USGS science for a changing world

Introduction to GenEst
Generalized Estimator of Mortality

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U.S. Department of the Interior
U.S. Geological Survey

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Financial Support

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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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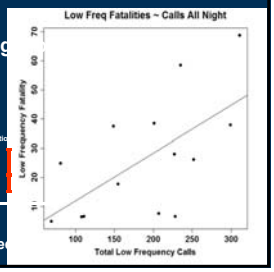
Why GenEst is Needed

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



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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

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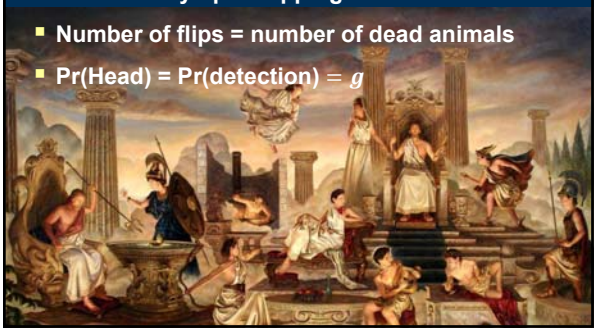
Analogy

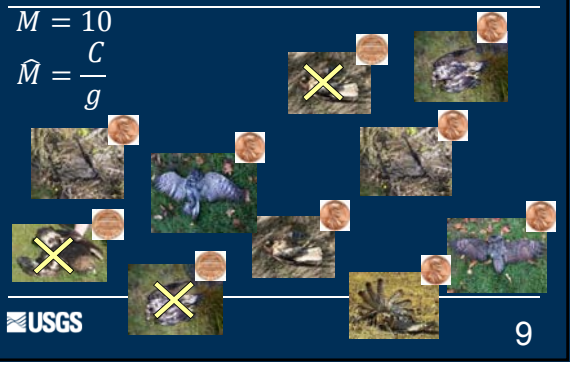
- Gods on Olympus flipping coins
- Number of flips = number of dead animals
- Pr(Head) = Pr(detection) = g



Estimating Mortality: Analogy

$M = 10$

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



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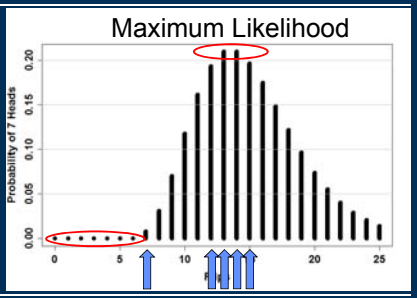
Probability of 7 Heads with fair coin

$M \geq 7$

$\hat{M} = 14$



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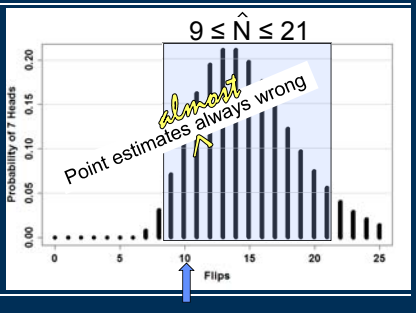
Probability of 7 Heads with fair coin

$\hat{N} = 14$

$N \geq 7$



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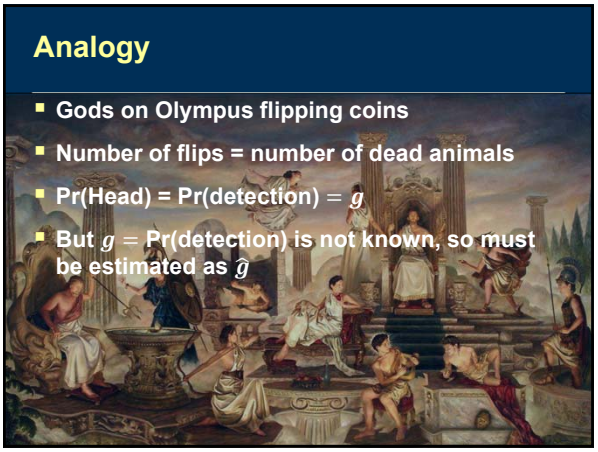
Analogy

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



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

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

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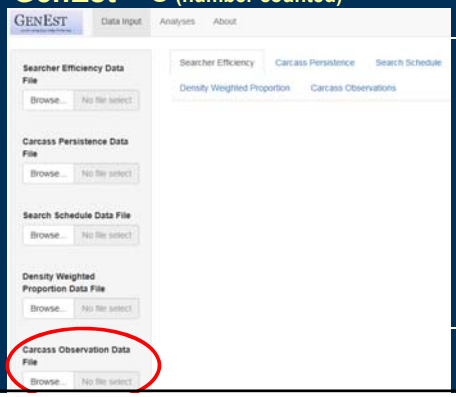
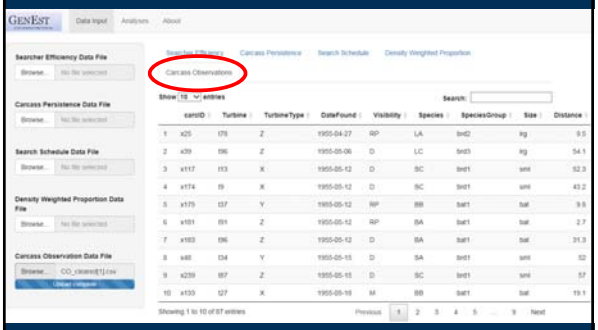
GenEst – C (number counted)



GenEst – C (number counted)



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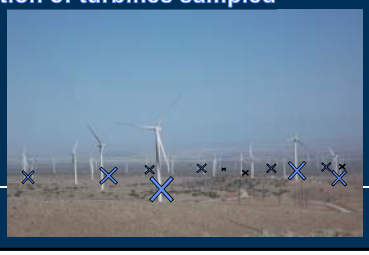
Major sources of imperfect detection

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

f = fraction of turbines sampled



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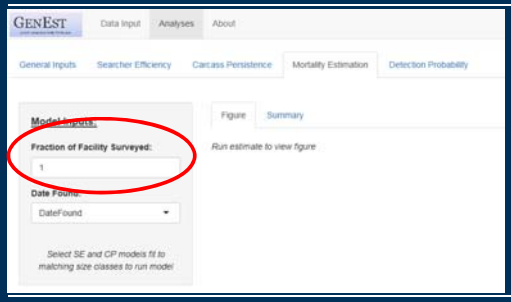
GenEst – *f* (fraction of facility surveyed)



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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?

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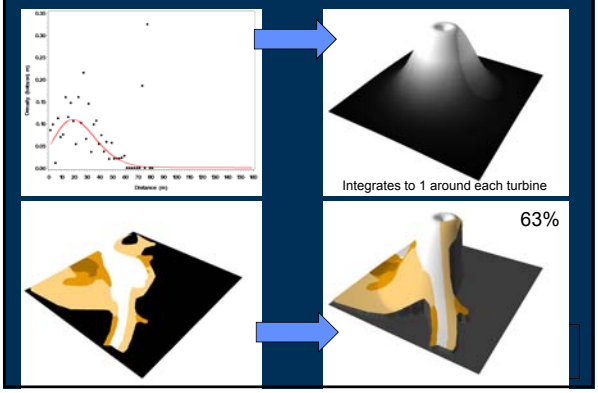
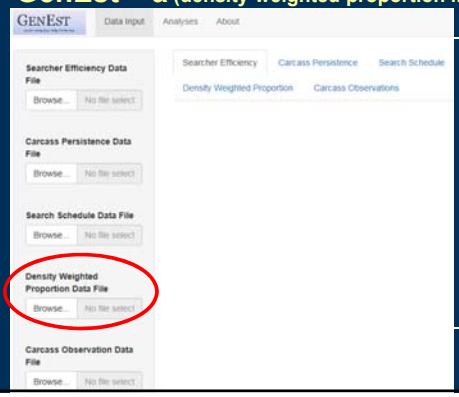
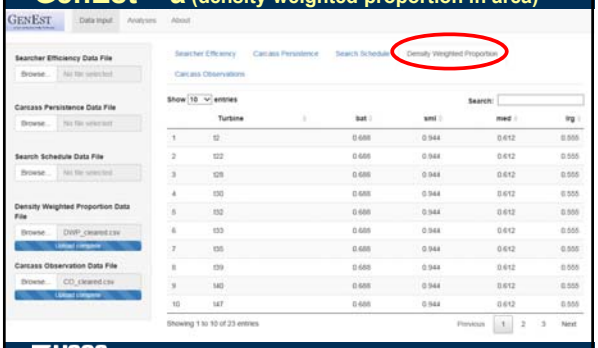
Current Protocol – *a* (proportion in search area)



GenEst – a (density-weighted proportion in area)



GenEst – a (density-weighted proportion in area)



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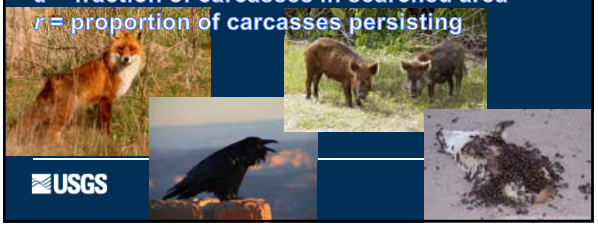
Major sources of imperfect detection

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

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



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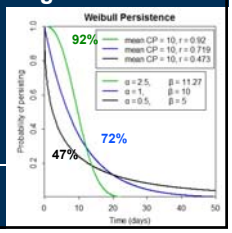
Current Protocol – *r* (proportion persisting)

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



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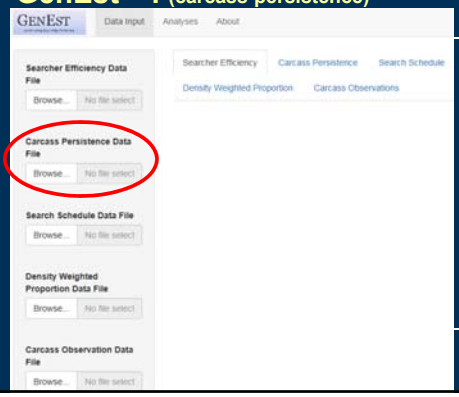
GenEst – r (carcass persistence)



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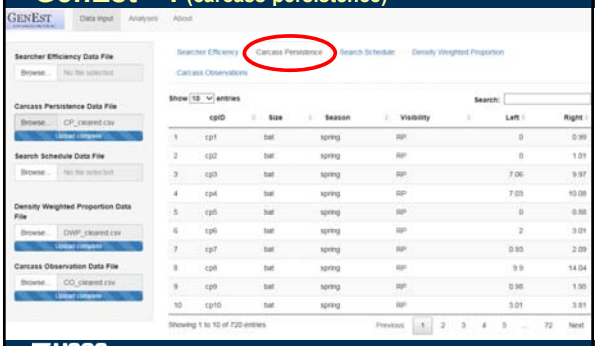
GenEst – r (carcass persistence)



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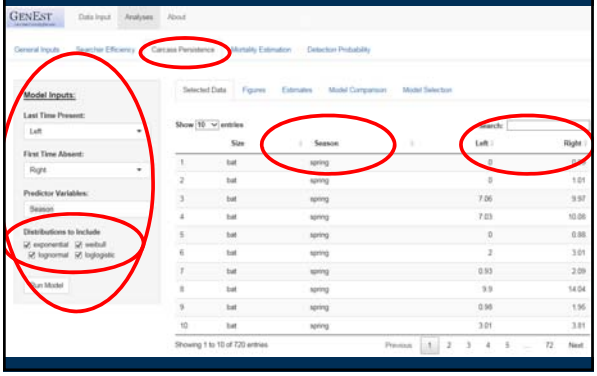
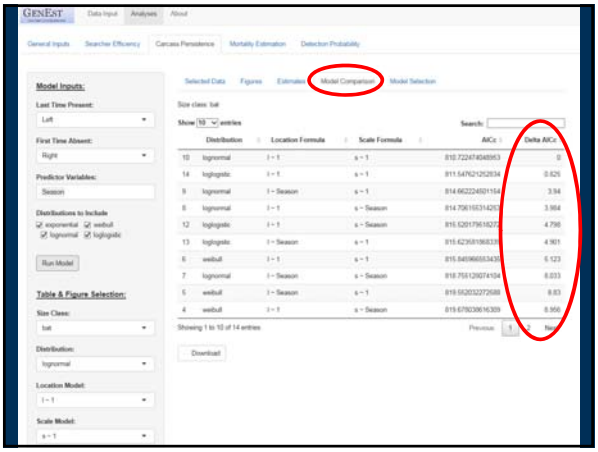
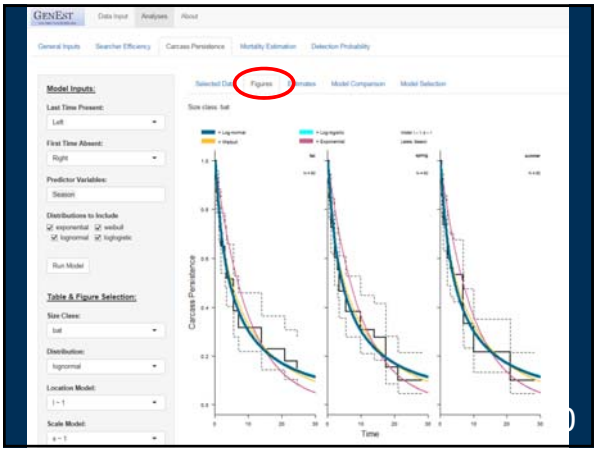
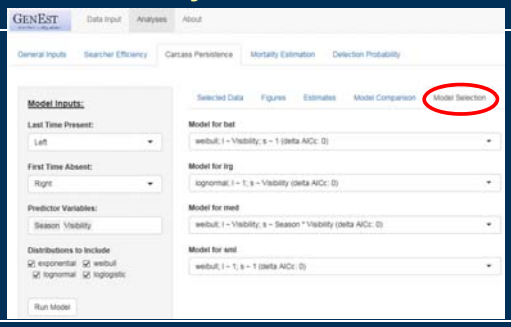
GenEst – Analyses – Carcass Pers







GenEst – Analyses – Carcass Pers



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Major sources of imperfect detection

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

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

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

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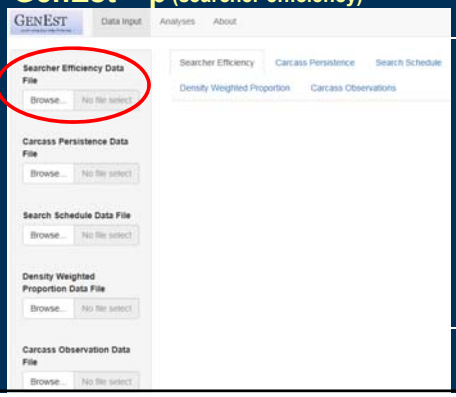
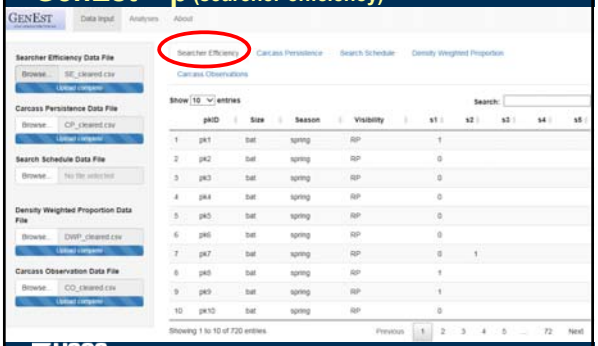
GenEst – p (searcher efficiency)



GenEst – p (searcher efficiency)



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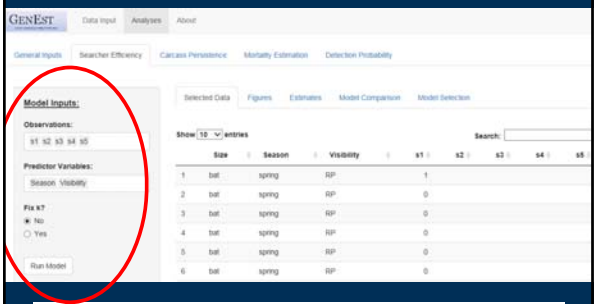
GenEst – Analyses – Searcher Eff.



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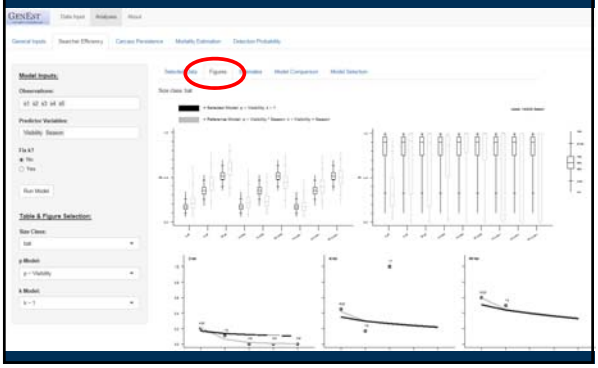
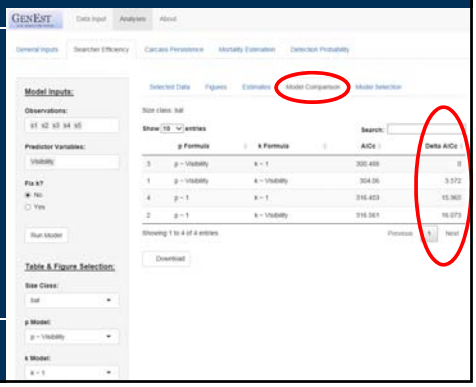
GenEst – Analyses – Searcher Eff.



GenEst – Analyses – Searcher Eff.



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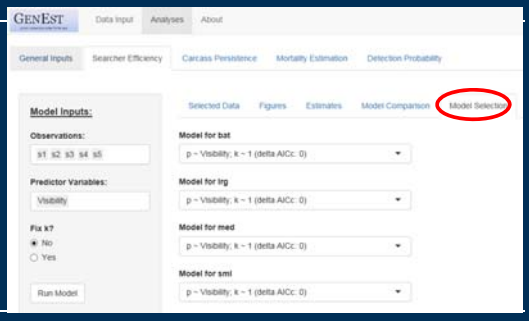
GenEst – Analyses – Searcher Eff.



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Major sources of imperfect detection

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

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

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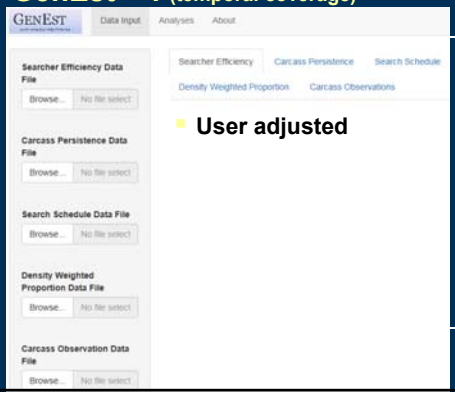
GenEst – v (temporal coverage)



- User adjusted

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GenEst – *g* overall pr(detection)

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

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

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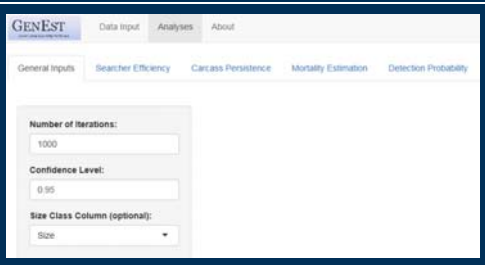
GenEst – Analyses – General Inputs



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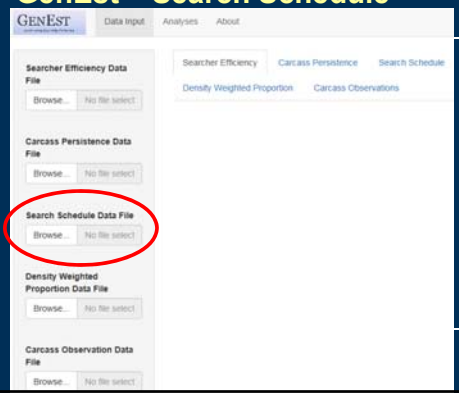
GenEst – Search Schedule



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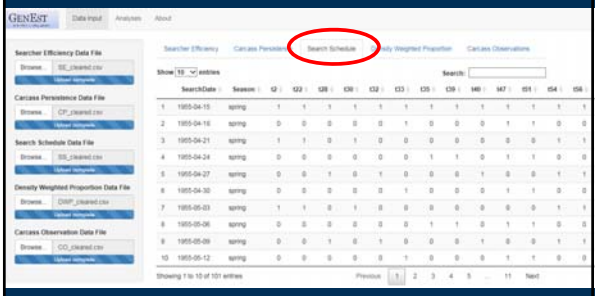
GenEst – Search Schedule



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GenEst – Analyses – Mortality Estimate

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GenEst – Analyses – Mortality Estimate

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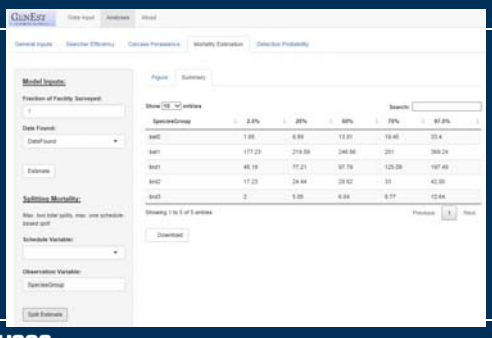
GenEst – Analyses – Mortality Estimate



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GenEst – Analyses – Mortality Estimate

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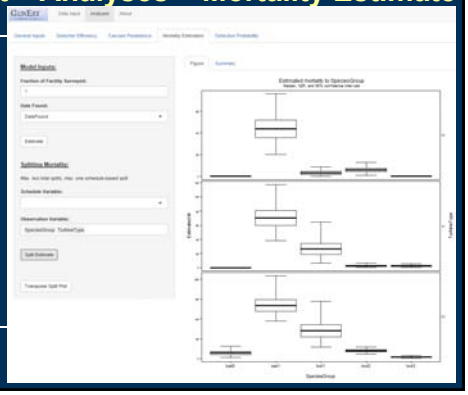
GenEst – Analyses – Mortality Estimate



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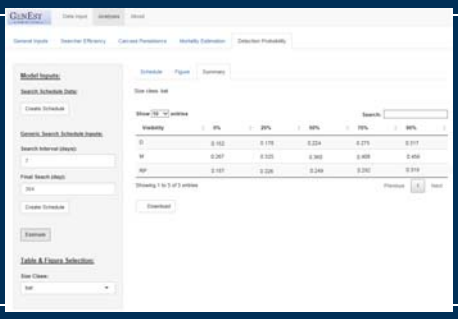
GenEst – Analyses – Pr(Detection): g



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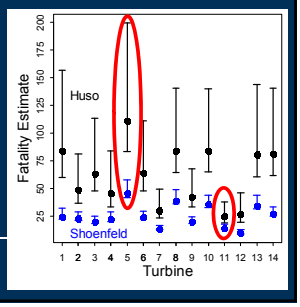
Current Protocol – Estimating *M*

Simplifying assumptions re:

- Persistence patterns
- Proportion observed
- Proportion in search area



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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

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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

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What GenEst Does

- Accounts for 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

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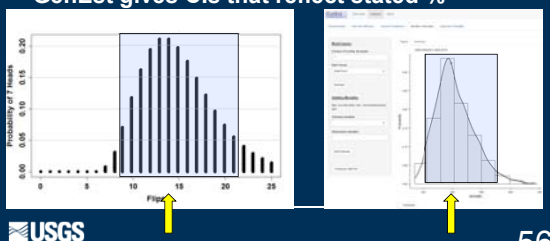
What GenEst Does

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



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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)

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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

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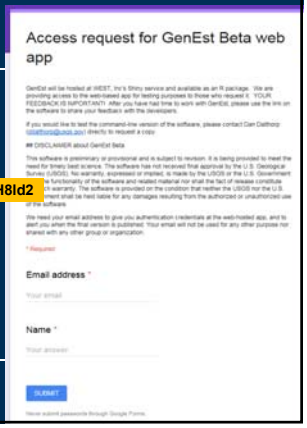
Current Status

Request reviews from larger community

You!

https://goo.gl/forms/bYKOWA5vELhOH8Id2

Will reconcile as we receive them



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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?

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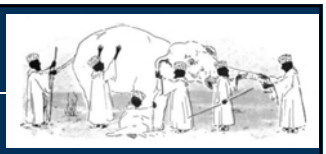
Summary



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

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

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THANK YOU!

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