



Introduction to GenEst Generalized Estimator of Mortality

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Alternative Energy Development

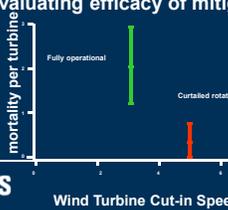
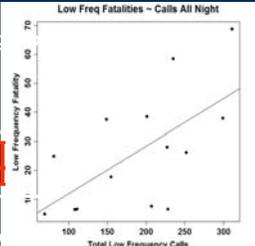
- What is the cost to wildlife?
- Are some species differentially affected?
 - Cave-roosting bats after WNS
 - Migratory tree bats
 - Golden eagles
- Can we avoid/reduce impacts? 
- **Need accurate estimates**
- **Need measure of uncertainty**
- **Need to correctly account for all we don't see**



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Why GenEst is Needed

- Accuracy of estimator critical for
 - Meaningful comparisons
 - Sites (and site properties)
 - Estimating trends
 - Evaluating efficacy of mitigation



Monitoring widely differing

- Countries - States/provinces - Counties
- Monitoring required at...
 - All ... some... none
- Public access to data
 - All publicly available...
 - some proprietary...
 - none need be public
- Adjustments for non-detection vary widely
 - Different estimators adjust differently



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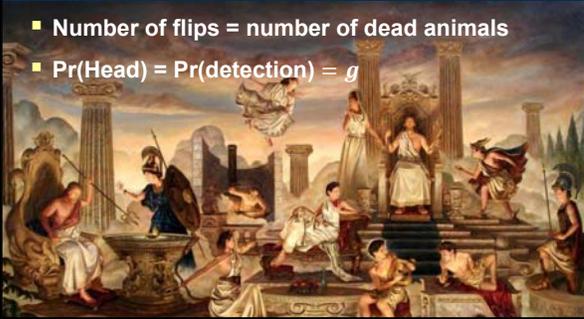
Monitoring widely differing



USGS 7

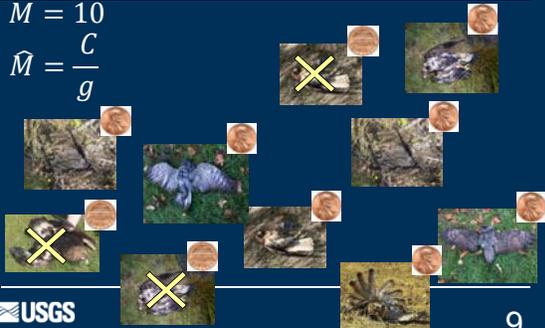
Analogy

- Gods on Olympus flipping coins
- Number of flips = number of dead animals
- $\Pr(\text{Head}) = \Pr(\text{detection}) = g$



Estimating Mortality: Analogy

$$M = 10$$

$$\hat{M} = \frac{C}{g}$$


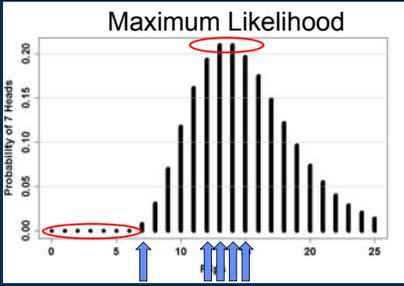
USGS 9

Probability of 7 Heads with fair coin

$M \geq 7$

$\hat{M} = 14$

Maximum Likelihood



USGS 10

Probability of 7 Heads with fair coin

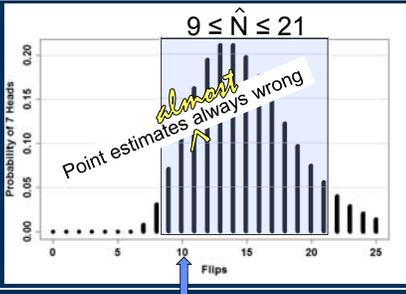
$\hat{N} = 14$

$N \geq 7$

$9 \leq \hat{N} \leq 21$

almost always wrong

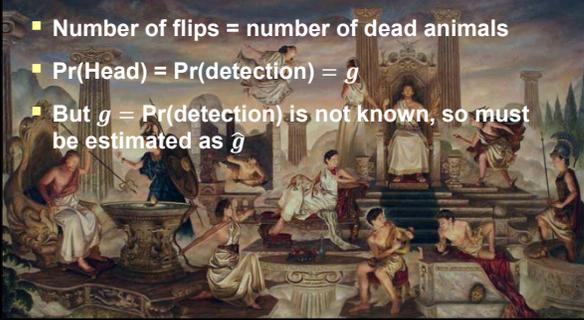
Point estimates



USGS 11

Analogy

- Gods on Olympus flipping coins
- Number of flips = number of dead animals
- $\Pr(\text{Head}) = \Pr(\text{detection}) = g$
- But $g = \Pr(\text{detection})$ is not known, so must be estimated as \hat{g}



Current Protocol – Estimating $\hat{M} = \frac{C}{\hat{g}}$

Estimating g is notoriously difficult

Different assumptions → different estimators:

- Persistence patterns
- Probability a searcher sees a carcass
- Fraction in searchable area

Assumptions aren't necessarily wrong... they're just not always right.



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Current Protocol



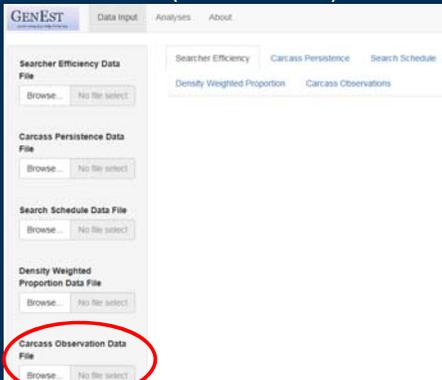
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Current Protocol – C (number counted)

- Send crews out on regular basis to search for carcasses beneath turbines
- Count the number of “heads” observed
- Search protocol similar for all estimators

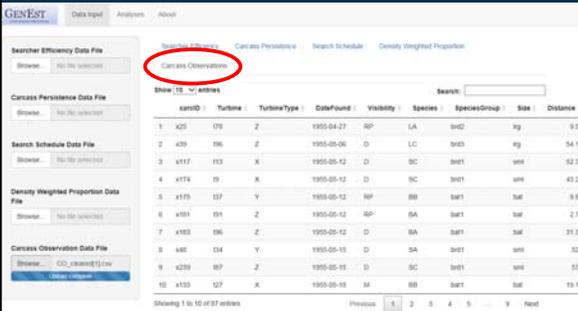



GenEst – C (number counted)




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GenEst – C (number counted)



spnID	Turbine	TurbineType	DateFound	Visibility	Species	SpeciesGroup	Size	Distance	
1	425	Z	1955-04-27	SP	LA	brd	rg	5.3	
2	429	06	Z	1955-05-06	D	LC	brd	rg	54.1
3	4147	03	X	1955-05-12	D	SC	brd	wh	523.3
4	4174	09	X	1955-05-12	D	SC	brd	wh	432.3
5	4175	137	Y	1955-05-12	RP	BB	brd	wh	3.5
6	4181	01	Z	1955-05-12	RP	SA	brd	wh	2.7
7	4183	06	Z	1955-05-12	D	SA	brd	wh	213.8
8	448	134	Y	1955-05-15	D	SA	brd	wh	30
9	4239	07	Z	1955-05-15	D	SC	brd	wh	57
10	4130	07	X	1955-05-18	SA	BB	brd	wh	193.1



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Major sources of imperfect detection

$$M_{ij}f \neq C_{ij}$$

f = fraction of turbines sampled




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GenEst – f (fraction of facility surveyed)

USGS 19

Major sources of imperfect detection

$$M_{ij} f a_i \neq C_{ij}$$

f = fraction of turbines sampled
 a = fraction of carcasses in searched area

What fraction of carcasses was in the searched area?
Not what fraction of plot was searched?

USGS

Current Protocol – a (proportion in search area)

Integrates to 1 around each turbine
 63%

GenEst – a (density-weighted proportion in area)

USGS 22

GenEst – a (density-weighted proportion in area)

Turbine	id	lat	lon	used	sig
1	12	0.688	0.944	0.612	0.555
2	122	0.688	0.944	0.612	0.555
3	128	0.688	0.944	0.612	0.555
4	130	0.688	0.944	0.612	0.555
5	132	0.688	0.944	0.612	0.555
6	133	0.688	0.944	0.612	0.555
7	135	0.688	0.944	0.612	0.555
8	139	0.688	0.944	0.612	0.555
9	140	0.688	0.944	0.612	0.555
10	147	0.688	0.944	0.612	0.555

USGS 23

Major sources of imperfect detection

$$M_{ij} f a_i r_{ij} \neq C_{ij}$$

f = fraction of turbines sampled
 a = fraction of carcasses in searched area
 r = proportion of carcasses persisting

USGS

Current Protocol – r (proportion persisting)

- Place trial carcasses in field
- Check often to determine fate
- Model persistence pattern not just average time
- Estimate probability of persisting to next scheduled search

USGS

GenEst – r (carcass persistence)

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GenEst – r (carcass persistence)

USGS

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GenEst – Analyses – Carcass Pers

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GenEst – Analyses – Carcass Pers

USGS 31

Major sources of imperfect detection

$$M_{ij} f a_i r_i p_{ij} \neq C_{ij}$$

f = fraction of turbines sampled
 a = fraction of carcasses in searched area
 r = proportion of carcasses persisting
 p = proportion of carcasses found

Photo: E. Adam

Current Protocol – p (proportion observed)

- Place trial carcasses in field
- Determine if observed by searcher or not
- If not, leave for next search
- Estimate probability of searcher observing carcass
- Estimate decline in probability (k) with each search

USGS

GenEst – p (searcher efficiency)

USGS 34

GenEst – p (searcher efficiency)

pkID	Size	Season	Visibility	s1	s2	s3	s4	s5
1	pk1	bat	spring	RP	1			
2	pk2	bat	spring	RP	0			
3	pk3	bat	spring	RP	0			
4	pk4	bat	spring	RP	0			
5	pk5	bat	spring	RP	0			
6	pk6	bat	spring	RP	0			
7	pk7	bat	spring	RP	0	1		
8	pk8	bat	spring	RP	1			
9	pk9	bat	spring	RP	1			
10	pk10	bat	spring	RP	0			

USGS 35

GenEst – Analyses – Searcher Eff.

pkID	Size	Season	Visibility	s1	s2	s3	s4	s5
1	bat	spring	RP	1				
2	bat	spring	RP	0				
3	bat	spring	RP	0				
4	bat	spring	RP	0				
5	bat	spring	RP	0				
6	bat	spring	RP	0				

USGS 36

GenEst – Analyses – Searcher Eff.

GenEst – Analyses – Searcher Eff.

g Formula	k Formula	AICc	Delta AICc
3	p ~ Visibility, k ~ 1	355.453	0
1	p ~ Visibility, k ~ Visibility	354.56	0.893
4	p ~ 1, k ~ 1	355.453	0.000
2	p ~ 1, k ~ Visibility	355.541	0.088

GenEst – Analyses – Searcher Eff.

Major sources of imperfect detection

$$M_{ij} f a_i r_{ij} p_{ij} v \neq C_{ij}$$

f = fraction of turbines sampled
a = fraction of carcasses in searched area
r = proportion of carcasses persisting
p = proportion of carcasses found
v = proportion of annual mortality arriving during monitoring period

GenEst – v (temporal coverage)

■ User adjusted

GenEst – g overall pr(detection)

$$\sum_j \sum_h \left(\prod_{t=0}^{j-h-1} (1 - k^t p) k^{j-h-p} \right) \int_{t_{h-1}}^{t_h} S(t_j - t) v(t) dt$$

f = fraction of turbines sampled
a = fraction of carcasses in searched area
r = proportion of carcasses persisting
p = proportion of carcasses found
v = proportion of annual mortality arriving during monitoring period

GenEst – Analyses – General Inputs

USGS 43

GenEst – Search Schedule

USGS 44

GenEst – Search Schedule

SearchDate	Season	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Q11	Q12	Q13	Q14	Q15	Q16	Q17	Q18	Q19	Q20	
1	1995-04-15	spring	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
2	1995-04-16	spring	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	1995-04-21	spring	1	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4	1995-04-24	spring	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5	1995-04-27	spring	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6	1995-04-30	spring	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7	1995-05-03	spring	1	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8	1995-05-06	spring	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
9	1995-05-09	spring	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10	1995-05-12	spring	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

USGS 45

GenEst – Analyses – Mortality Estimate

USGS 46

GenEst – Analyses – Mortality Estimate

USGS 47

GenEst – Analyses – Mortality Estimate

Searcher Group	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Q11	Q12	Q13	Q14	Q15	Q16	Q17	Q18	Q19	Q20	
Searcher Group	1.00	0.00	13.01	18.40	32.4																
Searcher Group	177.23	219.58	246.86	291	369.24																
Searcher Group	46.18	77.21	97.78	128.28	167.48																
Searcher Group	17.23	24.44	29.62	35	42.55																
Searcher Group	2	5.36	6.94	8.77	10.84																

USGS 48

GenEst – Analyses – Mortality Estimate

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GenEst – Analyses – Mortality Estimate

USGS

GenEst – Analyses – Pr(Detection): g

Search Date	10%	20%	50%	75%	90%
g	0.102	0.176	0.224	0.271	0.317
M	0.267	0.325	0.365	0.405	0.445
MP	0.107	0.228	0.234	0.232	0.219

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Current Protocol – Estimating M

Simplifying assumptions re:

- Persistence patterns
- Proportion observed
- Proportion in search area

USGS

GenEst

- Natural evolution of methods – each new estimator offered improvements
- Relaxes restrictive assumptions
 - Persistence patterns
 - Proportion found on 1st, 2nd, 3rd ... search
 - Proportion in search area
- Information with which to evaluate assumptions
- Accurate estimate of uncertainty
- Data collection process little changed

USGS

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GenEst is...

- GenEst R package for Windows, Mac, Linux with GUI and command line implementations
- GenEst Statistical Models technical manual "USGS Techniques and Methods"
- GenEst User Guide
- R Vignettes:
 - GenEst - A Tutorial with Wind Examples
 - GenEst - A Solar Example with Carcass Size
 - GenEst - Command Line Walkthrough

USGS

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What GenEst Does

- Accounts for *almost* all sources of non-detection
- Unbiased* → Meaningful...
 - Comparisons of sites (and site properties)
 - Estimation of trends
 - Evaluation of efficacy of mitigation treatments
 - Estimates for different
 - Locations, e.g., power lines vs buildings
 - Groups, e.g., passerines vs raptors
- ... from same study, same software
- * As unbiased as possible when g is not known

USGS 55

What GenEst Does

- Variance is critical
 - Single point estimate almost certainly wrong
- GenEst gives CIs that reflect stated %

USGS 56

What GenEst Does Not Do

- NOT make decisions for the user
 - User must input valid data
 - Select best model
- NOT interpret results
- NOT estimate when 0 carcasses observed

GenEst is NOT EoA
 (EoA and GenEst estimates converge when >>0 carcasses are observed)

USGS 57

Current Status

- First Beta-test reviews
 - Returned and currently being reconciled
 - Statistics specialists
 - Users very experienced in mortality estimation
 - Anonymous unless waived by reviewer
- Publish Spinoffs:
 - cbinom package – Dalthorp
 - \bar{X} paper – Madsen, Dalthorp, Huso
 - p and k simultaneous estimation – Dalthorp, Madsen, Schirmacher, Huso

USGS 58

Current Status

Request reviews from larger community **You!**

<https://goo.gl/forms/bYKOWA5vELhOH8ld2>

Will reconcile as we receive them

USGS

Future Work

- Training workshops around the US
- Simulation analysis comparing GenEst to other estimators
- With funding...
 - Incorporate Design Module
 - Optimize: search intervals vs spatial coverage vs searcher eff
 - Develop DWP Module
 - Other?

USGS 60

Summary

- Collaborative effort
- Peer reviewed
- Open source
- No decision regarding “which estimator”
- Unbiased*
- Comparability among estimates
- We can all see the same elephant!



USGS * To the level any estimator can be unbiased when detection probability is unknown **61**

THANK YOU!

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Cris Hein	Ed Arnett	Michael Schirmacher
Jerry Roppe	Joana Bernardino	Linda Schuek
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