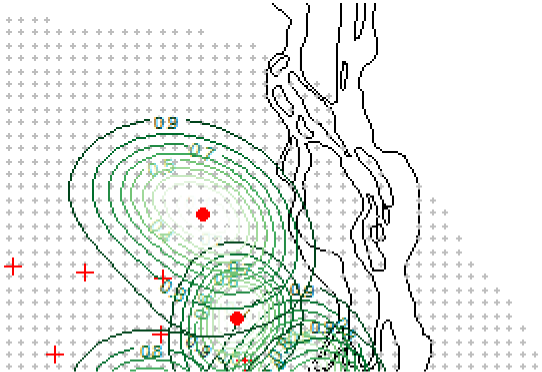
SECR – *Spatially Explicit Capture-Recapture*

Modelo Espacialmente Explícito de Capture e Recaptura

- Funções para estimar a densidade de uma população fechada amostrada por diferentes tipo de detectores

- Os modelos populacionais incorporam a detecção dependente da distância e são ajustados pela máxima verossimilhança



SECR – *Spatially Explicit Capture-Recapture*

http://cran.r-project.org/web/packages/secr/index.html
http://www.otago.ac.nz/density/SECRinR.html

Desenvolvido por:

http://www.otago.ac.nz/zoology/staff/otago008940.html

BIOMETRICS 64, 377–385
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Spatially Explicit Maximum Likelihood Methods for Capture–Recapture Studies

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SUMMARY. Live-trapping capture–recapture studies of animal populations with fixed trap locations inevitably have a spatial component: animals close to traps are more likely to be caught than those far away. This is not addressed in conventional closed-population estimates of abundance and without the spatial com-

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Estimation of population density by spatially explicit capture–recapture analysis of data from area searches

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Abstract. The recent development of capture recapture methods for estimating animal population density has focused on passive detection using devices such as traps or automatic cameras. Some species lend themselves more to active searching: a polygonal plot may be searched repeatedly and the locations of detected individuals recorded, or a plot may be searched just once and multiple cues (feces or other sign) identified as belonging to particular individuals. This report presents new likelihood-based spatially explicit capture recapture (SECR) methods for such data. The methods are shown to be at least as robust in simulations as an equivalent Bayesian analysis, and to have negligible bias and near-nominal confidence interval coverage with parameter values from a lizard data set. It is recommended on the basis of simulation that plots for SECR should be at least as large as the home range of the target

SCR – *Spatial Capture-Recapture*

Desenvolvido por:

USGS
Patuxent Wildlife Research Center

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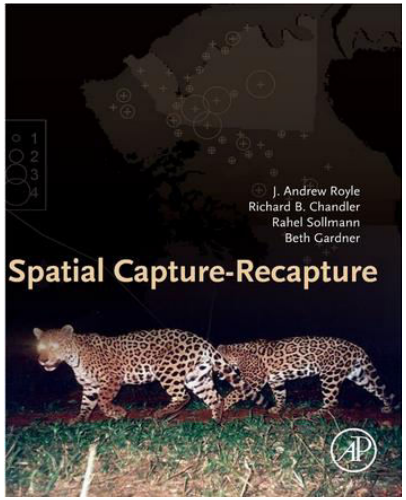
Dr. Royle is a Research Statistician engaged in the development of statistical methods and analytic tools for animal demographic modeling, statistical inference and sampling wildlife populations and communities. His current research is focused on hierarchical models of animal abundance and occurrence, Bayesian analysis in ecology, spatial modeling, and the development of spatial capture-recapture models.

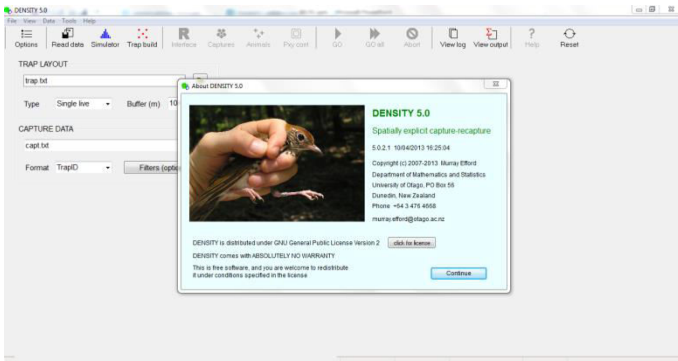
Education/Training:

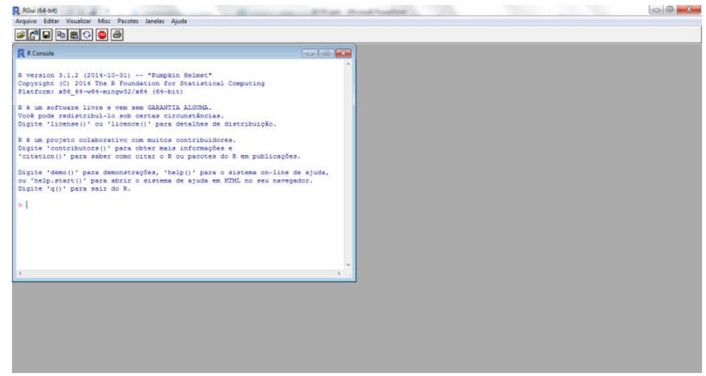
Ph.D. (Statistics), North Carolina State University, 1996.
M.St. (Statistics), North Carolina State University, 1993
B.S. (Fisheries and Wildlife Management), Michigan State University, 1990



SECR – *Spatially Explicit Capture-Recapture*

DENSITY X R





O Density:
- Funciona apenas no Windows
- Algoritmos não bem documentados
-Ajusta somente o processo homogêneo de Poisson
- Omite avanços recentes do SECR

O R possui a mais:
- Funciona em outros sistemas operacionais
- Modelagem de superfícies de densidade
- Especificação do modelo baseado em fórmula flexível
- Modelo médio
- Detecção acústica
- Processo paralelo
- Modelos híbridos (inferência Bayesiana)
- a0 parametrização para heterogeneidade compensatória
- telemetria integrada com captura-recaptura
- Distâncias não euclidianas (fornecida pelo usuário)

SECR – detectores

Table 3: Detector types

Exemplos		
Sherman	single	traps that catch one animal at a time
Pitfall	multi	traps that may catch more than one animal at a time
AF/Pêlos	proximity	records presence at a point without restricting movement
	count	proximity detector allowing >1 detection per animal per time
Área	polygon	counts from searching one or more areas
Trilhas	transect	counts from searching one or more transects
Quando há dependência	polygonX	binary data from mutually exclusive areas
	transectX	binary data from mutually exclusive transects
Vocalização	signal	detections and signal strengths at multiple microphones
Rádio colar	telemetry	locations from radiotelemetry

SECR

- Permite:

• definir área de amostragem inicial com base no:

1- histórico de captura (capthist)
2- log da verossimilhança (mask.check) no ajuste do modelo*

*Não estima buffer com modelos híbridos (classe)

- histórico de captura do modelo ajustado (suggest.buffer)

- MMDM, dbar, RPSV, ARL e moves

SECR

<u>3 parâmetros</u> primários compõem o modelo SECR

1 - densidade populacional (*D*)

(*D*) é um parâmetro derivado, computado de um objeto do secr.

2 - probabilidade (g0) ou risco acumulativo (λ) de detecção para um detector no centro da área de vida do indivíduo

3 - Escala espacial (σ)

SECR

<u>Dois parâmetros</u> adicionais podem compor todos os modelos em concorrência

1 - parâmetro de forma (z) → função de detecção

2 - Parâmetro de classe, (hcov) nos modelos
finite mixture modelsI e *hybrid mixture models* → estimativas por classe

Três parâmetros de detecção podem ser estimados diretamente quando o modelo é ajustado pela verossimilhança condicional (CL = TRUE no secr.fit)

SECR - detecção

Estimativas populacionais de uma população fechada no SECR, modela-se a detecção do indivíduo ***i*** na ocasião ***s*** pelo detector ***k***.

i.s.k

i = indivíduo
S = ocasião
k = detector

SECR - detecção

Considerando ***n*** observações de ***i*** indivíduos em ***S*** ocasiões em ***K*** detectores:

n.S.K

n = indivíduos observados
S = ocasiões
K = detectores

SECR - detecção

Modelo nulo (constante), ***n.S.K*** tem a mesma probabilidade de detecção.

$$n.S.K$$

n = indivíduos observados
S = ocasiões
K = detectores

SECR - detecção

Segundo Otis et al (1978), as formas convencionais de variação na probabilidade de detecção (captura) incluem:

n.S.K

heterogeneidade
Individual (h)

Ex: classe de idade

SECR - detecção

Segundo Otis et al (1978), as formas convencionais de variação na probabilidade de detecção (captura) incluem:

n.S.K

Variação no tempo (t)

SECR - detecção

Segundo Otis et al (1978), as formas convencionais de variação na probabilidade de detecção (captura) incluem:

n.S.K

heterogeneidade Individual (h)

Variação no tempo (t)

Resposta comportamental a 'captura' (bt)

Trap-happy

Trap- shy

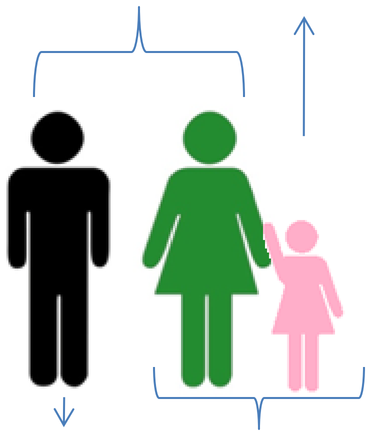
SECR - detecção

Diferenças entre indivíduos (*i*) esforço (*s*) e ambientes amostrados (*k*), podem ser inseridos como **co-variáveis** do modelo.

indivíduo, ocasião, detector

http://ultradownloads.com.br/papel-de-parede/Trilha-na-Floresta/

Classe de idade



Classe de sexo

SECR - detecção

No SECR, há duas adições de complexidade:

Podem ser inseridas

variações entre sessões (temporadas) – (1...*R*)

e entre classes latentes– (1...*M*)

$$n.S.K.M.R$$

SECR - detecção

Estrutura de uma matriz

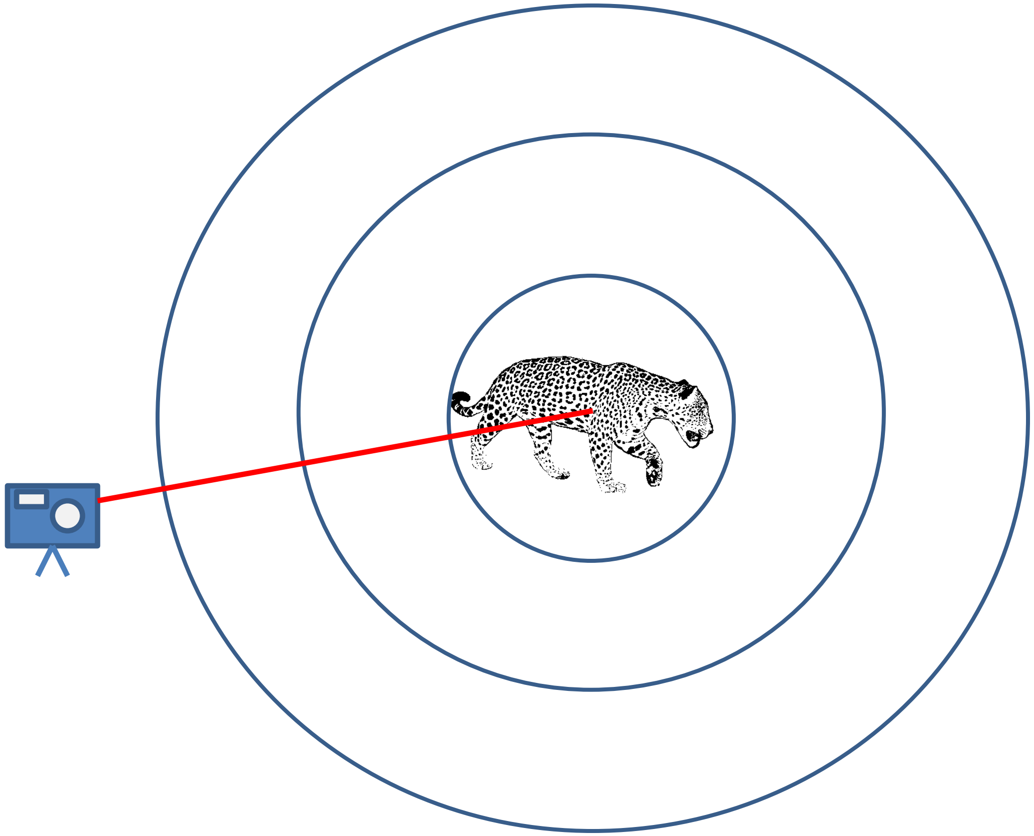
n.S.K.M.R

	A
1	id,detector,x,y,/1,2,3,4,5,6,7,8,9
2	1,TS1,358597,8914064,/216,241,221,287,262,330,175,224,272
3	2,TS2,360498,8913916,/216,241,218,289,262,314,191,238,257
4	3,TS4,362500,8912302,/216,241,146,311,262,312,193,38,254
5	4,TS5,361631,8910940,/237,215,215,311,264,313,191,237,241
6	5,TS6,359707,8911736,/219,233,215,316,260,313,192,238,241
7	6,TS7,357769,8910418,/220,214,232,314,262,313,192,238,241

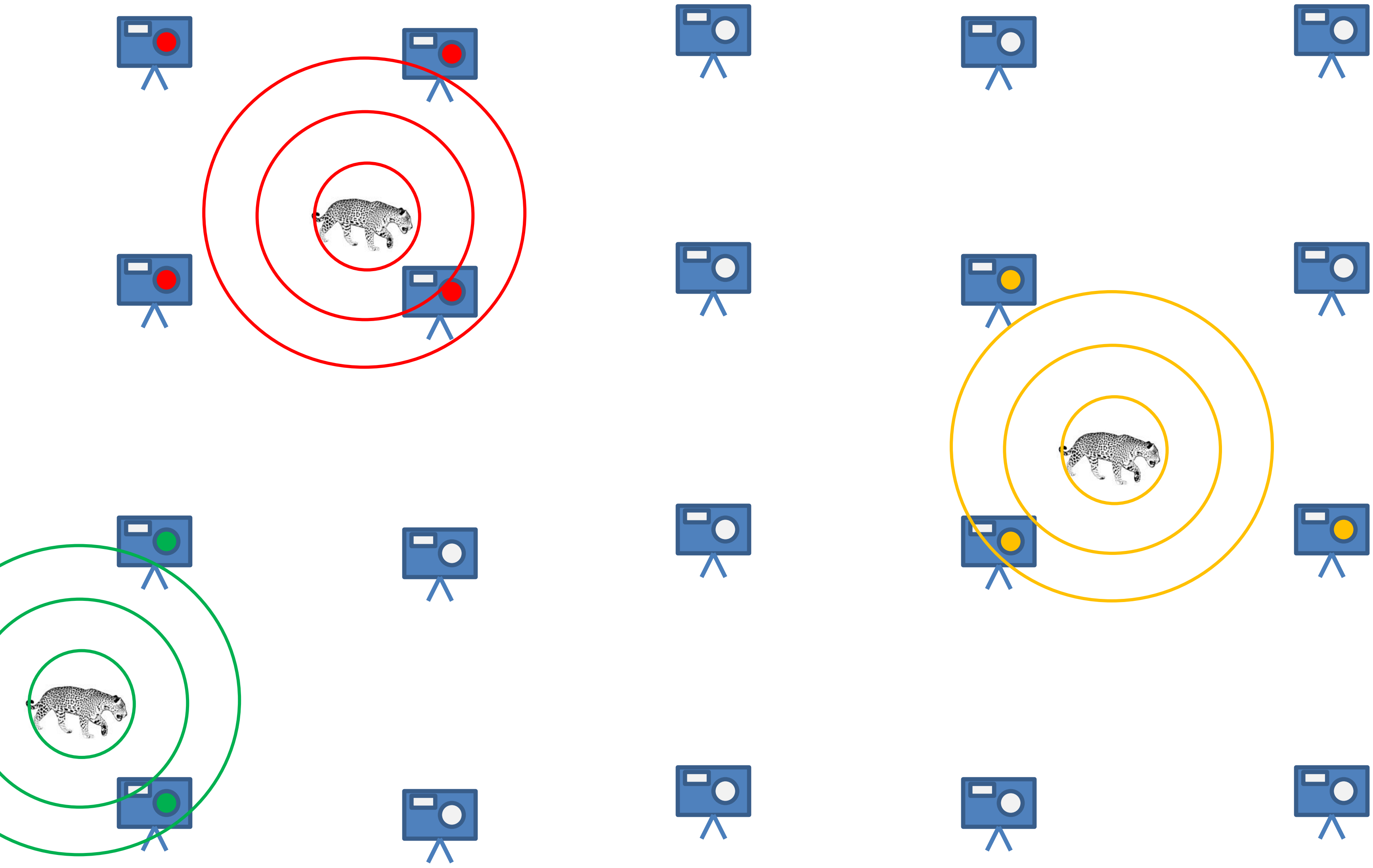
```
session,id,occasion,trapid, sex
F1,1F,3,2,f
F1,1F,3,3,f
F1,2M,1,2,m
F1,3F,6,2,f
F1,4M,5,2,m
F1,5F,1,8,f
F1,5F,4,9,f
F1,5F,6,8,f
F1,5F,9,9,f
F1,6M,3,5,m
```

SECR - detecção

Relaciona a probabilidade de detecção “g” ou o esperado número de detecções “λ” de um animal à distância do detector ao “centro potencial de atividade do indivíduo”



SECR - detecção



SECR - detecção

No SECR a detecção é definida por uma função.

Dois parâmetros para *halfnormal* – g0 e sigma

$$g(d) = g_0 \exp\left(\frac{-d^2}{2\sigma^2}\right)$$

Três parâmetros para função *hazard-rate* – g0, sigma e z

$$g(d) = g_0[1 - \exp\{-(^d/_\sigma)^{-z}\}]$$

Outras possibilidade são discutidas
?detectfn

d = distância

g0 = magnitude (intercepção) da função de detecção

sigma (σ)= escala espacial da função de detecção

z = parâmetro de forma (área)

SECR - detecção

Code	Name	Parameters	Function
0 HN	halfnormal	g0, sigma	$g(d) = g_0 \exp\left(\frac{-d^2}{2\sigma^2}\right)$
1 HR	hazard rate	g0, sigma, z	$g(d) = g_0[1 - \exp\{-({}^d/_\sigma)^{-z}\}]$
2 EX	exponential	g0, sigma	$g(d) = g_0 \exp\{-({}^d/_\sigma)\}$
3 CHN	compound halfnormal	g0, sigma, z	$g(d) = g_0[1 - \{1 - \exp\left(\frac{-d^2}{2\sigma^2}\right)\}^z]$
4 UN	uniform	g0, sigma	$g(d) = g_0, d <= \sigma; g(d) = 0$, otherwise
5 WEX	w exponential	g0, sigma, w	$g(d) = g_0, d < w; g(d) = g_0 \exp\left(-\frac{d-w}{\sigma}\right)$, otherwise
6 ANN	annular normal	g0, sigma, w	$g(d) = g_0 \exp\{\frac{-(d-w)^2}{2\sigma^2}\}$
7 CLN	cumulative lognormal	g0, sigma, z	$g(d) = g_0[1 - F\{(d-\mu)/s\}]$
8 CG	cumulative gamma	g0, sigma, z	$g(d) = g_0\{1 - G(d; k, \theta)\}$
9 BSS	binary signal strength	b0, b1	$g(d) = 1 - F\{-(b_0 + b_1 d)\}$
10 SS	signal strength	beta0, beta1, sdS	$g(d) = 1 - F[\{c - (\beta_0 + \beta_1 d)\}/s]$
11 SSS	signal strength spherical	beta0, beta1, sdS	$g(d) = 1 - F[\{c - (\beta_0 + \beta_1(d-1) - 10\log_{10} d^2)\}/s]$
14 HHN	hazard halfnormal	lambda0, sigma	$\lambda(d) = \lambda_0 \exp\left(\frac{-d^2}{2\sigma^2}\right); g(d) = 1 - \exp(-\lambda(d))$
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18 HCG	hazard cumulative gamma	lambda0, sigma, z	$\lambda(d) = \lambda_0\{1 - G(d; k, \theta)\}; g(d) = 1 - \exp(-\lambda(d))$

0 ⇨ *Default* - recomendada

0-3 e 5-8 ⇨ Trabalham com a probabilidade de detecção “g”

SECR - detecção

Code	Name	Parameters	Function
0 HN	halfnormal	g0, sigma	$g(d) = g_0 \exp\left(\frac{-d^2}{2\sigma^2}\right)$
1 HR	hazard rate	g0, sigma, z	$g(d) = g_0[1 - \exp\{-(^d/_\sigma)^{-z}\}]$
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18 HCG	hazard cumulative gamma	lambda0, sigma, z	$\lambda(d) = \lambda_0\{1 - G(d; k, \theta)\}; g(d) = 1 - \exp(-\lambda(d))$

14 a 18 ⇨ Parametrizadas em termos do número esperado de detecções "λ" ao invés da probabilidade de detecção "g"

⇨ Detectores tipo "count", se a função é interpretada como uma distribuição de atividade

SECR - detecção

	Code	Name	Parameters	Function
	0 HN	halfnormal	g0, sigma	$g(d) = g_0 \exp\left(\frac{-d^2}{2\sigma^2}\right)$
Hayes & Buckland, 1983 →	1 HR	hazard rate	g0, sigma, z	$g(d) = g_0[1 - \exp\{-(^d/_\sigma)^{-z}\}]$
→	2 EX	exponential	g0, sigma	$g(d) = g_0 \exp\{-(^d/_\sigma)\}$
Efford & Dawson, 2009 →	3 CHN	compound halfnormal	g0, sigma, z	$g(d) = g_0[1 - \{1 - \exp\left(\frac{-d^2}{2\sigma^2}\right)\}^z]$
Simulações * →	4 UN	uniform	g0, sigma	$g(d) = g_0, d <= \sigma; g(d) = 0$, otherwise
	5 WEX	w exponential	g0, sigma, w	$g(d) = g_0, d < w; g(d) = g_0 \exp\left(-\frac{d-w}{\sigma}\right)$, otherwise
	6 ANN	annular normal	g0, sigma, w	$g(d) = g_0 \exp\{\frac{-(d-w)^2}{2\sigma^2}\}$
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	18 HCG	hazard cumulative gamma	lambda0, sigma, z	$\lambda(d) = \lambda_0\{1 - G(d; k, \theta)\}; g(d) = 1 - \exp(-\lambda(d))$

* Problemas de maximização da verossimilhança por métodos de gradiente.

Não recomendadas para uso no secr devido a longa cauda (buffer irracionalmente muito grande para estabilizar a estimativa de densidade)

SECR - detecção

Code	Name	Parameters	Function
0 HN	halfnormal	g0, sigma	$g(d) = g_0 \exp\left(\frac{-d^2}{2\sigma^2}\right)$
1 HR	hazard rate	g0, sigma, z	$g(d) = g_0[1 - \exp\{-({}^{d}/_{\sigma})^{-z}\}]$
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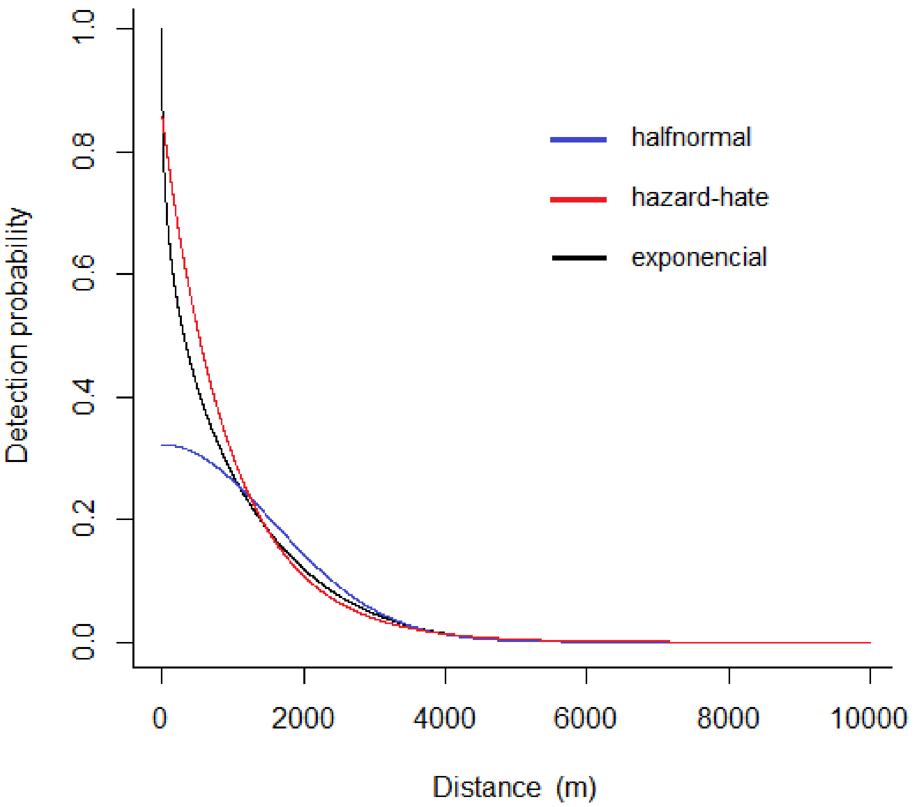
Similaridades com SCR (Royle & Gardner, 2011)

cumulative hazard = exposure function
hazard halfnormal = halfnormal exposure (- fator 2 no σ^2)
hazard exponential = exponential function

SECR - detecção

Duas funções relacionando a probabilidade de detecção à distância (*d*) e suas respectivas formas gráficas.



SECR

Ajusta o modelo “state” e o modelo observacional

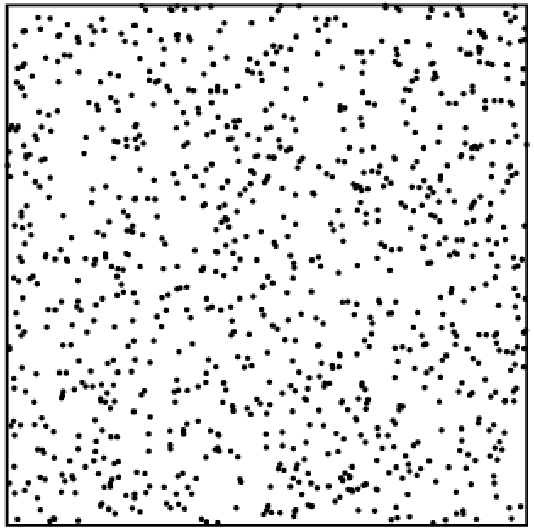
a) <u>Observacional</u> → função de detecção dependente da distância (g0 ou λ).

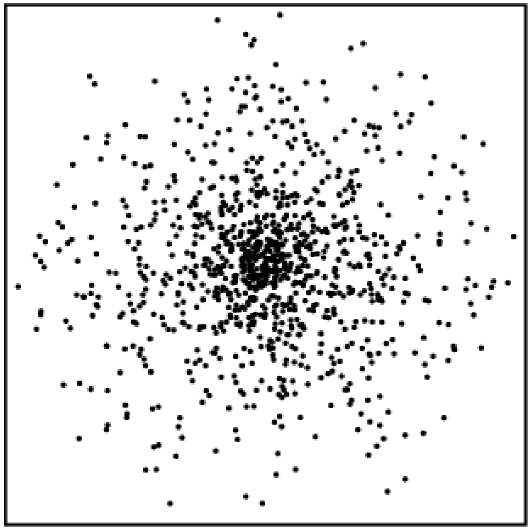
– Probabilidade de detecção de um indivíduo em um detector em relação à distância do centro de atividade

b) *<u>State</u>* → Processo de Poisson para distribuição espacial

-Homogêneo
(constante ao longo do espaço)

-Não uniforme
(variando ao longo do espaço)





SECR - estrutura

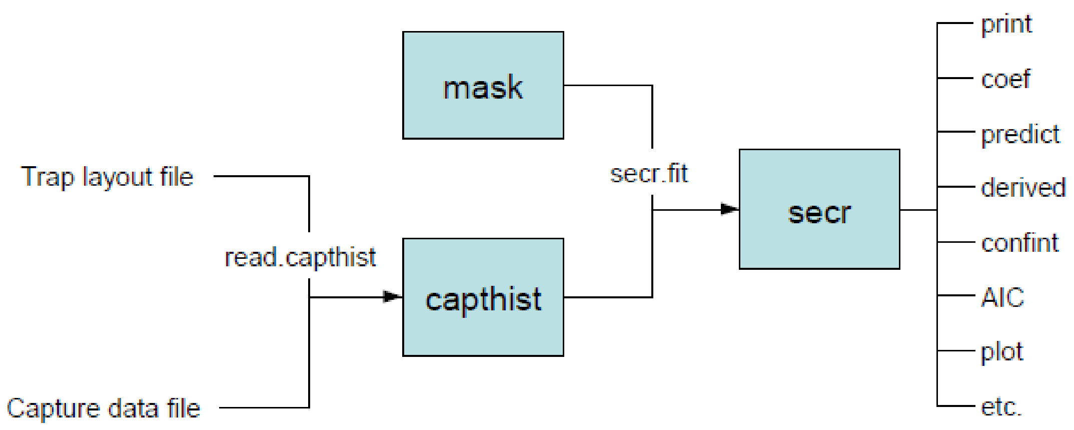


Figure 3: Essentials of the secr package. Each object class (shaded box) comes with methods to display and manipulate the data it contains (e.g. `print`, `summary`, `plot`, `rbind`, `subset`). The function `read.capthist` forms a `traps` object from the trap layout data and saves it as an attribute along with the capture data in a `capthist` object. If a habitat mask is not provided, one will be generated automatically by `secr.fit`. Any of the objects input to `secr.fit` may include a dataframe of covariates whose names may be used in a model formula. Fitted secr models may be further manipulated with the methods shown on the right. Additional functions (not shown) construct a regular detector array (e.g. `make.grid`, `make.circle`), form a mask from a `traps` object (`make.mask`), or simulate detection of a known population (`sim.capthist`).

Efford, M. 'SECR' overview. 30, outubro, 2013.

SECR – como trabalha

Grupo de classes do R (conjunto de dados e funções que devem ser manipulados – S3 classe)

Classes fundamentais são:

- ***traps*** (localização dos detectores e o tipo)
- ***capthist*** (histórico de detecção espacial, incluindo o objeto ***traps***)
- ***mask*** (pontos na área de máscara, área amostrada)
- ***secr*** (ajuste de modelo SECR)

Co-variáveis dos detectores, dos indivíduos e do habitat podem ser incluídas

SECR - formato dos dados (*input*)

Duas tabelas (.txt ou .csv)

Capturas - no formato trapID

```
session,id,occasion,trapid, sex
F1,1F,3,2,f
F1,1F,3,3,f
F1,2M,1,2,m
F1,3F,6,2,f
F1,4M,5,2,m
F1,5F,1,8,f
F1,5F,4,9,f
F1,5F,6,8,f
F1,5F,9,9,f
F1,6M,3,5,m
```

(...)

Co-variável (hcov)

Detectores- (AF)

	A	B
1	detector,id,x,y	
2	1,TS1,358597,8914064	
3	2,TS2,360498,8913916	
4	3,TS3,362555,8913760	
5	4,TS4,362500,8912302	
6	5,TS6,359707,8911736	
7	6,TS7,357769,8910418	

(...)

SECR - formato dos dados (*input*) – ARMADILHAS DE REGISTR0

Duas tabelas (.txt ou .csv)

Capturas - no formato trapID

```
session,id,occasion,trapid, sex
F1,1F,3,2,f
F1,1F,3,3,f
F1,2M,1,2,m
F1,3F,6,2,f
F1,4M,5,2,m
F1,5F,1,8,f
F1,5F,4,9,f
F1,5F,6,8,f
F1,5F,9,9,f
F1,6M,3,5,m
```

(...)

Detectores- *proximity* (AF)

	A	B
1	detector,id,x,y	
2	1,TS1,358597,8914064	
3	2,TS2,360498,8913916	
4	3,TS3,362555,8913760	
5	4,TS4,362500,8912302	
6	5,TS6,359707,8911736	
7	6,TS7,357769,8910418	

(...)

make.capthist

```
Session =  F2
, , 1

    1 2 3 4 5 6 7 8
10M 0 0 0 0 0 0 0 0
11F 0 0 0 0 0 0 0 0
12M 0 0 0 0 0 0 0 0
13F 0 0 0 0 0 0 0 0
14M 0 0 0 0 0 0 0 0
15F 0 0 0 0 0 0 0 0
16F 0 0 0 0 0 0 0 0
17M 0 0 0 0 0 0 0 0
1F  0 0 0 0 0 0 0 0
2M  1 0 0 0 0 0 0 0
3F  0 0 1 0 1 0 0 0
6M  0 0 0 0 0 0 0 0
7F  0 0 0 0 0 0 0 0
8M  0 0 0 0 0 0 0 0
9F  0 0 0 0 0 0 0 0
```

```
, , 2

    1 2 3 4 5 6 7 8
10M 0 0 0 0 0 0 0 0
11F 0 0 0 0 0 0 0 0
12M 0 0 0 0 0 0 0 0
13F 0 0 0 0 0 0 0 0
14M 0 0 0 0 0 0 0 0
15F 0 0 0 0 0 0 0 0
16F 0 0 0 0 0 0 0 0
17M 0 0 0 0 0 0 0 0
1F  0 0 0 0 0 0 0 0
2M  1 0 1 0 0 0 0 0
3F  0 0 0 0 0 0 0 0
6M  0 0 0 0 0 0 0 0
7F  0 0 0 0 0 0 0 0
8M  0 0 1 0 0 0 0 0
9F  0 0 0 0 0 0 0 0
```

```
, , 3

    1 2 3 4 5 6 7 8
10M 0 1 0 0 1 1 0 0
11F 0 0 0 0 0 0 0 0
12M 0 0 0 0 0 0 0 0
13F 0 0 0 0 0 0 0 0
14M 0 0 0 0 0 0 0 0
15F 0 0 0 0 0 0 0 0
16F 0 0 0 0 0 0 1 1
17M 0 0 0 0 0 0 0 0
1F  0 1 0 0 0 0 0 0
2M  0 0 0 0 0 0 0 0
3F  0 0 0 0 0 0 0 0
6M  0 0 0 0 0 0 0 0
7F  0 0 0 0 0 0 0 0
8M  0 0 0 0 0 0 0 0
9F  0 0 0 0 0 0 0 0
```

```
, , 4

    1 2 3 4 5 6 7 8
10M 0 0 0 0 1 1 0 0
11F 0 0 0 0 0 0 0 0
12M 0 0 0 0 0 0 1 0
13F 0 0 0 0 0 0 0 0
14M 0 0 0 0 0 0 0 0
15F 0 0 0 0 0 0 0 0
16F 0 0 0 0 0 0 0 0
17M 0 0 0 0 0 0 0 0
1F  0 0 0 0 0 0 0 0
2M  0 0 0 0 0 0 0 0
3F  0 0 0 0 0 0 0 0
6M  0 0 0 0 0 0 0 0
7F  0 0 0 0 0 0 0 0
8M  0 0 0 0 0 0 0 0
9F  0 0 0 0 0 0 0 0
```

5 tabelas omitidas

(...)

```
, , 10

    1 2 3 4 5 6 7 8
10M 0 0 1 0 0 0 0 1
11F 1 0 0 0 0 0 0 0
12M 0 0 0 0 0 0 0 0
13F 0 0 0 0 0 0 0 0
14M 0 0 0 0 0 0 0 0
15F 0 0 0 1 1 0 0 0
16F 0 0 0 0 0 0 0 0
17M 0 0 0 0 0 1 0 0
1F  0 0 0 0 0 0 0 0
2M  0 0 0 0 0 0 0 0
3F  0 0 0 0 0 0 0 0
6M  0 0 0 0 0 0 0 0
7F  1 0 0 0 1 0 0 0
8M  0 0 0 0 0 0 0 0
9F  1 1 0 0 1 0 1 0
```

SECR - formato dos dados (*input*) – ARMADILHAS DE CAPTURA

Duas tabelas (.txt ou .csv)

Capturas - no formato trapID

```
session,id,occasion,trapid, sex
F1,1F,3,2,f
F1,1F,3,3,f
F1,2M,1,2,m
F1,3F,6,2,f
F1,4M,5,2,m
F1,5F,1,8,f
F1,5F,4,9,f
F1,5F,6,8,f
F1,5F,9,9,f
F1,6M,3,5,m
```

(...)

Detectores- *multi* (*live traps*)

	A	B
1	detector,id,x,y	
2	1,TS1,358597,8914064	
3	2,TS2,360498,8913916	
4	3,TS3,362555,8913760	
5	4,TS4,362500,8912302	
6	5,TS6,359707,8911736	
7	6,TS7,357769,8910418	

(...)

make.capthist

```
Session =  F2
      1  2 3  4  5  6  7  8
10M   0  3 9  0  3  3  9 10
11F  10  0 0  0  0  0  0  0
12M   0  0 0  0  0  0  4  0
13F   8  0 0  0  0  0  0  0
14M   0  8 0  0  7  0  0  0
15F   0  0 0 10 10  0  0  0
16F   0  0 0  0  0  0  3  3
17M   0  0 0  0  0 10  0  0
1F    0  3 0  0  0  0  0  0
2M    1  0 2  0  0  0  0  0
3F    0  0 1  0  1  0  0  0
6M    0  0 5  0  5  0  0  0
7F   10  0 0  0 10  0  0  0
8M    0  0 2  0  0  0  0  7
9F    9 10 0  0 10  0 10  0
```

SECR - formato dos dados (*input*) - TELEMETRIA

Uma tabela (.txt ou .csv) e um polígono (.shp)

Photo © 2005 Jesse Crocker

Arquivo Editar Formatar Exibir

```
#Session ID Occasion X Y
temp 1 1 361709 8901680
temp 1 2 361519 8901814
temp 1 3 359831 8902184
temp 1 4 362380 8903722
temp 1 5 358315 8903781
temp 1 6 362450 8903892
temp 1 7 356631 8904064
temp 2 4 358411 8904641
temp 2 5 369796 8904995
temp 2 6 361662 8905039
temp 2 7 364502 8905161
temp 2 8 360409 8905315
temp 2 9 354878 8905326
temp 3 1 363043 8905441
temp 3 2 361538 8905780
temp 3 3 362180 8905893
temp 3 4 362662 8905943
temp 3 5 371935 8905954
temp 3 6 368401 8906284
temp 3 7 363893 8906415
temp 3 8 359806 8906748
temp 3 9 369556 8906962
temp 4 1 364109 8907384
temp 4 2 357771 8907548
temp 4 3 355924 8907576
temp 4 4 366980 8907629
temp 4 5 367148 8907698
```

(...)
56 linhas omitidas

read.telemetry

ou

read.capthist
(detector=telemetry, fmt="XY")

```
Session =  temp
, , 1

  1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
1 1 1 1 1 1 1 1 0 0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0
2 0 0 0 1 1 1 1 1 1  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0
3 1 1 1 1 1 1 1 1 1  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0
4 1 1 1 1 1 1 1 1 1  1  1  1  1  1  1  1  1  1  1  1  1  0  0  0
5 0 0 0 1 1 1 1 1 1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1
6 0 0 0 1 1 1 1 1 1  1  1  1  1  1  1  1  1  1  1  1  1  1  0  0
```

SECR – preditores dos modelos

Table 4: Automatically generated predictor variables used in detection models

	Variable	Description	Notes
grupo	g	group	interaction of the capthist individual covariates listed in argument `groups` of `secr.fit`
tempo	t	time factor	one level for each occasion
	T	time trend	linear trend over occasions on link scale
indivíduo	b	learned response	step change after first detection
	B	transient response	depends on detection at preceding occasion (Markovian response)
	bk	animal x site response	site-specific step change
	Bk	animal x site response	site-specific transient response
local	k	site learned response	site effectiveness changes once any animal caught
	K	site transient response	site effectiveness depends on preceding occasion
temporadas	session	session factor	one level for each session
	Session	session trend	linear trend on link scale
classe	h2	2-class mixture	finite mixture model with 2 latent classes

SECR – argumentos dos modelos

Table 6: Some examples of the `model` argument in `secr.fit`

Model	Description
`g0 ~ 1`	g0 is constant across animals, occasions and detectors
`g0 ~ b`	learned response affects g0
`list(g0~b, sigma~b)`	learned response affects both g0 and sigma
`g0 ~ h2`	2-class finite mixture for heterogeneity in g0
`g0 ~ b + T`	learned response in g0 combined with trend over occasions
`sigma ~ g`	detection scale sigma differs between groups
`sigma ~ g*T`	group-specific trend in sigma
`D ~ cover`	density varies with 'cover' given in `covariates(mask)`
`list(D~g, g0~g)`	both density and g0 differ between groups
`D ~ session`	session-specific density

SECR – concorrência entre os modelos

Critério de Informação de Akaike – AIC

Importante:
Quando utilizar modelos:

- ajustado pela *conditional likelihood* (CL=TRUE);
- de mistura de classes (*hybrid mixture models*) hcov;
- utilizando argumento de grupo;
- multi-session ;

Comparar com outros que possuem as mesmas informações.

SECR – ajuste dos modelos

- Ajustados numericamente maximizando a estimativa da verossimilhança

- A probabilidade envolve a integração sobre os centros de atividade desconhecidos dos indivíduos (somatória dos pontos na área de máscara)

- Algoritmo de maximização utilizado é o Newton-Raphson (state::nlm)

SECR - *output*

```
> fit.0

secr.fit(capthist = ocelot1.data, mask = HabitatMask, hcov = "sex",
    trace = FALSE)
secr 2.9.3, 09:20:59 26 fev 2015

Detector type      proximity
Detector number    11
Average spacing    2014.6 m
x-range            357769 366270 m
y-range            8908010 8914064 m
N animals         :  10
N detections      :  29
N occasions       :  9
Mask area         :  24592.48 ha

Model             :  D~1 g0~1 sigma~1 pmix~h2
Mixture (hcov)    :  sex
Fixed (real)      :  none
Detection fn      :  halfnormal
Distribution      :  poisson
N parameters      :  4
Log likelihood    :  -102.9075
AIC               :  213.8151
AICc              :  221.8151
```

```
Beta parameters (coefficients)
                  beta   SE.beta       lcl        ucl
D        -7.146798e+00 0.3753632 -7.882497 -6.4111000
g0       -6.858587e-01 0.5190152 -1.703110  0.3313923
sigma     7.403547e+00 0.1684468  7.073397  7.7336963
pmix.h2m -1.969780e-06 0.6324558 -1.239593  1.2395887

Variance-covariance matrix of beta parameters
                     D            g0         sigma      pmix.h2m
D         1.408975e-01 -3.114667e-02 -3.083344e-02  6.238620e-08
g0       -3.114667e-02  2.693767e-01 -1.203667e-02  1.354182e-07
sigma    -3.083344e-02 -1.203667e-02  2.837432e-02 -2.436886e-08
pmix.h2m  6.238620e-08  1.354182e-07 -2.436886e-08  4.000004e-01

Fitted (real) parameters evaluated at base levels of covariates

 session = F1, h2 = f
       link     estimate  SE.estimate          lcl          ucl
D       log 7.873809e-04 3.062767e-04 3.772899e-04 1.643216e-03
g0    logit 3.349550e-01 1.156159e-01 1.540596e-01 5.820981e-01
sigma   log 1.641797e+03 2.785289e+02 1.180150e+03 2.284029e+03
pmix  logit 5.000005e-01 1.581140e-01 2.245076e-01 7.754931e-01

 session = F1, h2 = m
       link     estimate  SE.estimate          lcl          ucl
D       log 7.873809e-04 3.062767e-04 3.772899e-04 1.643216e-03
g0    logit 3.349550e-01 1.156159e-01 1.540596e-01 5.820981e-01
sigma   log 1.641797e+03 2.785289e+02 1.180150e+03 2.284029e+03
pmix  logit 4.999995e-01 1.581140e-01 2.245069e-01 7.754924e-01
```

SECR

Etapas de análise	Principais funções e atributos	Descrição
Leitura das planilhas	*read.csv* *read.traps* *timevaryingcov*	Análise descritiva dos dados e seleção das covariaveis de tempo
Histórico de captura e primeiras estatísticas	*make.capthist* *summary.capthist* *plot*	Conjunção das matrizes e primeiras estatísticas de captura
Teste de população fechada	*closure.test*	Estima o buffer com base no histórico de captura
Estimar o buffer e a detecção	*suggest.buffer*	Estima o buffer com base no histórico de captura e dá os parâmetros de detecção
Formulação dos modelos	*secr.fit*	Carrega os modelos a serem postos em concorrência
Concorrência entre modelos	*AIC*	Gera a concorrência entre os modelos e seleciona com base no critério de informação de Akaike
Criar e adicionar hábitat	*readShapePoly* *make.mask* *plot*	Estabelece a área efetivamente amostrada com uso de *shapefile* e do *buffer* sugerido
Reajuste do modelo escolhido	*secr.fit*	Refaz as análises com a área efetivamente amostrada e estima a densidade populacional
Probabilidade de detecção	*plot*	Gera o gráfico da probabilidade de detecção
Centros de atividade	*fxi.countour* *sapply*	Cria os centros de atividade potencial dos indivíduos e gera as coordenadas