Modelação Ecológica

AULA 23

4th December 2019

KIIRSTI OWEN
Conservation Biologist

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Kiirsti Owen · 2 days ago · 3 min read

THE 25 DAYS OF CHRISTMAS: AN R ADVENT CALENDAR

Updated: 12 hours ago

https://kiirstio.wixsite.com/kowen/post/the-25-days-of-christmas-an-r-advent-calendar

[MARMAM] PhD opportunities at the University of St Andrews

SH

MARMAM <marmam-bounces@lists.uvic.ca> on behalf of Sonja Hein

To 'marmam@lists.uvic.ca'

Reply | Reply All | Forward | ...

Tue 11/26/2019 3:04 PM

The actual sender of this message is different than the normal sender. Click here to learn more.

ATT00001.txt
423 bytes

We have several exciting and funded* PhD opportunities available at the University of St Andrews, UK – please see the School of Biology website for details (PhD projects at the SOI/SMRU):
https://synergy.st-andrews.ac.uk/research/phd-study/phd-study-projects/phd-study-soi-projects/

Please note different deadlines & funding opportunities – some closing very soon!
01 December 2019 (*funded for students **worldwide**):

- **The seasonal ocean dynamics of the Amundsen Sea Embayment (using telemetry & oceanographic data from seal-born sensors)– Supervisor: Dr Lars Boehme**
- Impacts of fishing-induced changes in forage fish school structure on African penguin foraging – Supervisor: Prof Andy Brierley

13 December 2019 (*funded for UK/EU students):

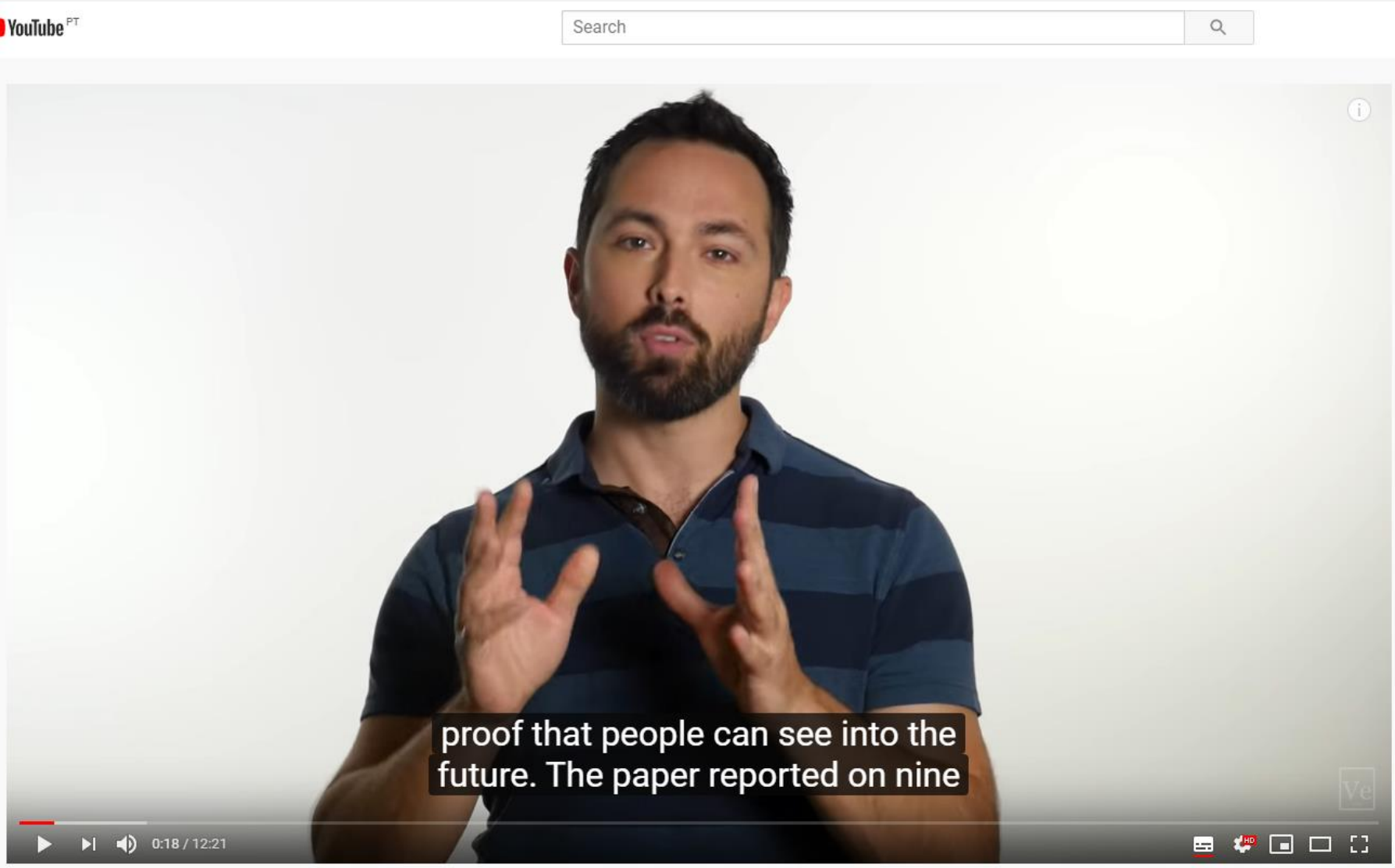
- A lab on a chip: using nano-plasmonics tongues for building miniaturized ecosystem sensors (SUPER DTP)- Supervisor: Dr Lars Boehme
-

06 January 2020 (*funded for UK/EU students)

- Killer whale predation of harbour seals in the coastal waters of Scotland: investigating the ecological drivers and consequences of an apex predator-prey interaction – Supervisors: Dr Gordon Hastie & Dr Saana Isojunno

Posted on behalf of my colleagues.
Best wishes from Scotland,
Sonja

Dr Sonja Heinrich
Sea Mammal Research Unit
School of Biology
University of St Andrews
Scotland, UK



Is Most Published Research Wrong?

2,158,496 views • 11 Aug 2016

82K 1K SHARE SAVE

https://www.youtube.com/watch?v=42QuXLucH3Q

nature

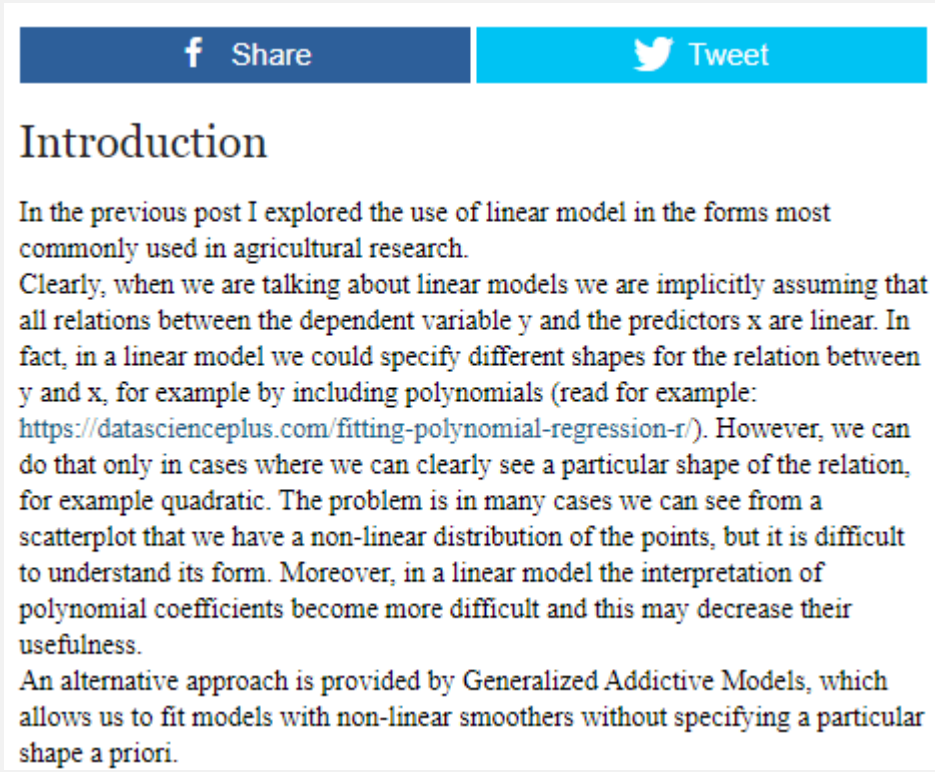
COMMENT · 27 NOVEMBER 2019

Climate tipping points — too risky to bet against

The growing threat of abrupt and irreversible climate changes must compel political and economic action on emissions.

Timothy M. Lenton ✉, Johan Rockström, Owen Gaffney, Stefan Rahmstorf, Katherine Richardson, Will Steffen & Hans Joachim Schellnhuber

https://www.nature.com/articles/d41586-019-03595-0



https://www.r-bloggers.com/generalized-addictive-models-and-mixed-effects-in-agriculture/

Re: a suggestion in your 2009 book and a quick question on top

HS

Highland Statistics Ltd <highstat@highstat.com>
To Tiago Marques

Reply | Reply All | Forward | ...

Thu 11/28/2019 8:21 PM

Flyer2020_02Lisbon_RGG.pdf
263 KB

On 28/11/2019 19:46, Tiago Marques wrote:

Hi Alain,

I hope all is well at your end. I guess you won't remember, but we have met a few years ago when I attended a course of yours in Lisboa. Any way, I am just writing with a suggestion for an improvement in the book, which I have been using as a resource in my Ecological Modelling classes.

In page 317, to obtain a required factor, you use the entire page with a quite complicated piece of code that you then try to simplify, but even the simplification is not straightforward. The result of all that code can be obtained with a single simple line of code:

```
Owls$NestNight=as.factor(paste0(Owls$Nest,".",substr(Owls$FoodTreatment,1,3)))
```

which avoids distracting the reader from the fundamental.

Hope you find it helpful. I take the chance to ask, I must be confusing something, but once you use the above code there are now 54 clusters (27 nests times 2 nights) and the largest number of observations is 28, for the Oleyes.Sat nest night combination. This will be the variable to define the grouping id in the GEE. Where does the output from the summary of the geeglm function output "Number of clusters: 277 Maximum cluster size: 18" shown in page 319 comes from –which I get in my computer too. I seem to be missing something rather obvious, as I was expecting "Number of clusters: 54 Maximum cluster size: 28", but I am not sure what! Many thanks in advance for any feedback sent this way.

Cheers,

Tiago

Re: a suggestion in your 2009 book and a quick question on top

Reply | Reply All | Forward | ...

HS

Highland Statistics Ltd <highstat@highstat.com>
To Tiago Marques

Thu 11/28/2019 8:21 PM

Flyer2020_02Lisbon_RGG.pdf
263 KB

Dear Tiago,

Thank you for your email..and for your suggestions.

The thing with GEE is that I haven't used it since 2009. Since then I went more into GLMMs...and since the last 3 or 4 years more towards INLA. So..I don't think I'm the most appropriate person to ask. Maybe create a dummy data set and ask the programmers?

Maybe you could also have a look at the GEE chapter in the same book? That was something with badgers. Perhaps it is due to the coding of the ID? What happens if it is coded as a numerical variable? Shouldn't make a difference...but you never know.

Kind regards,

Alain

PS...I see that you also have contacts in Lisboa. Can you forward the attached flyer to any potential interested colleagues?

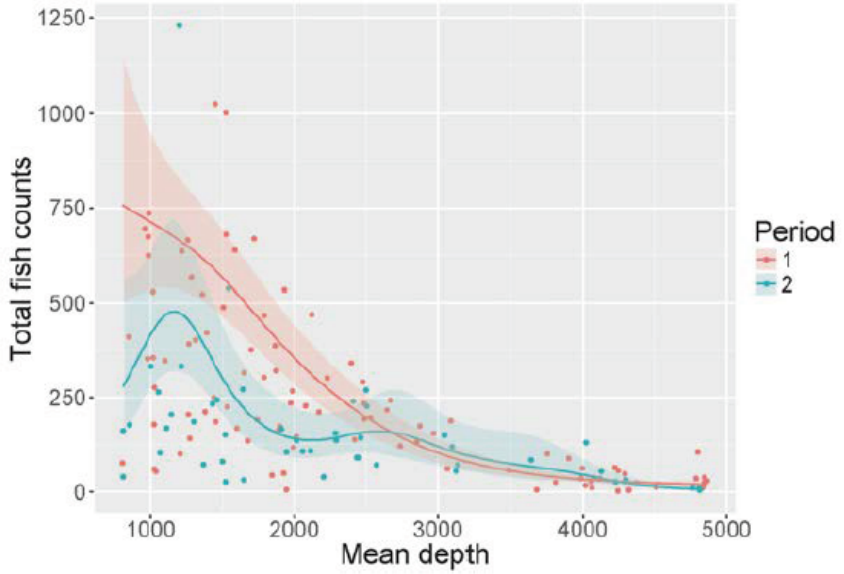
COURSE FLYER

Data Exploration, Regression, GLM & GAM with introduction to R

Provided by: Highland Statistics Ltd

In cooperation with:

cE3c – eChanges, Faculty of Sciences, University of Lisbon, Portugal



We begin with an introduction to R and provide a protocol for data exploration to avoid common statistical problems. We will discuss how to detect outliers, deal with collinearity and transformations.

Date & Venue

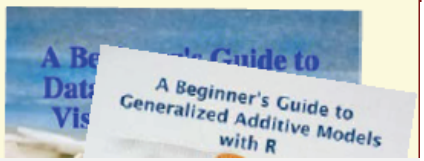
Date: 3 - 7 February 2020

Venue: PT Meeting Centre, R. Bojador 47, Parque das Nações, Lisbon, Portugal

Price: £500

Instructors: Dr. Alain Zuur
Dr. Elena Ieno

Authors of 11 books and providers of over 150 courses



REGISTRATION

www.highstat.com

Dr Alain F Zuur
highstat@highstat.com
www.highstat.com

RE: question on geepack output

Tiago Marques
To Søren Højsgaard

Reply | Reply All | Forward | ...

Wed 12/4/2019 11:06 AM

Fra: Tiago Marques <tiago.marques@st-andrews.ac.uk>
Sendt: 30. november 2019 20:04:21
Til: Søren Højsgaard
Emne: question on geepack output

Dear Dr. Søren Højsgaard,

I am using the geepack and it's function glmgee. While reproducing an analysis in the book by Zuur et al 2009, I realized there's a bit of the output that is not sensible to me (also shown in the book in fact). I attach here a short RMarkdown report that ends up with the question: the output lists as the number of clusters and the maximum cluster size something that is not what it should be – at least the way I see it. Can you possibly explain what I might be doing wrong?

All the best,

Tiago

From: Søren Højsgaard <sorenh@math.aau.dk>
Sent: Monday, December 2, 2019 9:01 AM
To: Tiago Marques <tiago.marques@st-andrews.ac.uk>
Subject: Sv: question on geepack output

```
I can't possibly reproduce / comment on anything you send me without the data.

You know: "A minimal reproducible example"...

Best

S
```

RE: question on geepack output

Tiago Marques
To Søren Højsgaard

y | Reply All | Forward | ...

Wed 12/4/2019 11:06 AM

Hi Soren,

Any feedback on this? I have a class this afternoon on GEE's and I was hoping I'd be able to tell the students something about what I have asked you. Why are the number of groups (and maximum number of observations per group) in the GEE output not what I'd expect.

Am I doing something stupid, or is the software doing something funny?

Cheers

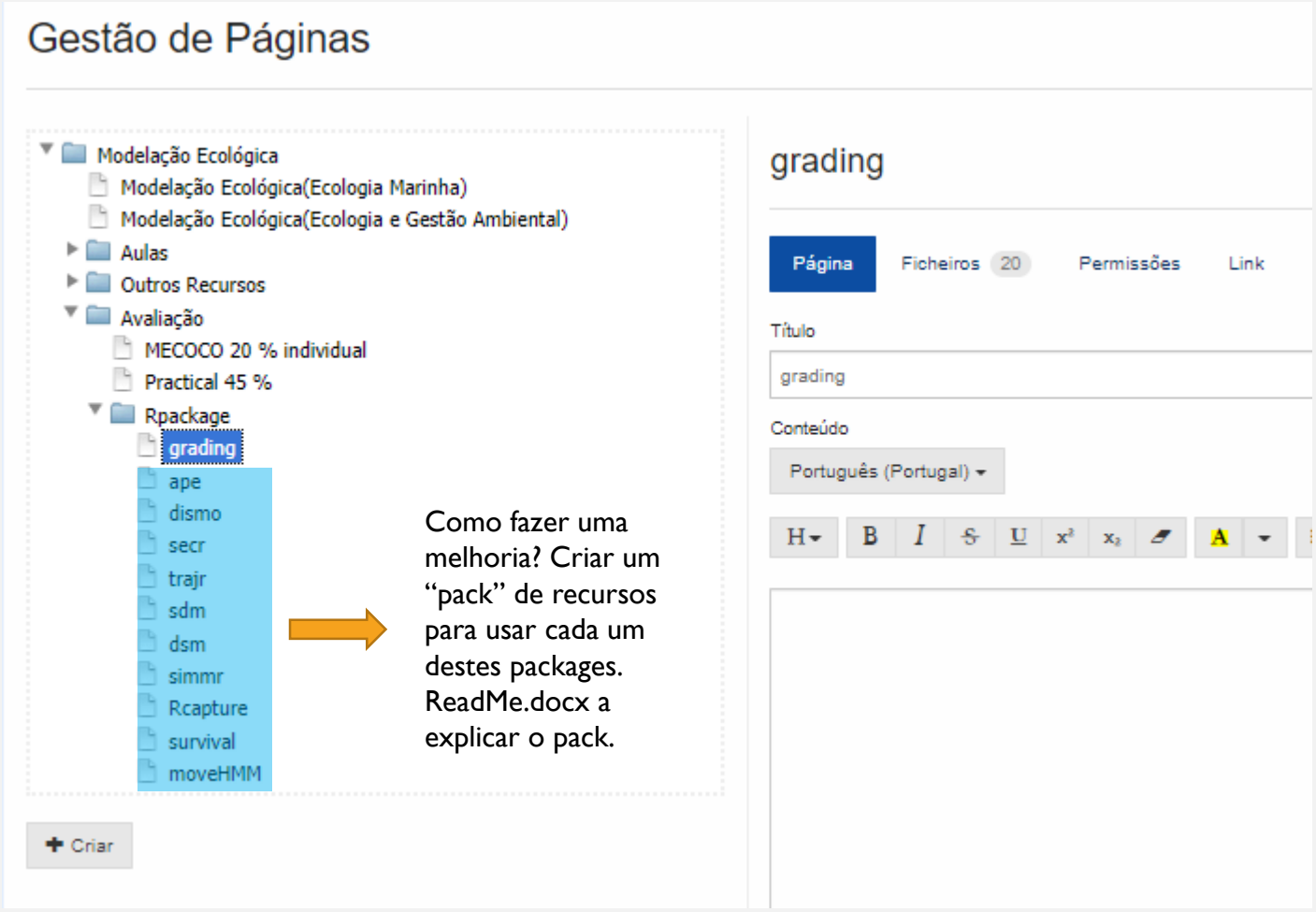
T

TODAY'S MENU

- Discussion on model averaging paper
- Bespoke useful models in ecological statistics (capture recapture, occupancy, spatial point processes, distance sampling, hierarchical models)
- Wrapping up GEEs - Modelling the owl data and the deer data
- Modelling "your" grades data
- Any other stuff you might want to discuss with me

- I will leave at 16:00, to compensate you from having spent an extra hour in class yesterday
- Pure coincidence: I have to be at ISPA at 16:30 for a PhD defense on dolphin sound production

GRADING


Gestão de Páginas
Modelação Ecológica
Modelação Ecológica(Ecologia Marinha)
Modelação Ecológica(Ecologia e Gestão Ambiental)
Aulas
Outros Recursos
Avaliação
MECOCO 20 % individual
Practical 45 %
Rpackage
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ape
dismo
secr
trajr
sdm
dsm
simmr
Rcapture
survival
moveHMM
Criar
Como fazer uma melhoria? Criar um "pack" de recursos para usar cada um destes packages. ReadMe.docx a explicar o pack.
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Página
Ficheiros 20
Permissões
Link
Título
grading
Conteúdo
Português (Portugal)

MODEL AVERAGING

Ecological Monographs, 0(0), 2018, pp. 1–20

Model averaging in ecology: a review of Bayesian, information-theoretic, and tactical approaches for predictive inference

Carsten F. Dormann,[1,22] Justin M. Calabrese,[2] Gurutzeta Guillera-Arroita,[3] Eleni Matechou,[4] Volker Bahn,[5] Kamil Bartoń,[6] Colin M. Beale,[7] Simone Ciuti,[1,8] Jane Elith,[3] Katharina Gerstner,[9,10] Jérôme Guelat,[11] Petr Keil,[10] José J. Lahoz-Monfort,[3] Laura J. Pollock,[12] Björn Reineking,[13,14] David R. Roberts,[1,15] Boris Schröder,[16,17] Wilfried Thuiller,[12] David I. Warton,[18] Brendan A. Wintle,[3] Simon N. Wood,[19] Rafael O. Wüest,[12,20] and Florian Hartig[1,21]

Dealing with correlation
Random Effects, Mixed Models &
Generalized Estimating Equations

Wrap up –
Generalized Estimating Equations

LAST WEEK's TASK - continued

Revisit two datasets from FT7b4ME 20 11 2019.pdf in "Aula 19"

7. Find a GLM that best fits the data "Owls.txt", where you are trying to explain the begging behavior of owls offspring when the parents are absent from the nest. The variable "SiblingNegotiation" represents the number of calls produced by the chicks in the nest during a 30 second period, while "BroodSize" represents the size of the brood. More details about this data can be found in Zuur et al. 2009.

Account for variation over time in the same nest

8. The data "DeerEcervi.txt" contains the incidence of *E. cervi* parasites in deer pellets, and we have also the corresponding sex, length and farm the deer were on. How many farms were available? Ignore them for now, and model the presence/absence of parasites in pellets as a function of deer characteristics. This is a dataset also used by Zuur et al. 2009.

Account for variation across farms

```
> fmodelo <- formula(SiblingNegotiation~offset(LBroodSize)+FoodTreatment+ArrivalTime)
> mod1 <- geeglm(formula=fmodelo,data=owls,family = poisson,id = Nest, corstr = "ar1")
> summary(mod1)

Call:
geeglm(formula = fmodelo, family = poisson, data = owls, id = Nest,
    corstr = "ar1")

 Coefficients:
                    Estimate  Std.err  Wald Pr(>|W|)
(Intercept)          3.70322  0.66935 30.61 3.16e-08 ***
FoodTreatmentSatiated -0.56417  0.12254 21.20 4.15e-06 ***
ArrivalTime          -0.12418  0.02691 21.30 3.93e-06 ***
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Estimated Scale Parameters:
            Estimate Std.err
(Intercept)    6.242   0.387

Correlation: Structure = ar1  Link = identity

Estimated Correlation Parameters:
      Estimate Std.err
alpha   0.3854  0.0582
Number of clusters:   27   Maximum cluster size: 52
```

```
> sort(with(owls,tapply(BroodSize,Nest,length)))
          Forel           Sevaz        Chevroux             GDLV CorcellesFavres         Henniez
              4               4              10               10               12              13
    Gletterens     LesPlanches           Lully          Rueyes           Jeuss           Trey
             15              17              17               17               19              19
       ChEsard          Bochet         StAubin          Murist         Payerne         Franex
             20              23              23               24               25              26
         Seiry         Marnand      AutavauxTV          Lucens     Champmartin        Etrabloz
             26              27              28               29               30              34
      Yvonnand          Montet          Oleyes
             34              41              52
> length(unique(owls$Nest))
[1] 27
```

```
> mod.by.nestnight <- geeglm(formula=fmodelo,data=owls,family = poisson,id=NestNight,corstr="ar1")
> summary(mod.by.nestnight)

Call:
geeglm(formula = fmodelo, family = poisson, data = owls, id = NestNight,
    corstr = "ar1")

 Coefficients:
                     Estimate Std.err Wald Pr(>|W|)
(Intercept)             3.593   0.668 28.9  7.6e-08 ***
FoodTreatmentSatiated  -0.578   0.115 25.4  4.6e-07 ***
ArrivalTime            -0.122   0.027 20.3  6.6e-06 ***
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Estimated Scale Parameters:
            Estimate Std.err
(Intercept)     6.64   0.524

Correlation: Structure = ar1  Link = identity

Estimated Correlation Parameters:
      Estimate Std.err
alpha    0.517  0.0676
Number of clusters:   277   Maximum cluster size: 18
```

?

Just as in GLMs, non-normal responses and link functions get added to models with random effects

Review

Cell PRESS

Generalized linear mixed models: a practical guide for ecology and evolution

Benjamin M. Bolker[1], Mollie E. Brooks[1], Connie J. Clark[1], Shane W. Geange[2], John R. Poulsen[1], M. Henry H. Stevens[3] and Jada-Simone S. White[1]

"… Despite the availability of accurate techniques for estimating GLMM parameters in simple cases, complex GLMMs are challenging to fit and statistical inference such as hypothesis testing remains difficult…"

"…GLMMs are surprisingly challenging to use even for statisticians. Although several software packages can handle GLMMs (Table 1), few ecologists and evolutionary biologists are aware of the range of options or of the possible pitfalls…."

https://biologyforfun.wordpress.com/2014/03/12/generalized-linear-mixed-models-in-ecology-and-in-r/

Ecology and Evolution
Open Access

Ecol Evol. 2013 Sep; 3(9): 3141–3151.
Published online 2013 Aug 2. doi: 10.1002/ece3.707

PMCID: PMC3790557
PMID: 24102000

Generalized additive mixed models for disentangling long-term trends, local anomalies, and seasonality in fruit tree phenology

Leo Polansky and Martha M Robbins

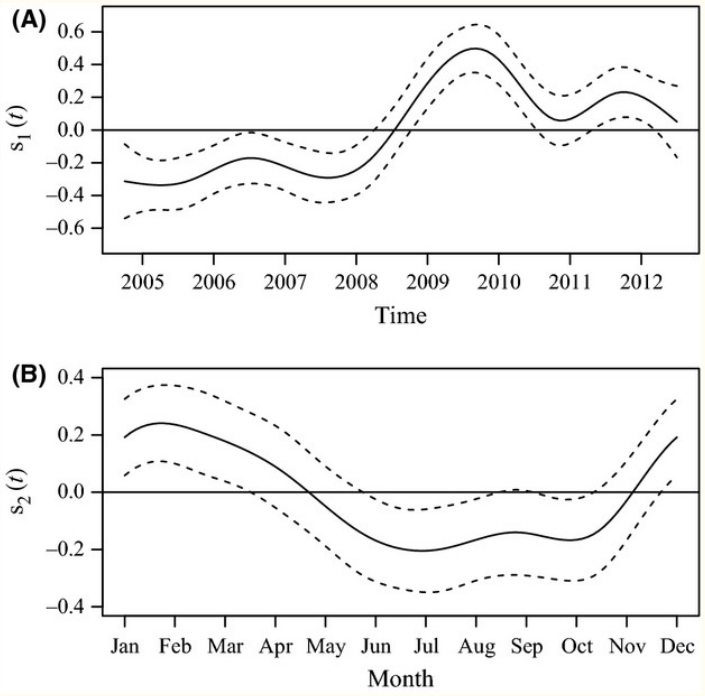


Figure 3

Smooth functions (solid lines) with 95% credible region delineated by the dashed lines estimated from the forest aggregated data for the (A) interannual smooth $s_1(t)$ and the (B) intraannual smooth function $s_2(t)$, both plotted on the linear scale.

PeerJ Life & Environment

View 510 tweets

Related research

✔ PEER-REVIEWED Ecology section >

Hierarchical generalized additive models in ecology: an introduction with mgcv

Bioinformatics tool | Ecology | Statistics | Data Science | Spatial and Geographic Information Science

Eric J. Pedersen [1,2], David L. Miller [3,4], Gavin L. Simpson [5,6], Noam Ross [7]

Published May 27, 2019

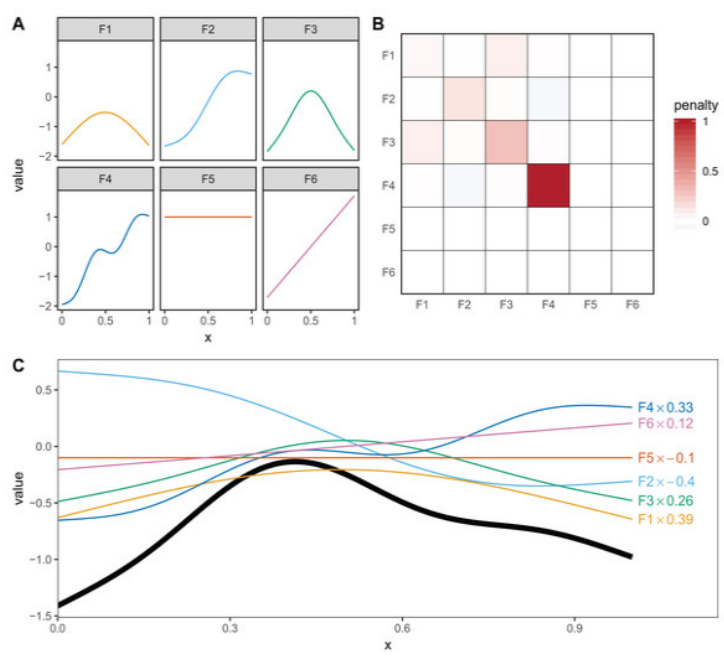
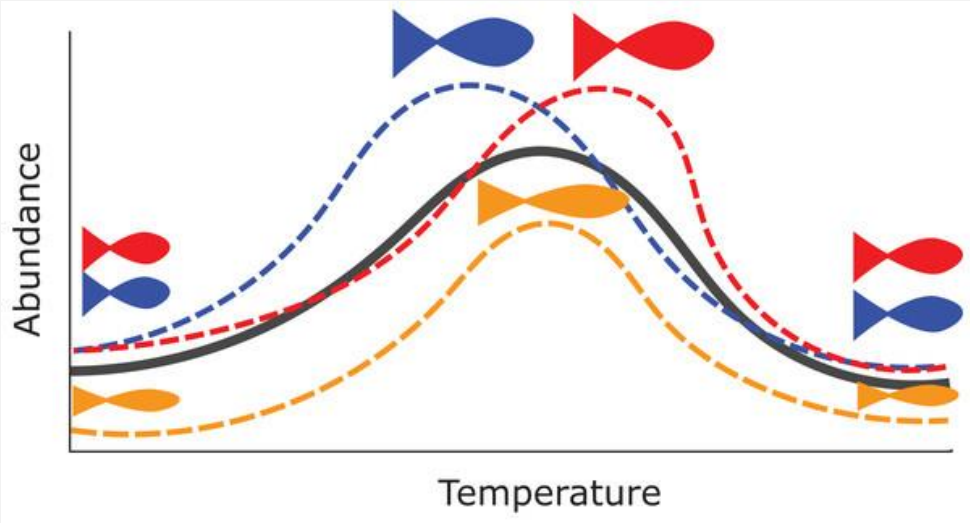


Figure 3: (A) Examples of the basis functions associated with a six basis function thin plate regression spline (TPRS, $m = 2$), calculated for data, x, spread evenly between $x = 0$ and $x = 1$.



https://peerj.com/articles/6876/

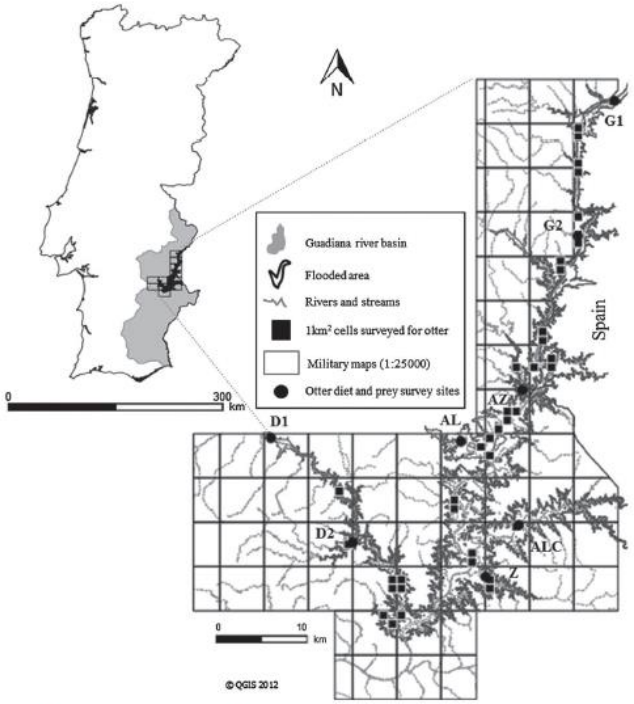


Figure 1. Location of the Alqueva Reservoir in southern Portugal, showing the 25 km² and the 1 km² (black squares) otter survey grid c
circles) where otter diet and prey were assessed. Two sites (G1 and G2) were located in the main Guadiana River. Other sites were locat
Guadiana River: the Azevel stream (AZ), Álamo stream (AL), Degebe stream (D1 and D2), Alcarrache stream (ALC) and Zel

To account for multiple surveys of the same location, a generalized additive mixed model (GAMM) regression framework was used (Wood, 2006). Presence/absence of otter signs was modelled by smoothing of trimester values, with the smoothness chosen by using the default generalized cross-validation procedure in the R mgcv library (Wood, 2006; R Development Core Team, 2011). Grid was included as a random effect and the residuals within sites were assumed to follow a first-order autoregressive model.

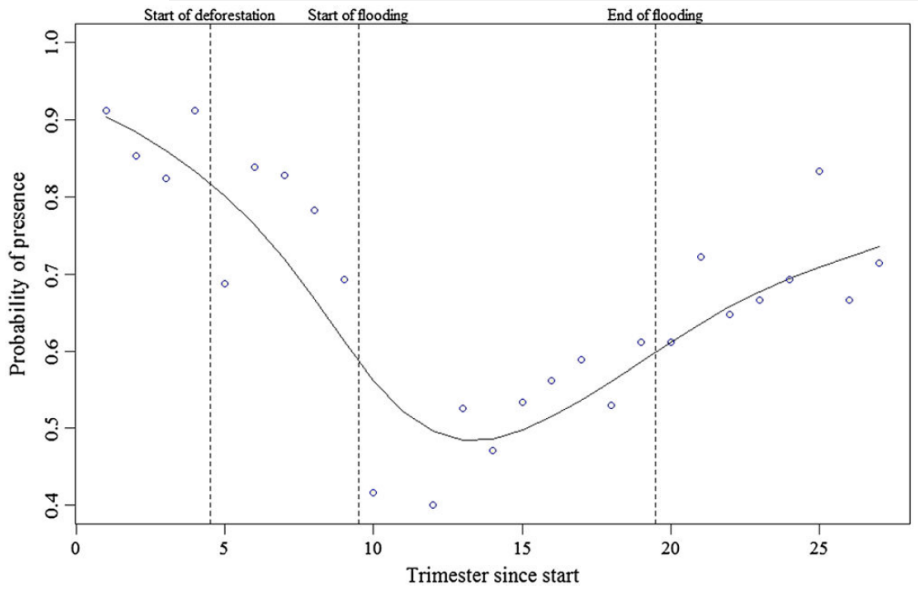
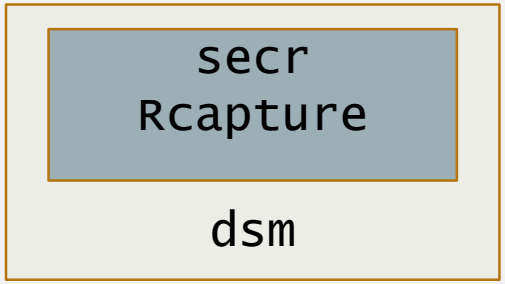


Figure 3. Probability of otter presence as a function of trimester in the flooded area of the Alqueva Reservoir. Data are represented by points and fitted model by a black line.

Pedroso, N. M.; Marques, T. A. & Santos-Reis, M. 2014 The response of otters to environmental changes imposed by the construction of large dams *Aquatic Conservation: Marine And Freshwater Ecosystems* **24**: 66–80

Já usado na Aula 3, slide 70.

The theory R package work – a summary



Estimating abundance :
capture recapture vs. distance sampling

moveHMM
tarjr

Animal movement:
modelling vs. descriptive

survival

Survival analysis: just a very special GLM

dismo
sdm

Species distribution models, also just very special regression models

See also next class with Prof. Susana França

simmr

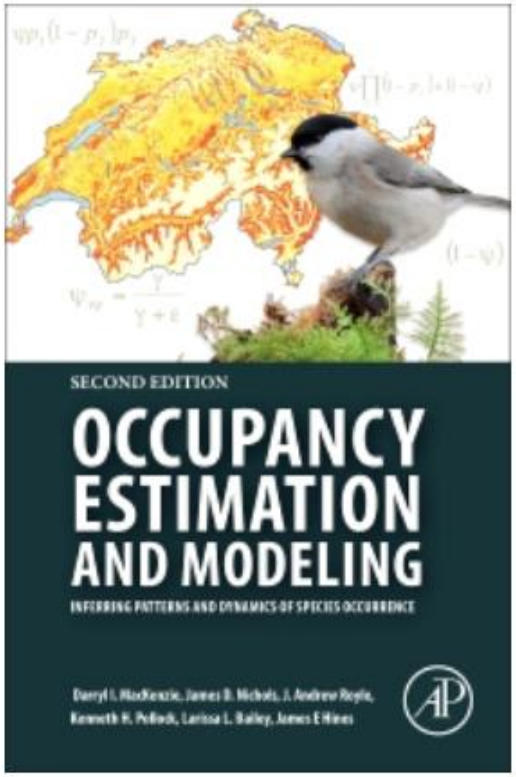
Stable Isotope Mixing Models – really, just a fancy regression with mixture models (also present in moveHMM)

ape

Genetic data – just another clustering method

SPECIFIC YET STILL VERY LARGE CLASSES OF MODELS FOR ECOLOGICAL DATA (SO LARGE THAT EACH OF THESE COULD BE A FULL SEMESTER COURSE!)

OCCUPANCY MODELLING

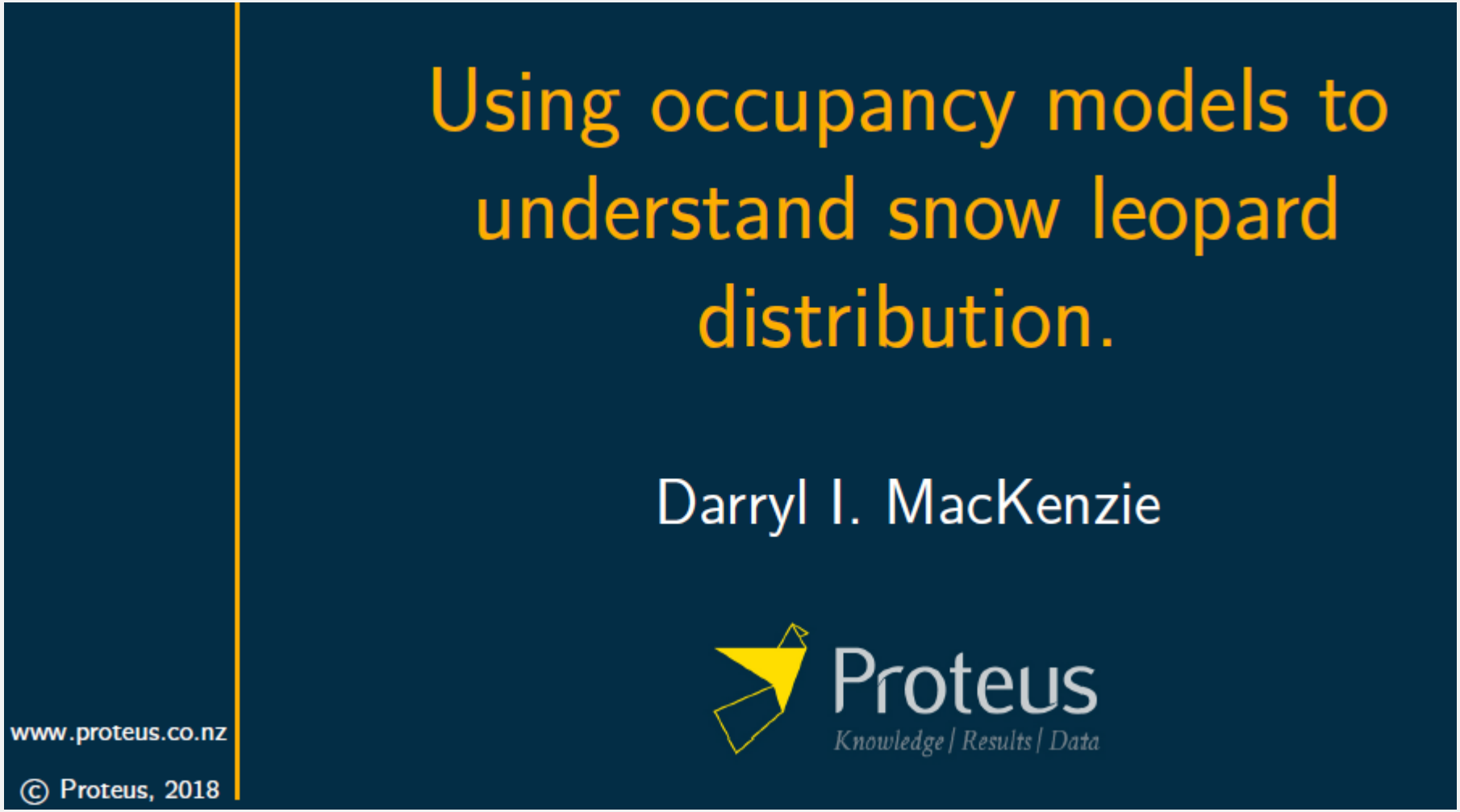


Occupancy Estimation and Modeling

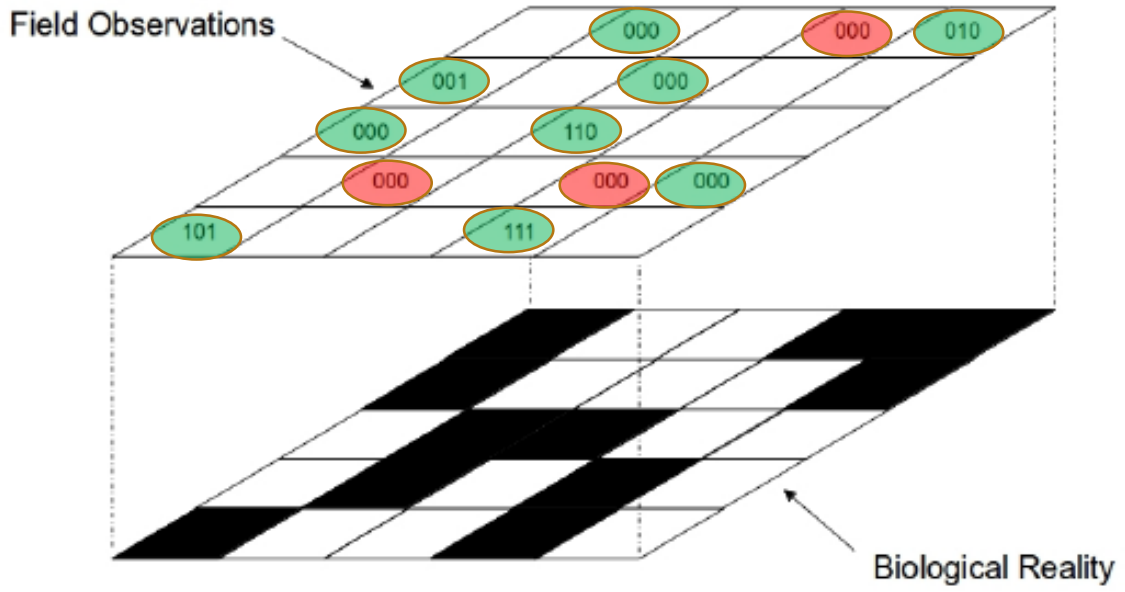
2nd Edition

Inferring Patterns and Dynamics of Species Occurrence

Material blatantly stolen from



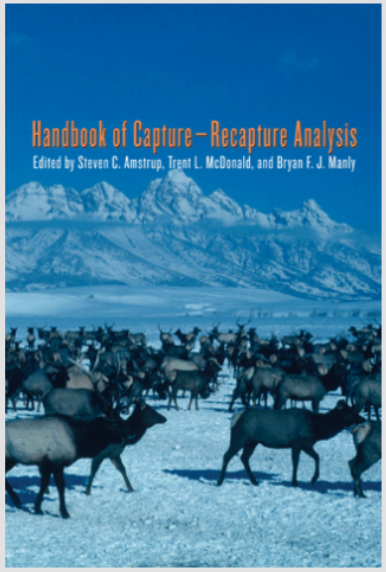
https://www.researchgate.net/publication/328417995_Using_occupancy_models_to_understand_snow_leopard_distribution



- Field observations are a combination of biological and observation processes.
- Important to account for observation process.
  - i.e., sampling and detection

- Many popular methods of analysis ignore imperfect detection.
  - e.g., logistic regression, MaxENT, random forests.
- Model where snow leopards were *found*.
- Occupancy models explicitly account for detection probability.
  - separate the observation and biological processes
- Require repeated surveys of each survey unit.
- Often have that information.
  - e.g., multiple camera-trap days, multiple segments along a transect.

CAPTURE RECAPTURE MODELS



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Handbook of Capture-Recapture Analysis

Edited by Steven C. Amstrup, Trent L. McDonald & Bryan F. J. Manly

Editions

Paperback | 2005 | © 2006 | **$90.00** | **£70.00** | ISBN: 9780691089683 | 336 pp. | 6 x 9 1/4 | 20 halftones. 6 line illus. 74 tables.
E-book | ISBN: 9781400837717

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A mais simples questão que se coloca quando pensamos numa espécie é: Quantos animais de uma determinada espécie existem?

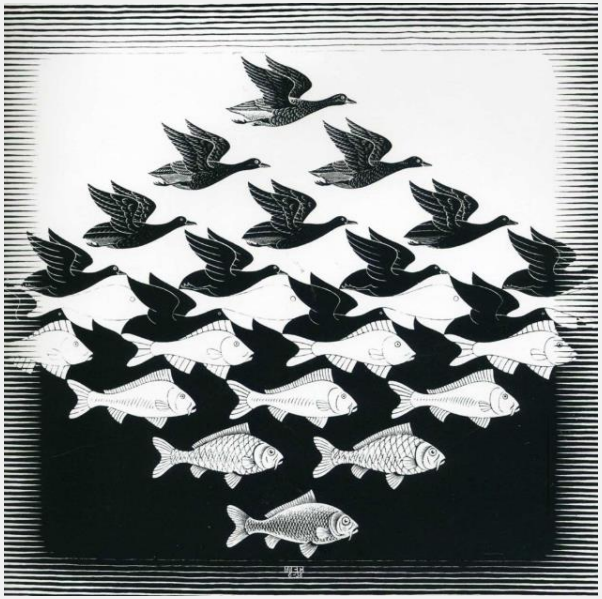
Outras questões poderão ser, “o que comem?”, “que habitats preferem?”, “o que podemos fazer para ajudar na sua conservação, caso seja preciso?”, “quais as principais ameaças?”.

Para responder a estas perguntas é necessário usar modelos, pois a realidade é demasiado complexa para ser compreendida como um todo.

Como estimar a dimensão de uma população?

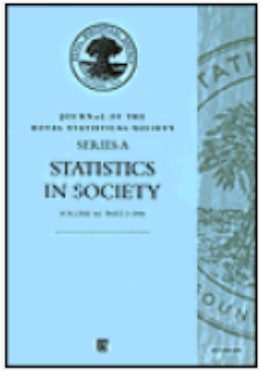
Uma área de ativa investigação em estatística é a da estimação do tamanho de populações naturais, que terá começado com Laplace quando este usou as ideias subjacentes aos métodos de captura-recaptura para estimar o tamanho da população de França, em 1783.

Em 1896, Carl G. J. Petersen foi o primeiro a empregar este método no estudo do fluxo migratório de peixes no mar Báltico. Em 1930, Frederick Lincoln utilizou-o para estimar o tamanho da população de patos selvagens da América do Norte. Nas décadas de 30 e 40 observou-se um consistente desenvolvimento teórico e aplicado do método.
São frequentes estudos de captura-recaptura para estimar e monitorizar o tamanho das populações de várias espécies, tanto em populações fechadas como abertas.



Who Captures the Marks for the Petersen Estimator?

I. B. J. Goudie and M. Goudie

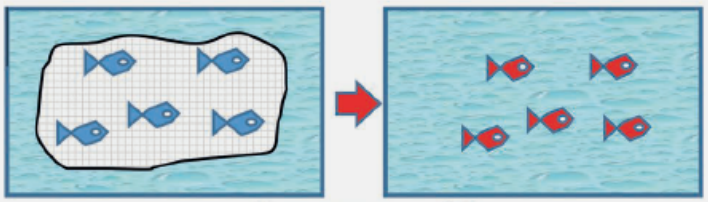


Journal of the Royal Statistical Society. Series A (Statistics in Society)
Vol. 170, No. 3 (2007), pp. 825-839 (15 pages)

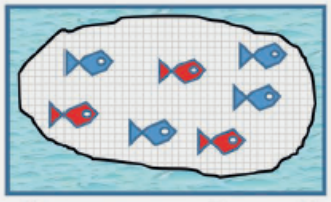
Published by: Wiley for the Royal Statistical Society

O método utilizado por Laplace consistia em recolher uma primeira amostra da população (captura) de dimensão n_1, "marcando" todos os indivíduos recolhidos e devolvendo-os de seguida à população. Posteriormente, recolhe-se uma segunda amostra (recaptura) de dimensão n_2 e conta-se o número de indivíduos marcados, n_3. Como a segunda amostra é aleatória, a proporção de marcados na segunda amostra deve ser igual à proporção de marcados na população, donde se conclui que a dimensão estimada da população, N, é dada por:

$$\frac{n_3}{n_2} = \frac{n_1}{N} \Leftrightarrow N = \frac{n_1 \times n_2}{n_3}$$



1ª amostra: $n_1 = 5$



2ª amostra: $n_2 = 7, n_3 = 3$

$\Longrightarrow N = 35/3 \approx 12$

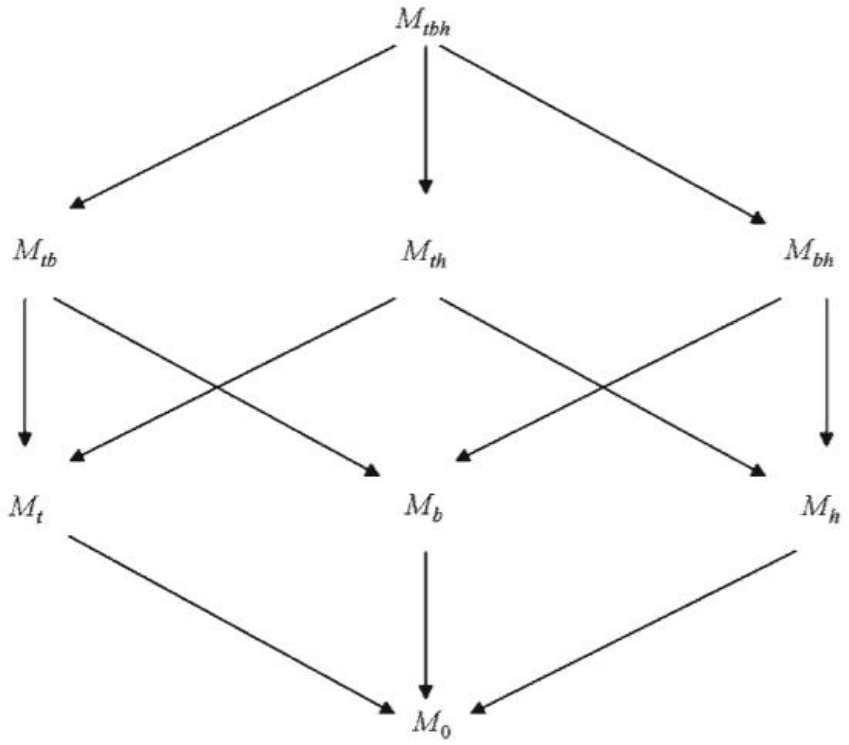


Fig. 1 The suite of eight models proposed by Otis et al. (1978) to allow for time variation (t), behavioral response to initial capture (b), and individual heterogeneity (h) of encounter probabilities. Models pointed to by arrows are nested within the model above

Closed population estimation models and their extensions in Program MARK

March 2008 · Environmental and Ecological Statistics 15(1):89-99

DOI: 10.1007/s10651-007-0030-3

Gary C White

Table 1 A three-occasion example, where only eight possible encounter histories are possible, is presented to illustrate the construction of encounter history probabilities considering only time and behavior variation, where p_i is initial capture probability on occasion i, and c_i is the recapture probability on occasion i (with no c_1)

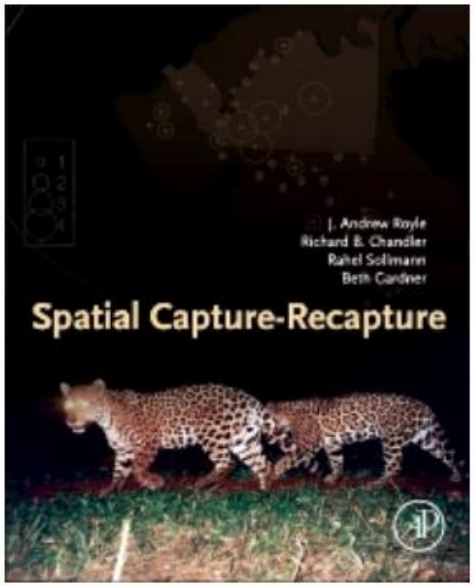
Encounter history (i)	Animals observed (X_i)	Probability (P_i)
100	X_{100}	$p_1(1-c_2)(1-c_3)$
010	X_{010}	$(1-p_1)\,p_2(1-c_3)$
001	X_{001}	$(1-p_1)(1-p_2)\,p_3$
110	X_{110}	$p_1c_2(1-c_3)$
101	X_{101}	$p_1(1-c_2)c_3$
011	X_{011}	$(1-p_1)\,p_2c_3$
111	X_{111}	$p_1c_2c_3$
000	X_{000}	$(1-p_1)(1-p_2)(1-p_3)$

These are never seen!

Unmodelled heterogeneity is a plague for conventional capture recapture !

And N is typically ill defined…

CAPTURE RECAPTURE MODELS



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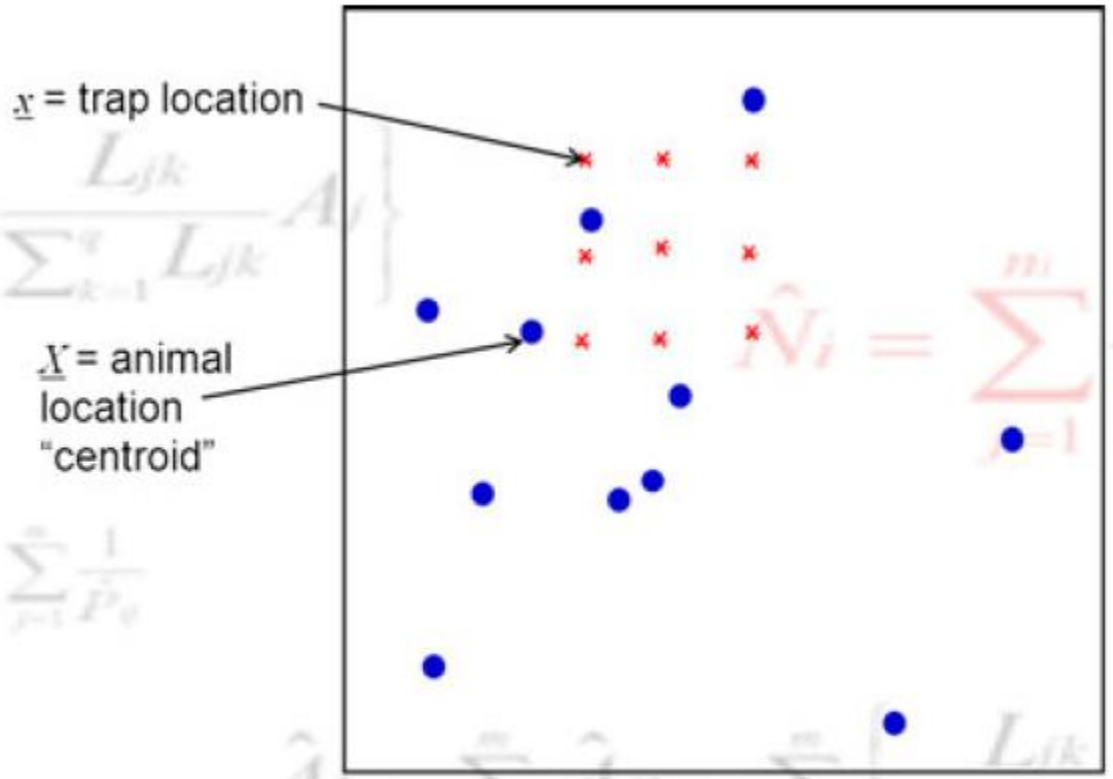

Fig. 1 Schematic representation of a spatial trapping grid relative to centroids of animal location

Borchers, D. L. 2012 A non-technical overview of spatially explicit capture-recapture models Journal of Ornithology152: 435-444

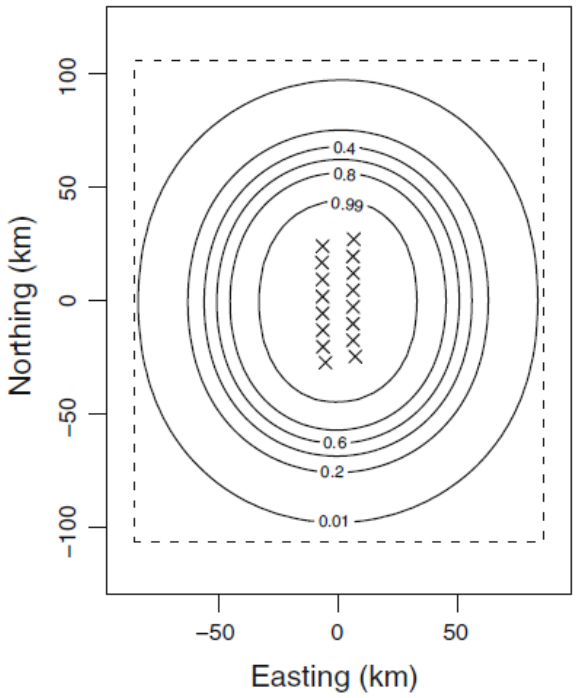

Fig. 1 Layout of BSURE case study hydrophones (*crosses*), *solid contour lines* showing probability of detecting a sound from that location with one or more hydrophones (denoted $p_.(X;\theta)$ in the text) estimated from a likelihood-based analysis with the half-normal detection function model, and the *dashed rectangle* showing the 80-km buffer used in that analysis

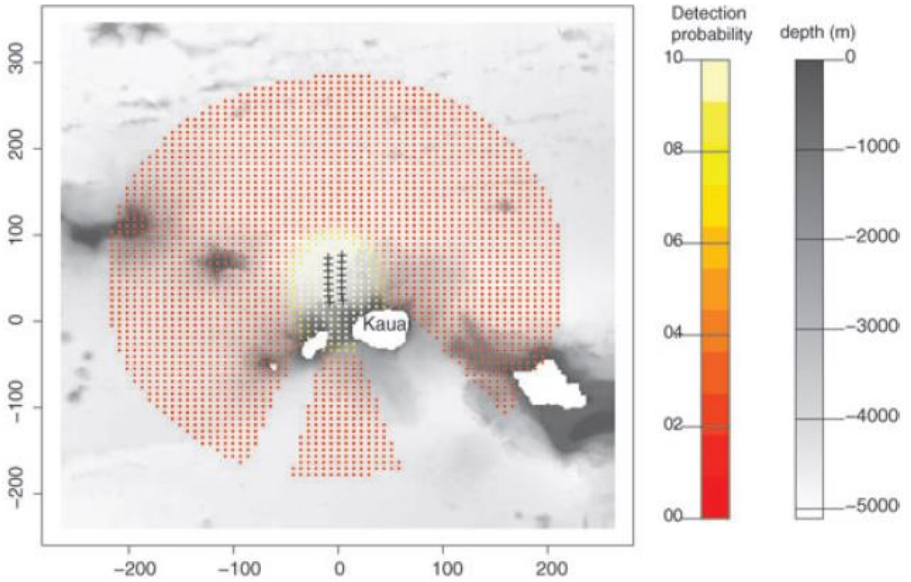

Figure 1. Study area showing hydrophone locations (black crosses) with habitat mask represented by small square dots (color, online, proportional to estimated detection probability at each grid point). Island masses are represented by white polygons, and acoustic shadow zones have no dots. Approximate bottom depth is shown in gray scale. Horizontal and vertical scale units in kilometers.

Marques, T. A.; Thomas, L.; Martin, S. W.; Mellinger, D. K.; Jarvis, S.; Morrissey, R. P.; Ciminello, C.-A. & DiMarzio, N. 2012 Spatially explicit capture recapture methods to estimate minke whale abundance from data collected at bottom mounted hydrophones *Journal of Ornithology* **152**: 445-455

Martin, S. W.; Marques, T. A.; Thomas, L.; Morrissey, R. P.; Jarvis, S.; DiMarzio, N.; Moretti, D. & Mellinger, D. K. 2012 Estimating minke whale (*Balaenoptera acutorostrata*) boing sound density using passive acoustic sensors *Marine Mammal Science* **29**: 142-158

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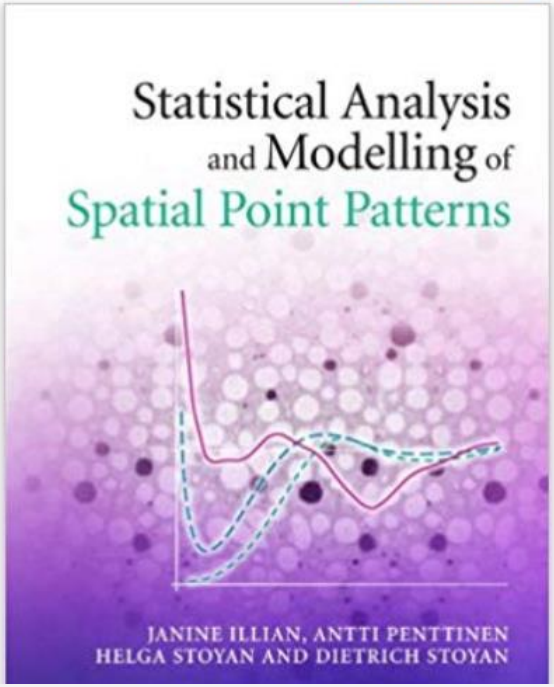

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Fig. 2. A point pattern, a window, and a pixel image.

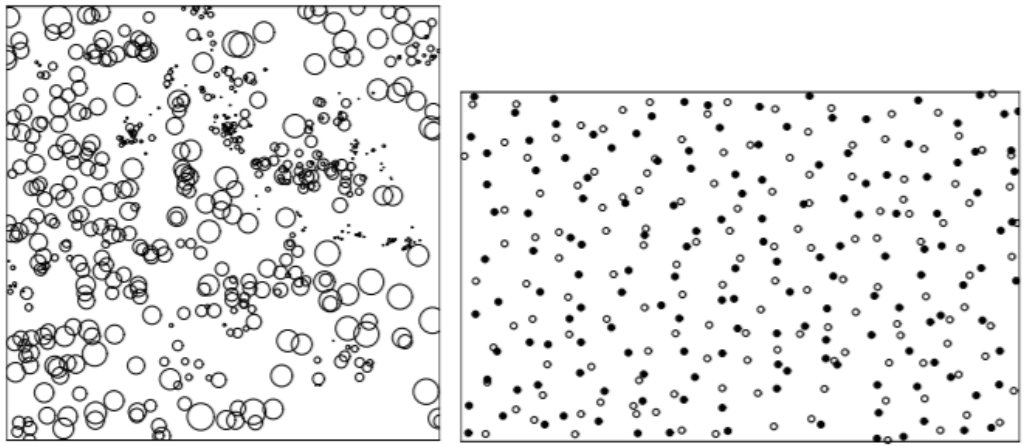

Fig. 3. Examples of marked point patterns. (a) continuous marks. Mark values (tree diameters) represented as radii of circles. The Longleaf Pines dataset, available as `longleaf`. (b) categorical marks. Mark values (cell types) represented as different graphical symbols. Hughes' amacrine cell dataset, available as `amacrine`.

http://www3.uji.es/~mateu/badturn.pdf

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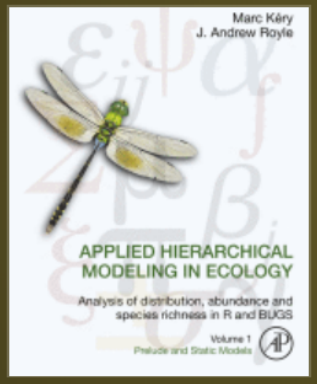

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keep that in mind…

always!

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José J. Lahoz-Monfort, Gurutzeta Guillera-Arroita, Brendan A. Wintle

First published: 29 November 2013 | https://doi.org/10.1111/geb.12138 | Cited by: 82

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Lahoz-Monfort, J. J.; Guillera-Arroita, G. & Wintle, B. A. 2014 Imperfect detection impacts the performance of species distribution models *Global Ecology and Biogeography* **23**: 505-515

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