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Diagnostic goodness-of-fit tests for capture-recapture data

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Overview

- Capture-recapture data and models
- Diagnostic goodness-of-fit tests
- Links to score tests
- Model discrimination strategies
- Applications
- Future Developments

Capture-recapture data and models

- Capture-recapture data
  - 10010
- Cormack-Jolly-Seber model
  - ϕ_t: probability an individual survives from occasion t to t+1
  - p_t: probability an individual is captured at occasion t given it is alive at occasion t
- All animals present at any given time are assumed to behave the same

Diagnostic goodness-of-fit tests

- Application of the factorisation theorem
- $L = Pr(data|s)Pr(s;\theta)$
- **Pr(data|s)** can be used to check model assumptions
- $Pr(s;\theta)$ used for parameter estimation
- Pollock et al, (1985) showed that the assessment of model adequacy can be decomposed into two conditionally independent checks

Diagnostic goodness-of-fit tests

- **Test 2:** captured and non-captured individuals have an equal chance of being captured at the next capture occasion
  - Test 2.CT
  - Test 2.CL
- **Test 3:** newly and already-marked animals have an equal chance of being seen again
  - Test 3.SR
  - Test 3.SL
- All tests are performed by means of a contingency table test of homogeneity

New diagnostic goodness-of-fit tests

- Joint recapture and recovery data
  - 10102
  - λ_t: probability an individual who dies between occasion t and t+1 is recovered dead

- Diagnostic tests for joint recapture and recovery data
  - Barker (1997, 1999)
  - Single and multi-site tests(McCrea et al, 2014a)
  - Detect **effects of capture** on survival probabilities, capture probabilities and recovery probabilities
  - Detect **transient** individuals: differentiate between permanent emigration of all individuals and transient behaviour of new individuals

Simulation study (McCrea et al, 2014a)

- Capturing an animal affects their survival probability

	Sample size			
	100	**200**	**500**	**1000**
Recaptures Only				
2.CT	7	9	6	4
2.CL	1	4	4	10
Joint recaptures and recoveries				
2.CTm	7	9	6	4
2.CTd	24	61	96	100
2.Cmd	27	48	90	100
2.CLm	1	4	4	10
2.CLd	1	6	6	1

Linking diagnostic tests and score tests

- Shown that certain diagnostic goodness-of-fit tests are **equivalent to score tests** (McCrea et al, 2014b)
- Test 2.CT
  - p_t*: probability of capture at occasion t given the individual was captured at occasion t-1
  - Score test of H_0: $p_t = p_t^*$
- Test 3.SR
  - ϕ_t*: probability an individual captured at occasion t survives until t+1
  - Score test of H_0: $\phi_t = \phi_t^*$

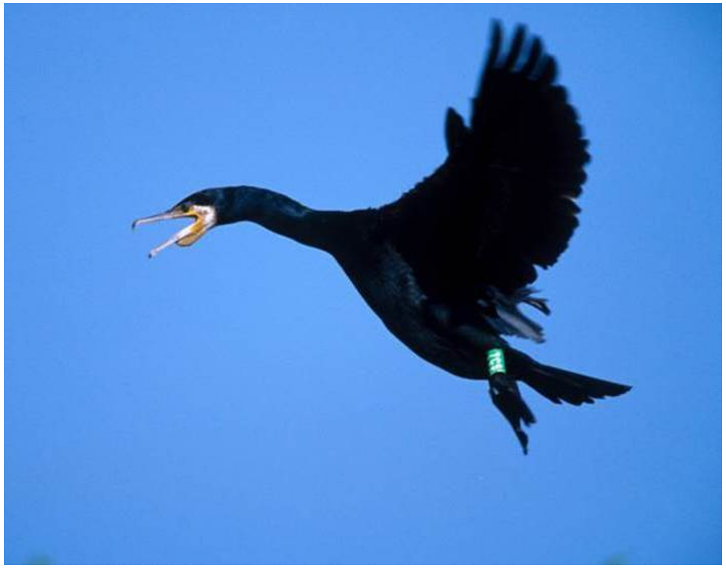
Model discrimination strategies

- Are diagnostic goodness-of-fit tests necessary?

- Strategy of including alternative models within model set and performing step-wise model selection procedure using score tests (McCrea and Morgan, 2011)

- Simulation has compared the performance of diagnostic tests for memory and score tests (Cole et al, 2013)

Application 1: Great cormorants, *Phalacrocorax carbo sinensis*



- Step-up score test approach
  - ϕ(t*trans),p(trap)

Test	df	X^2	P
2.CT	8	31.00	0.00
2.CL	7	9.63	0.21
3.SR	9	110.64	0.00
3.SM	8	16.78	0.03
Model	**k**	**$-\log L$**	**AIC**
$\phi(t * trans), p(trap)$	21	1831.27	3704.54
$\phi(t + trans), p(trap)$	13	1840.77	3707.54
$\phi(t + trans), p(t + trap)$	22	1833.62	3711.24
$\phi(t * trans), p(t + trap)$	29	1828.64	3715.28
$\phi(t + trans), p(t * trap)$	28	1832.48	3720.96
$\phi(t * trans), p(t * trap)$	36	1825.61	3723.21
$\phi(trans), p(t + trap)$	13	1852.13	3730.26
$\phi(trans), p(trap)$	4	1865.32	3738.64
$\phi(trans), p(t * trap)$	20	1850.28	3740.56

Application 2: European dippers, *Cinclus cinclus*

Model Code	Model	k	s	P	$-\log L$	AIC	LRT
A0	$\phi(\cdot), p(\cdot)$	2			333.42	670.84	
A1	$\phi(t), p(\cdot)$	7	7.15	0.210	329.87	673.73	7.11
A2	$\phi(trans), p(\cdot)$	3	0.40	0.526	333.22	672.44	0.40
A3	$\phi(\cdot), p(t)$	7	3.27	0.658	332.24	678.48	2.36
A4	$\phi(\cdot), p(trap)$	3	3.37	0.066	332.37	670.74	2.09

- Simulation: subtle trap-dependence within the parameter values
- Score test approach outperformed the diagnostic test approach
- ϕ(t),p(t) vs ϕ(t),p(t*trap)
- ϕ(.),p(.) vs ϕ(.),p(trap)

Application 3: Humpback Whales, *Megaptera novaeangliae*

Model Code	Model	k	s	P	$-\log L$	AIC	LRT
A0	$\phi(\cdot), p(\cdot)$	2			55.86	115.73	
A1	$\phi(t), p(\cdot)$	7	4.78	0.44	53.11	120.23	5.50
A2	$\phi(trans), p(\cdot)$	3	5.80	0.02	53.25	112.50	5.23
A3	$\phi(\cdot), p(t)$	7	2.22	0.82	54.49	122.97	2.75
A4	$\phi(\cdot), p(trap)$	3	1.59	0.21	55.05	116.10	1.63
B0	$\phi(trans), p(\cdot)$	3			53.25		
B1	$\phi(trans * t), p(\cdot)$	12	12.53	0.19	49.18	122.36	8.14
B2	$\phi(trans), p(t)$	8	3.69	0.59	50.94	117.89	4.61
B3	$\phi(trans), p(trap)$	4	0.81	0.37	52.82	113.63	0.87

- Diagnostic test for transience Test 3.SR was not significant, P=0.38
- Important biological feature in this population

Further Developments

- Multievent models – multistate capture-recapture models with state uncertainty
- No diagnostic goodness-of-fit tests exist for these models
- Model selection strategy for multievent models
- Diagnosing heterogeneity in capture-recapture models

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