14.52	17.44	20.78

Comparing measures of centers and spread, 1000 simulations, no movement.

Empirical vs. Half-Normal

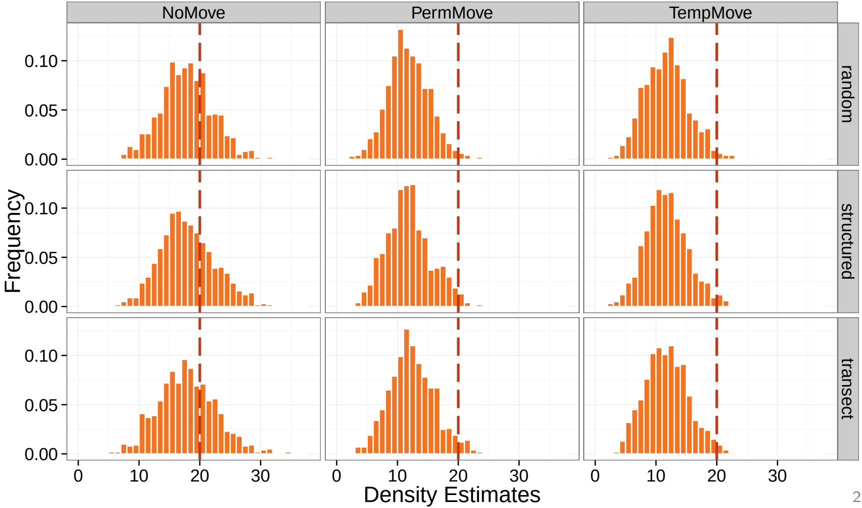
True Density Capture

	Empirical		Half Normal	
Layout	Mean $\hat{D}$	% Capture	Mean $\hat{D}$	% Capture
Random	14.47	73.6%	17.90	94.0%
Structured	14.49	77.5%	18.03	95.3%
Transect	14.27	69.6%	17.80	91.2%

Comparing rates of capture for true object density, 1000 simulations, no movement.

Movement Results

1000 simulations, comparing effect of movement types. Half-normal detection probability used for all.



Movement Results

Centers & Spread

Movement	Layout	Mean	Std Dev	25th	Median	75th
None	Random	17.86	4.28	15.03	17.64	20.65
None	Structured	18.01	4.51	14.95	17.62	20.94
None	Transect	17.90	4.78	14.74	17.67	20.95
Compounded	Random	11.86	3.42	9.58	11.61	14.09
Compounded	Structured	11.90	3.65	9.37	11.67	14.08
Compounded	Transect	12.42	3.72	9.93	12.17	14.79
Temporary	Random	11.76	3.57	9.22	11.75	14.02
Temporary	Structured	11.74	3.48	9.37	11.56	13.85
Temporary	Transect	11.75	3.57	9.24	11.72	14.20

Comparing measures of center and spread for different movement types. 1000 simulations, half-normal detection probability used for all.

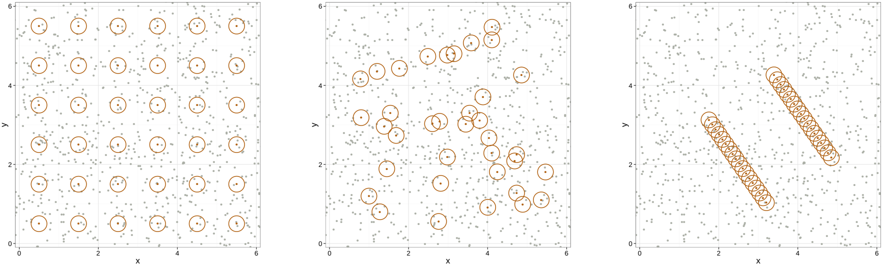
Movement Results

True Density Capture

	No Movement		Compounded		Temporary	
Layout	Mean $\hat{D}$	%	Mean $\hat{D}$	%	Mean $\hat{D}$	%
Random	17.86	94.2%	11.86	59.6%	11.76	59.3%
Structured	18.01	94.3%	11.90	59.9%	11.74	59.5%
Transect	17.90	90.8%	12.42	65.0%	11.75	58.0%

Comparing capture of true object density for different movement types. 1000 simulations, half-normal detection probability used for all.

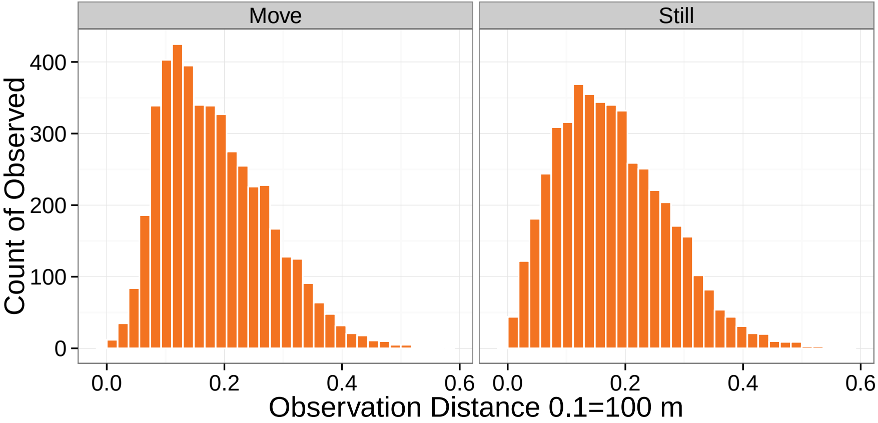
Movement And Layouts



1 unit = 1 km, circles represent 200 m out from station

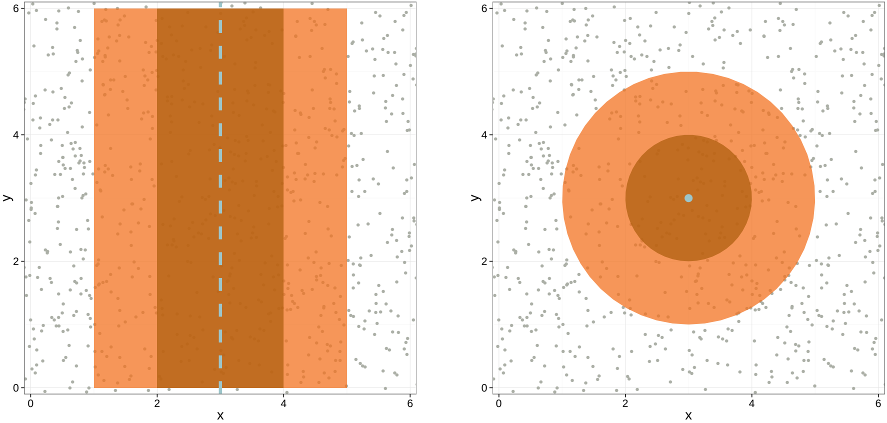
Movement Testing

Results of movement code test (left) vs no movement “baseline” (right).



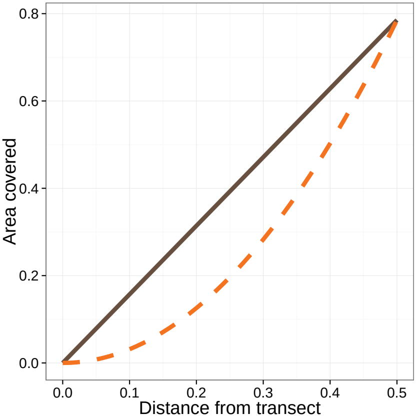
Change in Area

Area increase from 1 unit expansion in Line Transect does not equal the area from the same increase in a VCP.

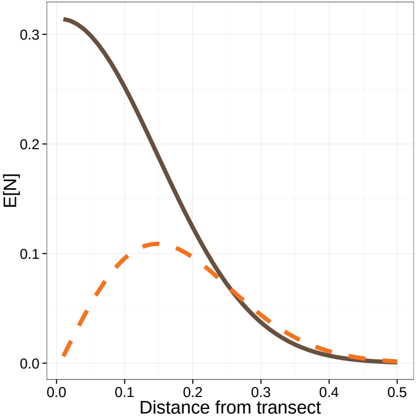


Circles vs. Rectangles

Area and Expected Observation Counts



Increase in Area



Expected number of observations, given distance.

Solid line is Line Transect, Dashed line is VCP

Conclusion

There are two primary conclusions:

- If all else is held equal, VCP layout does not seem to play a large role in the bias of population density estimates using the kernel method described by Quang (1993).
- Violations of the expected detection probability curve, or by movement of the objects away from the observer play a greater role in biasing the resulting estimate.

Future Work

Some possible areas for future research:

- Explore the possible interaction effect from Compounded Movement and the Transect Layout
- Modify simulation functions to return more information to assist diagnostics
  - Count of Observed Objects
  - Observation Distances
- Modify using the Empirical data as a detectability function, to account for difference between line and point transects.

Future Work

- Add the option to bias-correct the estimates, to see how well Quang's kernel method adjusts for these variations.
- Address analyzing transects as clusters, since observations on a transect are likely to be related.

Final Words

"All models are wrong, but some are useful." –George E. P. Box

Acknowledgements

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Masters Committee:

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- Alix Gitelman, Committee Member
- Charlotte Wickham, Committee Member

Questions?

“Collared Kingfisher (Todiramphus chloris)” by JJ Harrison, (CC-BY-SA 3.0) via Wikimedia Commons