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Abstract

Abstract

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Keywords: Model Construction, Line Tra<mark>nsect, Density Estimatior</mark>

Introduction

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Using this best combination, statisticians and biologists or
environmentalists in the field are able to estimate the density or
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At the heart of this analysis is a detection function, which has to
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Basic Concepts

The Detection Function

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 $g(y) = prob \{ \text{detection } / \text{ distance } y \}.$
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length The surveyed, an area of size $a = 2wL$ is censused. All n objects with

trips are enumerated, and estimated density is the expected num

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 $\check{D} = n / 2wL$
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- be the area surveyed within distance $\bf w$ of the $\bf e$ a measured vertical distance from the
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bbject is in $(x, x+dx)$ / objects is dete $f(x)dx =$ $\frac{p}{1}$ bject is in $(x,x+dx)$ / objects is detected}
objects is in $(x,x+dx)$ and object is detected}
pr{objects is detected} $=$ pr{objects is detected}

 \ddot{x} <u>predict</u> $\frac{p_1(b)^2 \cdot p_2(b)^2 \cdot p_3(b)}{p_3}$ object is in $(x, x+d)$
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f(x)dx = g(x) \cdot (dx \cdot L) / w \cdot L)
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P_a

Hence,

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f(\mathbf{x}) = \underline{g(\mathbf{x})}
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\mathbf{w} \cdot \mathbf{P}_a
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 $f(x) = \frac{g(x)}{w \cdot P_a}$
 $\mu = w \cdot P_a$ so that $f(x) = g(x)$ Let

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 $\int_{0^{\infty}}^{\infty} g(x) dx$. nd
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 $f(x) = 0$

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f(x) = g(x) / wP_a
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f(x) = g(x) / $\int_0^w g(x) dx$.

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 $f(0) = 1 / \int_0^w g(x) dx$ $\frac{1}{2}$ ero dis

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f(0) = g(0) / \int_0^w g(x) dx
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\n $f(0) = 1 / \int_0^w g(x) dx$.
\n $f(0) = 1 / \mu$

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\mathbf{\mu} &= \int_{0}^{\mathbf{w}} \mathbf{g}(\mathbf{x}) \, \mathrm{d}\mathbf{x}\n\end{aligned}
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Assumptions

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Modeling of the Detection Function

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In the program DISTANCE 3.5 (Laake et al, 1993), the

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they perform poorly relative to other models. Often, if two or three models seem to fit equally well to a data set, estimation of density under these models will be quite similar.

Methodology

1. Simulation by Match Stick Distance Project1 (MSDP1)

This project was purposed to compare density estimates of line transect distance sampling technique with the traditional square plot and strip transect sampling approaches.

Five hundred four black headed match sticks were stochastically distributed over a ten by six square meter field. The field was divided into sixty lxl square meter grids. The actual density was 8.4 match sticks per square meter.

1. Square plot sampling approach.

Forty percent of the total number of grids were taken as sample for the square plot sampling approach that is equal to 24 grids. Match sticks were counted in each grid and the total number n of match sticks in all 24 grids was taken. The total area a covered by the 24 grids was also computed so that estimate of match stick density \check{D} was computed as \check{D} = $n \, \ell \, a$ while estimate of total population was computed as $\check{N} = \check{D} A$ where A is the actual area of the field of study. The estimates were then compared to the actual density and population.

ii. Strip transect sampling approach

In strip transect sampling approach, the first strip was established with a random start at grid 53 to grid 21 with length = 4.33 m and $2w=$ 0.333 m where w is half the width. Three more strips of the same width were established parallel to the first strip. They have the same lengths equal to 7.4 m each. All match sticks n within the strips were counted and recorded. The total area a covered by the strips was computed as $a =$ $(L)(2w)$ where L_t is the total length of the four strips and w is half the width of the strips. The estimated density was then computed as $\tilde{D} = n / a$

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The ungrouped data were then entered into DISTANCE 3.5 and analyzed. The data was truncated at the largest vertical distance measured. To illustrate the process of modeling in detail twelve combinations of key functions and adjustment terms were constructed and the model with the lowest AIC was taken as the final model of the detection function. The resulting estimates of density and abundance were then compared to the actual.

3. Simulation by Rice Grains

One thousand rice grains were distributed over an area equal to 2.32 m^2 . Line transects of total length = 2.87 meters were established over the area and vertical distances between detected rice grains and the line transects were recorded. Every fourth rice grain detected is not recorded. These observations were keyed in to DISTANCE 3.5. Using the existing four key functions and three expansion series 'built in' in the program, the researcher analyzed the data exhausting all 12 combinations. The one with the lowest AIC was taken as the best combination for the detection function.

4. Primary Data from Coconut Distance Project (CDP)

A map of a 24-hectare farmland located at Mabuhay, Liloy Zamboanga del Norte was secured. A census of coconut trees was conducted. There were 706 coconut trees. Square quadrats were drawn over the map and quadrat 41 was randomly taken where the first line transect was established. Four parallel line transects with a total length of 1800 meters and a perpendicular distance of 60 m between each were traversed and distances between detected coconut trees and line transecis were measured. The data were then entered into $DISTANCE$ 3.5 for analysis.

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Results and Discussions $\frac{1}{2}$ d ana

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Table 2. gives the summarized results of Match Stick Distance Project₁ (MSDP₁).

Table 2. Results of the three sampling approaches $(MSDP₁)$

Where: SPS is square plot sampling STS is strip transect sampling LTDS is line transect distance sampling

Comparing the results of the three sampling approaches, the estimates yielded by line transect distance sampling (LTDS) are closest to the actual values.

2. Match Stick Distance Project₂ (MSDP₂)

Twelve combinations of detection functions were constructed out of the $MSDP₂$ data. Table 3 gives the summary.

The three combinations of the hazard rate key with the three types of expansion series yield the same AICs. The number of adjustment terms is zero. Hence, the hazard-rate key here needs no expansion series. It means that the key function alone is sufficient to model the detection function

The half-normal key function alone is also sufficient, but with one simple or Hermite polynomial adjustment term, the precision is increased as implied in the decrease of the AIC from -456.48 to -457.47 or -457.05

respectively. The uniform key function plus one simple or Hermite polynomial gives a lower AIC than the uniform key three cosine series.

Model detection function	Model selected	Number of parameters	Number of adjustment terms	AIC	
$Half-normal + C$	1	1	None	-456.48	
$Half-normal + Sp$	$\overline{2}$	$\overline{2}$	1	-457.47	
$Half-normal + Hp$	$\mathbf 2$	$\overline{2}$	1	-457.05	
Uniform $+ C$	4	3	3	-457.28	
Uniform $+$ Sp	$\mathbf{2}$	$\mathbf{1}$	1	-457.79	
Uniform $+$ H _p	$\boldsymbol{2}$	1		-457.79	
$\rm\,Hazard\rm\, rate + C$	1	$\overline{2}$	None	$-458.80*$	
$\text{Hazard-rate} + \text{Sp}$	1	$\overline{2}$	None	$-458.80*$	
$\text{Hazard-rate} + \text{Hp}$	1	$\boldsymbol{2}$	None	$-458.80*$	
Negative $\exp + C$	1	1	None	-453.27	
Negative $\exp + \text{Sp}$	2	$\overline{2}$	2	-455.79	
Negative $\exp + Hp$	$\overline{2}$	$\overline{2}$	$\overline{2}$	-455.79	

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g(y) = 1 - \exp(-(y/\sigma)^{-b})
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 $g(y) = 1 - \exp(-(y/\sigma)^{-b})$

e parameters are $\sigma = A(1) = 0.1097$ and $b = A(2) = 3.5$ (Appen
 $g(y) = 1 - \exp[-y/0.1097)^{-(3.5)}$].

ec
;(y $[-y/0.1097)^{-(3.5)}].$ Hence,

 $g(y) = 1 - \exp[-y/0.1097)^{-(3.5)}].$

mated density of matchstick per square meter is 8.12 while

the is 8.4, a difference of 0.28. The estimated abundance timated density of matchstick per square meter is 8
nsity is 8.4, a difference of 0.28. The estimated abultion at a statual is 504 matchsticks, a difference of 17 matricles. tual density is 8.4, a difference of 0.28. The estimated aburatively is 8.4, a difference of 0.28. The estimated aburatively while the actual is 504 matchsticks, a difference of 17 mate stimate is closest to 504 matchstick difference of 0.28. The esti
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istance Project (RGDP) matan
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i<mark>st</mark>a 3. Rice Grain

oject (RGDP)
etraversed and dist ransects were traversed and distances between detected rice
ansects were measured and recorded. We have the following
Total effort = 2.87 m and n = 102 distances.
ata were keved in to Distance 3.5 for analysis. Analysis of er
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trans nd transects were measured and recorded. We
ion: Total effort = 2.87 m and $n = 102$ distances
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bmbinations of key functions and adjustment terms were ma
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mbination with the lowest AIC was taken. The following are
 $\text{Model: Uniform} + 1 \text{ Cosine term}$
 $\text{AIC} = -611.86 \text{ (lowest AIC)}$ it
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.86 (lowest A
2 grains/m². -611.86 (lowest AI(
39.92 grains/m².
82 grains ov
in : 439.92 gra
: 982 grains

Superior University Coconut Distance Project (CD)
From the twenty four hect \mathcal{L} ne twenty-four hectares there are a total of 706
one hectare. The analysis is based on the larg
ch is 9.98 meters. The total number of detecte ec
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Th he
is
ne total of 706 trees or
d on the largest which is 9.98 meters. The total number of detected obje
he total number of line transects is 4 , which sums up t
h of 1800 meters. The following are some histogram .98 meters. The total number of detected objects is

mber of line transects is $\,$ 4, which sums up to a

meters. The following are some histograms of ees in one hectare. The analysis is based on
which is 9.98 meters. The total number of
The total number of line transects is 4, which 17 trees in one hectare. The analysis is based on the largest

ince, which is 9.98 meters. The total number of detected objects

ces. The total number of line transects is 4, which sums up to a

length of 1800 meters. The he total number of line transects is 4, which su
th of 1800 meters. The following are some hi $\frac{1}{d}$ s
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a ength of 1800 meters. The following and the cut points with different key functional the cut points with different key function 1800 meters. The following are some his points with different key functions. ata at 6 cut points with different key function \mathbb{R}^n

Exercise Brook is upon the plot of the set of eut point Half-nor.
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hat can be observed in the histograms, all four models sho
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ese the best. In Table 5 below, the smallest AIC is 399 As what can be observed in the histograms, all four models showed
road shoulder so any of them can be used to model the data. But we
can to choose the best. In Table 5 below, the smallest AIC is 399.41 the histograms, all α
can be used to mode
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mal key alone and the houlder so any of them can be used to model the data. Bu
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to
: r o choose the best. In Table 5 below, the smallest AIC is 399.41 corresponds to the half-normal key alone and the uniform key plumple/Hermite polynomial. How to judge between these two? $\inf_{t\in\mathbb{R}}$ rresponds to the half-normal key alone and
ble/Hermite polynomial. How to judge betwe
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ju $\frac{1}{2}$ Iow to judge bet<mark>v</mark>
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Model	$W = 10 M$								
$Key + adj$	AIC	D	N	Cv ^(%)	X ² value	\mathbf{X}^2 р value	P		
				15.28	0.679	$0.954*$	$.406*$		
Hn	$399.41*$	29.46	707	16.15	0.919	0.922	.378		
$U + C$	399.62	30.33	728	13.98	0.648	$0.958*$	$.411*$		
$U+Sp/Hp$	$399.41*$	28.98	696	21.60	0.791	0.852	.321		
Hr	401.41	29.64	711						
					$U = Uniform,$	\cdot 1			

Table 5. Distance 3.5 Analyses on Coco Distance Project

Where: $C = Cosine$, Hn = Half-normal, Hp = Hermite polynomial,

 $Sp =$ Simple polynomial, $Hr =$ Hazard-rate

Lets look at the χ^2 goodness of fit test. The uniform key plus one simple or Hermite polynomial has better fit than the half-normal key alone. In terms of detection probability value it has a higher P-value.

Hence, the uniform key plus one simple or Hermit polynomial model is the best model for the detection function of the coconut distance data.

5. Mangrove Distance Project (MDP)

Mangrove trees are detected whether they are just seedlings, sapling or matured. Vertical distances between detected mangrove trees and the line transect are measured and recorded. The number of trees detected are $n_1 = 33$, $n_2 = 36$, $n_3 = 11$, and $n_4 = 0$, hence, a total of 80 vertical distances. The total transect length $L_t = 960$ meters.

With truncation at largest distance, the researcher entered the data into DISTANCE 3.5 for analysis. Histograms at different cut points (Figures 3-6) were plotted to explore the data and to see its characteristic. In here, the histogram with five cut points shall be used for illustration and each of the candidate model will be fitted into it.

. MDP data at 5 cut poi

. MDP data at 13 cut poi:

. MDP data at 8 cut poi:

 \mathbf{S} . MDP data at 7 cut poi

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of data (Figures 7-10). Table 6 is about the hazard rate key

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s lata (Figures 7-10). Table 6 is about the hazard rate key
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Model combination	Model $#$ of selected models		# of parameters	Adjustment terms		AIC
	fitted			#	Order	
$Hr + C$	$\overline{2}$	1 st	$\overline{2}$	$\mathbf{0}$	None	273.91
$Hr + Sp$	$\overline{2}$	1st	2	$\mathbf{0}$	None	273.91
$Hr + Hp$	$\overline{2}$	1st	2	$\bf{0}$	none	273.91

6. GALELA,

7. The hazard rate key (alone), \bm{p} = er
C

the uniform ke \mathbf{m} wonder, all three combinations have the same AIC. Table 7 is ^{all}
he uniform key combinations. ll
m DISTANCE 3.5 selected the 1st model as the final model for the hazard
rate key combinations based on lowest AIC. Take notice of the AICs, no
worder, all three combinations have the same AIC. Table 7 is all about DISTANCE 3.5 selected the 1^{st} model a rate key combinations based on lowest μ wonder, all three combinations have the uniform key combinations. as polynomials) to the key function has not improved the fit of the dat
mplied by a higher AIC in model 2 (Appendix A: Model fitting) so
DISTANCE 2.5 soleted the 1st model as the first model for the ha nig
3.5
bina ted the 1^{st} model as the final model for the hazar ddition of adjustment terms (i.e. cosine term
olynomials) to the key function has not improved
nplied by a higher AIC in model 2 (Appendix A:
ISTANCE 3.5 selected the 1st model as the final
ate key combinations based on tion of adjustment terms (i.e. cosine term, simple or hermite
nomials) to the key function has not improved the fit of the data as
ied by a higher AIC in model 2 (Appendix A: Model fitting) so that
 Γ^{AMCF} 3.5 selected th addition of adjustment terms (i.e. cosine term, simple or hermit in the state of the data and all the state of the data and all the fit of the data and all the state of the data and all the state of the data and all the st first model is just the key function alone while the second model is with
the addition of the adjustment terms with their corresponding order. The
addition of adjustment terms (i.e., cosing, term, simple or hermi $\int \tanh \frac{1}{\sin \theta}$ tte key combinations yields tv be del is just the key function alone while the second model is with it is not the adjustment terms with their corresponding order. The second ent terms with their corres of alc
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Model	Model $#$ of models selected fitted	$#$ of	Adjustment terms		AIC	
comb'n			paramete rs	#	Order	
$U + C$		3 rd	2	2	റ	280.15
$U + Sp$		3rd	2	2	$\mathbf 2$	281.49
$U + Hp$	ð	4 th	3	3	2. 6 4.	283.05

Table 7. The Uniform key combinations

Figure 6. The Uniform key + two cosine series of orders 1 and 2

There are also three uniform key combinations. The uniform key + cosine combination has four models fitted into the data and the third model was selected based on minimum AIC. The uniform key + simple polynomial combination has four models fitted into the data and the third model was selected again based on minimum AIC. The uniform key + Hermite polynomial combination has five models fitted into the data and the fourth model was selected.

For the uniform key combinations, the model with the lowest AIC is the uniform key function plus two cosine series of orders 1 and 2.

There are also three half-normal key combinations which yield two models each (Table 8).

. The half-normal key (alone) $p=$ rmal kev (a

no adjustment terms. The AIC for this model is 279.87 is model for each of the three combinations based on minimum AIC. So, the half-normal key combinations is represented only by the key function
with no adjustment terms. The AIC for this model is 279.870. the fit of the key function so that the program chose the each of the three combinations based on minimum AIC. S
that key combinations is represented only by the key functions of the section of the section of the section e the fit of the key function so that the program chose the 115 st addition of adjustment terms to the halfcom
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The p-value (Figure 7) is 0.13710 whi
f-normal key alone fits well into the da
The three negative exponential key con
'able 9) Based on minimum AIC t Figure 7) is 0.13710 which
alone fits well into the dat \mathfrak{p} with no adjustment terms. The AIC for this i

The p-value (Figure 7) is 0.13710 which

the half-normal key alone fits well into the d

The three negative exponential key co nt
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neg he AIC for this model is 279.870.
 f) is 0.13710 which is not significant. H

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ponential key combinations yield four m

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and two adjustment terms. The cosine series are of orders 1 and 2 while on
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able 10 gives the results of mangrove distance data analysis
ive combinations are finally considered. Three (*) models are
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key alone and the hazard-rate key rh
os
. 0 gives the results of mangrove distance data an mbinations are finally considered. Three $(*)$ model
the best, the Uniform key plus two cosine terms, the $\frac{1}{2}$ ives the results of ma $\begin{array}{c} \text{di} \ \text{T} \ \text{c} \ \text{e}. \end{array}$ or the best, the Uniform key plus two cosine terms, the hall alone and the hazard-rate key alone. To choose the best west AIC is considered. $\frac{1}{2}$ e lowest AIC : ey
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azard-rate key has the lowest AIC which is 273.91. To ass
the fit is considered by looking at the $x^2 - p$ value. It has ey
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fc IC which is 273.91. To
at the χ^2 – p value. It h
l-rate key, alone, is th lequacy, the fit is considered by looking at the χ^2 – p value. It has the fit which is 0.324. Hones, the Hazard rate key, alone, is the best equacy, the fit is considered by looking at the χ^2 – p value. It has the twhich is 0.224. Hence, the Hazard-rate key, alone, is the best for this mangrove distance sampling data.
Hence, the model for the detection fun consider
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 $-\exp\left[-\left(y/\sigma\right)\right]$
 $d_b = A(2) = 3$ $-\exp [-(y/\sigma)^{b}]$
d b = A(2) = 3.015 (/ $p^{-1} (y/q)^{-1}$
= $A(2) = 3$

= A(1) = 2.78 and b = A(2) = 3.015 (Appendix A: Par
 $g(y) = 1 - \exp[-(y/2.78)^{3.015}].$ =3.015 Hence $-\exp\left[-\left(\frac{y}{2}\right)\right]$

With this detection function model, the density estimate is 116.51 mangroves per hectare and the abundance estimate is 466 mangroves.

Table 11. Summary of Results

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